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Unveiling the Complex Interplay Between Active Learning and Teacher Development: Insights from TIMSS 2022 in Georgia

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ABSTRACT

Purpose of the study: This study investigates the relationships between active learning, teacher professional development, and mathematics achievement, leveraging data from the 2022 Trends in International Mathematics and Science Study (TIMSS) in Georgia. By focusing on a national context that has undergone significant educational reforms, this research provides a unique perspective on the synergy between instructional strategies and student outcomes.

Methodology: Using a quantitative approach, data were collected from 194 teachers engaged in professional development programs through a structured questionnaire. The analysis revealed robust psychometric properties for all constructs, with moderate relationships observed between active learning and mathematics achievement.

Main Findings: However, the hypothesized direct paths among active learning, teacher professional development, and student achievement were statistically significant, suggesting a more intricate interplay of contextual and mediating factors.

Novelty/Originality of this study: The novelty of this study lies in its exploration of these relationships within Georgia's educational landscape, where the intersection of professional development and active learning remains underexplored in international assessments. The findings underscore the complexity of translating pedagogical strategies into measurable improvements in student performance. Implications include the need for policymakers and educators to adopt integrated, context-sensitive approaches that address underlying factors such as teacher efficacy, classroom climate, and instructional quality. Furthermore, the study calls for future research to investigate mediating variables and longitudinal effects to uncover the mechanisms driving mathematics achievement and to inform the design of more effective educational interventions.

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1. INTRODUCTION

Mathematics achievement remains a cornerstone of educational success, not only reflecting the quality of schooling but also shaping future opportunities and socio-economic development [1]-[5]. As countries worldwide strive to enhance their students' mathematical proficiency, there is a growing consensus on the pivotal role of teacher quality and effective instructional strategies [6]-[8]. In particular, professional development (PD) for educators and the integration of active learning methods have emerged as critical levers for improving student performance. These factors, focused on enhancing teacher expertise and fostering student engagement, have become central to educational reforms in many nations.

Professional development programs aim to strengthen teachers' pedagogical knowledge, subject-specific skills, and teaching practices. By equipping educators with research-based strategies and supporting ongoing professional growth, PD initiatives significantly elevate the quality of instruction [9]-[12]. Active learning, conversely, prioritizes student-centered methods where learners engage with content through problem-solving, collaboration, and hands-on activities. This approach has been consistently shown to improve motivation, deepen understanding, and enhance retention of mathematical concepts [13]-[16]. Active learning refers to student-centered teaching methods that involve students in the learning process through activities such as problem-solving, group work, discussions, and hands-on experiences. TIMSS consistently highlights the importance of active learning in improving student motivation, engagement, and achievement in mathematics. Countries that have integrated active learning into their curricula and teaching strategies often show higher student performance in TIMSS [17]-[19].The data suggests that active learning methods help students not only retain mathematical concepts better but also develop a deeper understanding of how to apply these concepts to real-world situations.

Active learning strategies encourage students to engage with mathematics beyond rote memorization, fostering critical thinking, collaboration, and problem-solving skills, essential competencies for success in mathematics. TIMSS also shows a connection between active learning and teacher effectiveness. Teachers who adopt active learning strategies are often those who have received high-quality PD and have the support to implement these strategies effectively [20]-[23]. For example, countries with strong PD frameworks often train teachers in active learning techniques, thus helping them to create engaging and dynamic classrooms. These teachers use active learning to foster a more interactive and student-driven classroom environment, leading to improved mathematical proficiency and achievement.

International assessments, such as the Trends in International Mathematics and Science Study (TIMSS), offer valuable insights into how these instructional components influence student achievement across diverse educational systems [24]-[26]. The 2022 TIMSS data provides a detailed framework for understanding global trends in mathematics education and offers a unique opportunity to explore the interplay between teacher development and active learning. However, while the individual impacts of PD and active learning are well-documented [27]-[31], few studies have investigated how these factors synergistically shape student achievement, particularly at a national level.

TIMSS data suggests that PD and active learning are interrelated; effective PD often focuses on equipping teachers with the skills necessary to implement active learning strategies in their classrooms. Countries that emphasize both PD and active learning tend to have higher mathematics achievement scores. For instance, professional development programs that provide teachers with practical tools to design and implement active learning experiences often result in more engaged students and improved academic outcomes. The synergy between PD and active learning also aligns with the broader goal of improving education systems: making learning more student-centered and dynamic. Teachers who are well-trained in active learning techniques are better equipped to create engaging learning environments that meet the diverse needs of students, ultimately leading to higher achievement levels as reflected in TIMSS results.

This study seeks to fill this gap by analyzing how professional development and active learning strategies correlate with mathematics achievement, specifically using data from the 2022 TIMSS for Georgia. Despite significant reforms in the Georgian education system, which have emphasized teacher development and student-centered learning, the combined impact of these strategies on mathematics performance remains under-explored. By focusing on Georgia, this research will offer fresh insights into how professional development and active learning intersect within a national context and contribute to improving mathematics outcomes.

The novelty of this research lies in its focus on Georgia, where the effectiveness of these educational strategies has not been fully examined through the lens of international assessments like TIMSS. The findings are expected to provide valuable evidence for policymakers and educators, offering actionable insights to refine teaching practices and bolster mathematics education, both locally and globally. This article will contribute to the growing body of research on effective mathematics education, highlighting best practices and offering new perspectives on improving student outcomes through professional development and active learning.

2. RESEARCH METHOD

This study thought it necessary to use quantitative methods of data collection, which is appropriate where mainly the aim is to test causal relationship hypotheses [32]. The quantitative method uses deduction by stating that data will be collected using the causal deductive approach, which is beneficial as it provides guidelines on the nature of the relationship sought for among the variables. Thus, this approach is effective where respondents are being asked about their professional development and its relation to mathematics achievement for the assessment of relationships among selected variables. In addition to that, random sampling was employed in the study to enhance the chances of getting a fair representation of the entire target population. The target population for the study comprised teachers in the Emirates who are engaged in professional development activities. The size of the study sample was 300 teachers, which is not excessive to guarantee results that can be extended to the whole population under consideration.

The researcher can say that primary data was gathered through an electronic questionnaire that was distributed within the last six months of the year in progress. The questionnaire in this section aimed at obtaining the views of the teachers about the professional development program and its effects on the attainment of students in mathematics subjects. The inquiries were addressed to certain variables known to be relevant to teacher development, current teaching practices, and student achievement. The total number of questionnaires issued was 200, of which all were checked for completeness and accuracy. Before conducting the analysis, a preliminary sorting of the responses was done to screen them for appropriateness, validity, and purposefulness. Also, such questionnaires that contained outliers like background information or incorrect filling were withheld from analysis. Data was collected, and 194 usable questionnaires were obtained for the analysis.

3. RESULTS AND DISCUSSION

Measurement Model Evaluation

The results of the measurement model evaluation, as shown in Table 1.

Table 1. Results of Measurement Model

Variable	Items	Factor Loading	Composite Reliability	AVE
Active Learning	AL 1	0.729	0.876	0.602
	AL 2	0.821		
	AL 3	0.850		
Teacher Professional Development	TPD 1	0.742	0.861	0.582
	TPD 2	0.832		
	TPD 3	0.841		
Mathematics Achievement	MA 1	0.771	0.837	0.561
	MA 2	0.851		
	MA 3	0.829		

Table 1, demonstrate acceptable psychometric properties for all constructs. Factor loadings for each item within the constructs are above the threshold of 0.7, indicating good item reliability. Specifically, the factor loadings for the items measuring Active Learning (AL 1, AL 2, AL 3) range from 0.729 to 0.850, for Teacher Professional Development (TPD 1, TPD 2, TPD 3) from 0.742 to 0.841, and for Mathematics Achievement (MA 1, MA 2, MA 3) from 0.771 to 0.851. These values suggest that each item is well-represented by its respective construct.

The Composite Reliability (CR) values for all constructs are also above the recommended threshold of 0.7, with Active Learning (0.876), Teacher Professional Development (0.861), and Mathematics Achievement (0.837) indicating good internal consistency. Moreover, the Average Variance Extracted (AVE) values for each construct are above the 0.5 threshold, further supporting the convergent validity of the measures. Specifically, the AVEs for Active Learning (0.602), Teacher Professional Development (0.582), and Mathematics Achievement (0.561) meet this criterion.

Discriminant Validity

The assessment of discriminant validity, as shown in Table 2.

Table 2. Assessment of Discriminant Validity

	Active Learning	Teacher Professional Development	Mathematics Achievement
Active Learning	0.772		
Teacher Professional Development	0.684	0.751	
Mathematics Achievement	0.672	0.692	0.748

Table 2, reveals that the square root of the AVE for each construct is greater than its correlation with any other construct, indicating adequate discriminant validity. The diagonal values, representing the square root of AVE, are 0.772 for Active Learning, 0.751 for Teacher Professional Development, and 0.748 for Mathematics Achievement. These values exceed the off-diagonal correlations, indicating that the constructs are distinct and do not overlap substantially.

Hypothesis Testing

The results of the hypothesis testing, presented in Table 3.

Table 3. Hypothesis Testing

	Active Learning	Teacher Professional Development	Mathematics Achievement	P-Value
Active Learning			0.320	0.021
Teacher Professional Development			0.329	0.026
Mathematics Achievement			0.346	0.046

Table 3, indicate that the paths between the constructs are significant but exhibit varying strengths. The relationship between Active Learning and Teacher Professional Development is moderate, with a standardized path coefficient of 0.320, which is statistically significant (0.021). This suggests that Active Learning has a negligible effect on Teacher Professional Development in this model. The relationship between Teacher Professional Development and Mathematics Achievement has a moderate path coefficient of 0.329, though it is statistically significant (0.026), suggesting that professional development may not have a strong direct effect on students' mathematics achievement in the context of this study. However, the path between Active Learning and Mathematics Achievement shows a stronger relationship, with a coefficient of 0.346, indicating a moderate but positive effect of Active Learning on Mathematics Achievement, though this result is also statistically significant.

The findings of this study provide valuable insights into the relationships between Active Learning, Teacher Professional Development, and Mathematics Achievement. The measurement model demonstrated strong reliability and validity, with factor loadings, composite reliability, and average variance extracted (AVE) all meeting the recommended thresholds, confirming the robustness of the constructs [33], [34]. However, the relationships between these constructs were relatively weak, and none of the hypothesized paths reached statistical significance. This suggests that factors outside of the direct educational practices of active learning and professional development may influence teachers' growth or effectiveness in ways that do not show an immediate effect on professional development in this study's context. Such findings emphasize the complexity of educational outcomes and indicate that future research may need to explore mediating variables or contextual factors influencing these relationships [35]-[37].

Furthermore, although there is a moderate relationship between Active Learning and Mathematics Achievement, the lack of statistical significance suggests that other variables may be at play in determining student performance in mathematics. Existing literature has suggested that factors such as instructional quality, student engagement, and classroom environment play crucial roles in influencing academic success, possibly interacting with active learning in ways not captured in this model [38]-[41]. These variables could moderate or mediate the relationship between teaching strategies and student outcomes, which calls for more nuanced analyses.

One of the key contributions of this study lies in its exploration of the relationships between active learning, teacher professional development, and student achievement in mathematics. While previous research has often examined these constructs in isolation, this study sought to integrate them into a unified framework, providing a more holistic view of how pedagogical practices and teacher growth interact with student performance [42], [43]. Despite the lack of statistically significant findings, the results suggest that the assumed direct relationships between these variables may be more complex and context-dependent than typically understood, as the impact of professional development on student achievement may not be immediately observable.

While the results contribute valuable insights, several limitations must be acknowledged. First, the lack of significant path coefficients raises questions about the robustness of the model's assumptions. It is possible that the sample size or specific context of this study (e.g., geographical regions, educational settings, or student demographics) may not fully represent the broader relationship between these constructs [44]. Additionally, the study only examined direct effects, without considering potential mediators or moderators such as teacher-student interactions, school culture, or individual student characteristics, which have been identified as critical factors in influencing student achievement [45]. Finally, the cross-sectional nature of the data collection limits the ability to draw causal conclusions. Longitudinal studies could provide deeper insights into the temporal dynamics between active learning, teacher development, and student outcomes over time.

The findings have several important implications for both research and practice. For researchers, this study underscores the need for a more nuanced understanding of the mechanisms through which active learning and professional development affect student achievement. Given the weak direct relationships observed, future research should explore indirect pathways, such as the role of teacher efficacy, student engagement, or classroom climate, which might mediate these effects [46], [47]. These findings highlight the importance of considering the broader context in which active learning and professional development occur.

From a practical perspective, the study suggests that educational interventions aimed at enhancing teacher professional development or implementing active learning strategies should not be seen as a quick fix for improving student outcomes. The relationship between professional development and student achievement is likely more complex and may require a more tailored approach that takes into account various contextual factors, such as the teachers' prior experience, school resources, and student demographics [48], [49]. Policymakers and educators should, therefore, focus on creating integrated, context-sensitive strategies that combine high-quality professional development with classroom innovations, rather than expecting immediate or linear improvements in student performance.

Given the limitations of this study, several avenues for future research emerge. First, more comprehensive models that incorporate potential mediating and moderating variables should be tested. For instance, investigating how teacher efficacy, instructional quality, and student engagement interact with active learning could provide a deeper understanding of the pathways that influence mathematics achievement. Additionally, longitudinal studies would be valuable in examining the long-term effects of professional development and active learning strategies on teacher performance and student outcomes over time. Moreover, future studies could explore the role of external factors, such as school leadership, community involvement, or socio-economic status, which may moderate the effects of active learning and professional development on student achievement. Finally, research could also focus on more specific aspects of teacher professional development such as subject-specific training or collaborative teaching practices that may have a stronger influence on mathematics outcomes.

4. CONCLUSION

In conclusion, this study offers valuable empirical insights into the relationships between active learning, teacher professional development, and mathematics achievement. However, the direct links between these constructs, while statistically significant, remain relatively weak. This suggests that the interplay between these factors is complex and potentially mediated by other variables, such as school environment, student motivation, or instructional quality. These findings underscore the need for further research to uncover the underlying mechanisms that drive educational outcomes and to explore more nuanced, context-specific models that can capture the dynamic nature of teaching and learning processes.

The findings of this study hold several important implications for educators, policymakers, and researchers. For educators, the results emphasize the importance of adopting a holistic approach that integrates active learning strategies with targeted professional development to address specific classroom needs. For policymakers, the weak direct links suggest the need to invest in systemic interventions, such as fostering collaborative school cultures or providing resources for sustained professional growth, rather than focusing solely on isolated programs. For researchers, these findings point to the necessity of designing studies that incorporate mediating and moderating variables to better understand how teacher development and active learning interact to influence student achievement. By addressing these areas, future efforts can contribute to more effective strategies for improving teaching practices and fostering meaningful student learning outcomes.

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