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The Impact of Teacher Quality on Student Achievement: A Quantitative Analysis

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ABSTRACT:
This study uses data from the Trends in International Mathematics and Science Study (TIMSS) 2019 to examine how teacher quality affects students' academic performance. The research focuses at how teacher characteristics-like formal education, years of experience, confidence in the classroom, and work satisfaction- affect fourth- and eighth- grade students' performance in reading, science, and mathematics across 60 nations. In order to examine the hierarchical data structure of students nested within classes and schools, the methodology applies quantitative approach that combines correlation, regression, and multilevel modeling using Statistical Package for Social Sciences (SPSS) version 23. The results demonstrate that while job satisfaction and confidence in teaching science unexpectedly exibits negative relationships, indicating possible training and support gaps, beter formal education and more teaching experience positively predict student achievement with highest benefits in reading. Variations by subject emphasize the necessity of specialized tecahing methods. A small percentage of the variance is explained by the study, suggesting that other elements such as educational resources, are equally important. In order to match confidence with successful practice, these insights encourage improved teacher education standards, retention assistance, and focused professional development. Finally, to get a deeper understanding and guide policies that maximize teacher quality and advance fair education results, future research should include qualitative and longitudinal data.

Keywords: Academic Performance, Educational Research, Student Achievement, Teacher Effectiveness, Teaching Experience.

I. INTRODUCTION:

All the education systems are seeking for methods to improve student academic performance because these accomplishments support both personal growth and advancement of society. Besides family support, socioeconomic circumstances, curriculum design and other factors, teacher quality is one of the most important characteristics that affect student achievement. A teacher's credentials, years of experience, pedagogical abilities, and personal qualitites – confidence and job satisfaction – are all components of good education. Using data of 60 countries from TIMSS, a highly regarded international evaluation of students' mathematical and scientific proficiency, this research exmines the relationship between teacher quality and student academic performance.

The immediate impact that teacher have on the classroom and the way that instruction is delivered, make them crucial. Teachers with more training and experience are better equipped to work with a variety of students requirements, use creative teaching techniques, and create a positive learning environment. However, sociocultural viewpoints highlight how interactions between teachers and students shape both cognitive and non-cognitive results. While the exact processes by which good teachers lead to high academic preformance are still up for discussion, the results differ depending on the subject, school type, and cultural setting. This variation emphasizes the need of a thorough investigation to separate the roles playes by instructor charactersitics.

The multifaced levels of teacher efficacy and the complexity of educational data contribute to the incomplete understanding of the relationship between teacher and student, despite its acknowledged significance. According to several studies, greater formal education and teacher experience may improve student performance, however, the extent of these impacts varies according according to the subject taught and the larger educational setting. With its comprehensive collection of teacher and student variables from tens of nations, the TIMSS dataset offers a strong foundation for filling the gaps. This study intends to provide light on a crucial area of educational

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reform by investigating the relationship and predictors of student performance in core academic areas by focusing at credentials, experience, and other personal characteristics of teachers.

The study's main goals are to: (1) determine how different aspects of teacher quality, such as formal education, years of experience, job satisfaction, and subject-specific confidence, affect students' achievements; (2) investigate the relative significance of these aspects across the subjects evaluated by TIMSS; and (3) provide recommendations for educational policy and practice. The scope of this report goes beyond the individual characteristics of teachers taking into account their collective impact within many educational contexts. Its multifaceted significance provides guidance to legislators, school administrators, and teacher training programs in taking the initiative at improving teaching standards. Additionally, knowing which teaching qualitites result in the optimum academic performance could help with resource allocation, professional development programs and recruitment tactics, to promote educational equity.

II. LITERATURE REVIEW:

For many years, educational research has focused on the connection between student academic performance and teacher quality (Belsito, 2016), highlighting the crucial role that educators play in determining learning outcomes. This survey of the literature combines important theoretical viewpoints with empirical data to provide a basis for comprehending the relationship between teacher qualityand student accomplishment(Clotfelter, 2007). Through an examination of definitions, theoretical frameworks, and evidence from various educational contexts, this section highlights any gaps that the current study that uses TIMSS data(IEA, 2019) seeks to fill.

Across educational institutions and research paradigms, teacher quality is a complex concept that defies easy explanation. Typically, it comprises quantifiable qualities including years of teaching experience, subject-specific knowledge, and formal education level (such as degrees or certifications)(Hanushek, 2006). Beyond these qualifications, teaching is becoming more widely acknowledged that qualitative factors like educational efficacy, classroom management abilities, and character attributes like zeal and empathy are essential(Darling-Hammond, 2000). The ability of a teacher to impart curricular knowledge and encourage student engagement is influenced by these qualities taken together, which means that teacher quality is a dynamic interaction of both concrete and ethereal elements. The issue of operationalizing these components for empirical research is difficult, and studies frequently use proxies like test results or observational data to do this(Stronge, 2007).

The education production function and sociocultural theories are the two main theoretical frameworks that support the investigation of how teacher quality affects student outcomes(Anh, 2013). According to the education production function, which has its roots in economic models of education, student accomplishment depends on a variety of inputs, such as teacher attributes, student background, and school resources. This method places a strong emphasis on measurable teacher attributes, like training and experience, as indicators of academic achievement, which is frequently gauged by test results.

On the other hand, sociocultural theories—which are based on Vygotsky's work(Jaramillo, 1996)—emphasize how interactive learning is and how teachers behave as knowledge brokers in a social setting. This focus emphasizes the value of instructional tactics, teacher-student interactions, and the cultural relevance of teaching methods(Mason, 1997). It is believed that teachers who modify their teaching strategies to meet the cultural and cognitive demands of their students would increase motivation and foster a deeper comprehension of the material(Belland, 2013). This goes beyond test-based metrics to incorporate non-cognitive goals like engagement and resilience. According to these views, a teacher's quality is influenced by both their personal qualities and the atmosphere they create in the classroom.

The relationship between student academic performance and teacher quality has been thoroughly investigated empirically, with both consistent and contradictory results. Student achievement and teacher qualities are positively correlated(Scrivner, 2009), according to numerous studies. For example, students typically perform higher on tests taken by teachers who have advanced degrees or specialized training in their topic, especially in science and math(Clotfelter C. T., 2006). Deeper content knowledge, which makes training more effective, is frequently credited with this impact. But in some situations, the impact is less pronounced, indicating that credentials might not be enough on their own without supplementary abilities(Tomlinson, 2008).

Another extensively researched factor is teaching experience, which has been shown to have a curvilinear relationship with student outcomes. The efficiency of early-career teachers (1–5 years) frequently improves quickly, plateauing after 5–10

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years(Rivkin, 2005). This plateau could be the result of decreasing returns as experience builds up, or it could be that the effect is moderated by other factors like professional development. Additionally, longitudinal studies indicate that seasoned educators are highly skilled at adjusting instruction and managing diverse classrooms(Ingersoll, 2011), which are advantages that are especially noticeable in demanding educational environments.

Classroom procedures and pedagogical abilities are also very important. According to research, instructors who use active learning techniques, like group projects or problem-solving exercises, improve student performance more than those who only use lectures(Hattie, 2009). These benefits are further enhanced by classroom management, which includes the capacity to uphold order and provide a supportive environment. Research indicates that these advantages are more pronounced in the early educational phases.

Professional development (PD), which helps teacherskeep up with changing pedagogical practices, is becoming more widely acknowledged as a crucial element of teacher quality(Schifter, 2016). Long-term, subject-specific professional development programs have been shown to dramatically improve teacher effectiveness, especially in science and math, where conceptual understanding is crucial(Desimone, 2009). For example, as teachers learn to support rather than command learning, workshops emphasizing inquiry-based learning have been associated with enhanced student problem-solving abilities. PD's effectiveness varies, though, with one-time sessions having less of an effect than continuous, group models. This implies that more research is required to determine how professional development might be maximized to enhance teacher quality in a variety of educational situations, including those that are included in TIMSS.

Particularly in the digital age, using technology into instruction has become a critical component of teacher excellence. Particularly in STEM topics, teachers who are adept at leveraging technology—like interactive simulations or data analysis tools—can improve student engagement and comprehension(Ertmer, 2010). Research indicates that proficient educators frequently cultivate higher-order thinking abilities as their pupils engage with intricate ideas using visual aids. However, its impact is limited, especially in areas with little resources, by differences in teacher preparation and access to technology. This discrepancy is crucial in global datasets like as TIMSS, where variations in technology infrastructure across nations may moderate the connection between student performance and teacher quality, calling for further investigation(Glassow, 2021).

In addition to cognitive results, teacher quality affects non-cognitive elements including student self-efficacy and motivation. High work satisfaction or confidence in one's teaching skills increases the likelihood that a teacher will motivate students, which in turn improves academic engagement(Caprara, 2006). The quality of education can be compromised by burnout or low morale, which can therefore have an impact on student performance(Dworkin, 1997). According to research on teacher retention and its connection to student performance, this interaction implies that human qualities are just as important as professional credentials.

The relationship between teacher quality and student results is further complicated by contextual circumstances. Research using global datasets, such as TIMSS, shows differences by nation, class of school, and socioeconomic position. Experienced and well-trained teachers can dramatically reduce achievement inequalities in low-resource environments, while teacher credentials may have a lesser relative impact in high-resource settings due to the existing robust educational infrastructure(Cerqua, 2014). Because science and math are more technical than reading, they frequently exhibit more sensitivity to instructor expertise. Subject-specific impacts are particularly noticeable(Yastrebov, 2014).

III. METHODOLOGY:

3.1 Research Design:

The statistical analysis for this study was perfomed on SPSS (Statistical Package for the Social Sciences) version 23, a comprehensive software used for data management and statistical analysis. SPSS provides robust tools for handling multilevel modeling and other complex statistical techniques and it allows the efficent process of large datasets. In addition to regression modeling, SPSS provides feactures such as calculation of p-values to asses the significance of the coefficients, as well as diagnostic tolls like Hausman test to validate the model's appropiateness.

To investigate bivariate associations between teacher variables (such as education level and experience) and student performance scores (reasonable values for science and math), inferential research starts with correlation analysis. After adjusting for instructor age and student gender, multiple regression analysis is used to evaluate the predictive potential of teacher quality

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indicators. Student achievement is the dependent variable, and the regression model takes into account factors like work satisfaction, formal education level, and instructional time. The strength of these relationships is assessed by analyzing effect sizes and significance levels.

Multilevelel modeling was used to deal with the hierarchical data structure, treating students as nested within schools and classes. While fixed effects included control factors (e.g., student gender) and teacher quality variables, random intercepts were provided at the class and school levels to account for clustering. -2 Log Likelihood was utilized to evaluate the model's fit, and effect sizes were interpreted using standardized coefficients. In order to ensure representativeness and reflect the intricate sampling design of the dataset, all analyses were weighted using TIMSS-provided weights (e.g., MATWGT for mathematics). Normality and multicollinearity assumptions were checked, and any necessary modifications were made to preserve the robustness of the model. The descriptive information provided by the tables guides the choice of variables for these models, ensuring that the inferential analysis is based on the distributional properties of the data.

3.2 Selection Criteria:

To ensure data integrity, only valid responses from TIMSS 2019 are used in this study. Teacher variables- such as experience, education level, job satisfaction, and instructional time- are selected based on their relevance to student achievements. Stuent-level factors, including gender and subject-specific teacher asignment, provide contextual depth. The findings contribute to global educational research and inform policy interventions aimed at improving instructional effectiveness.

Table 1: Distribution of Teachers by Formal Education Level

Education Level	Frequency	Percent	Valid Percent	Cumulative Percent
No High School	1970	0.6	0.7	0.7
High School	17589	5.6	6.0	6.6
Some College	16612	5.3	5.6	12.3
Associate degree	28197	8.9	9.6	21.8
Bachelor's degree	166548	52.8	56.5	78.4
Master's degree	63736	20.2	21.6	100.0
Total	294652	93.4	100.0	

As shown in Table 1, over one-half of teachers (56.5%) hold at least a Bachelor's Degree, indicating a generally well-qualified teaching workforce. However, the 6.0% have only a high school education or less, highlighting variability in qualifications.

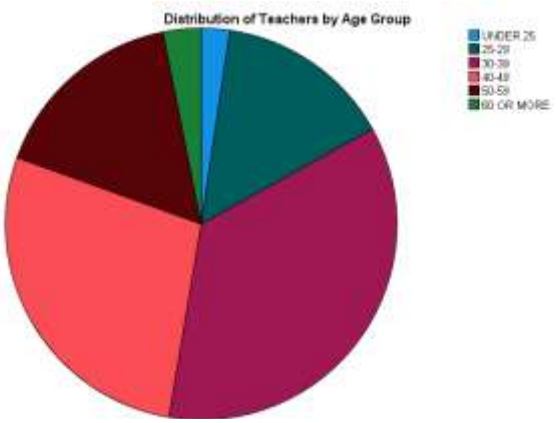

Figure 1. Pie Chart of Distribution of teachers by age Group

Figure 1 shows a concentration of teachers aged 30-49 (approximately 65%), suggesting a stable mid-career workforce. The smaller proportions of younger (under 25, approximately 2%) and older (60 or more, 3%) teachers may reflect recruitment or retention challenges, making age a relevant control variable to explore its influence on teaching effectiveness.

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Table 2: Distribution of Teachers by Job Satisfaction Level

Job Satisfaction Level	Frequency	Percent	Valid Percent	Cumulative Percent
Very High	53132	16.8	18.0	18.0
High	145439	46.1	49.3	67.3
Medium	87878	27.9	29.8	97.1
Low	6890	2.2	2.3	99.5
Very Low	1579	0.5	0.5	100.0
Total	294918	93.5	100.0	

As shown in Table 2, 67.3% of teachers report high or very high job satisfaction, reflecting a generally positive work environment. The 2.8% with low or very low satisfaction, however, suggests potential areas of concern, justifying its inclusion as a variable to explore its impact on student outcomes.

Further analysis suggested a nearly uniform assignment of one science instructor per student (approximately 97%), which is similar to the pattern observed in mathematics. This variable, which can represent variances in teaching specialization or consistency, is added to investigate if differences in the number of science teachers affect student outcomes.

Additionally, 48.1% of teachers spend 3-5 hours weekly on mathematics instruction, with a notable tail of 14.1% spending 6-10 hours. This distribution highlights varying instructional intensities, which may correlate with student achievement and is thus included as a variable. Conversly, 51.9% of teachers allocate 1-3 hours weekly to science instruction, with a smaller proportion (11.6%) spending 4-10 hours. This variation suggests differing emphases on science, which may influence student outcomes and is included to explore subject-specific effects.

The analytical approach enlightens the definition of the student academic performance by combining descriptive and inferential methodologies. In order to profile teacher and student characteristics, descriptive statistics, such as means, frequencies, and percentages were also calculated. Although 2.8% indicate poor or very low job satisfaction, which may call for more research, 67.3% of instructors express high or very high job satisfaction, indicating a generally favourable work environment. Subject-specific teaching patterns that may affect student outcomes, show that science instruction peaks at 1-3 hours per week for 51.9% of teachers and mathematics instruction concentrated between 3-5 hours per week for 48.1% of teachers.

IV. RESULTS AND DISCUSSION:

The findings of this study highlight the significant relationship between teacher quality and student academic performance, with a particular emphasis on mathematics and science outcomes. Using data from the TIMSS, the quantitative analysis incorporates multilevel modeling to account for the nested structure of students within schools. Several key teacher characteristics—including experience, formal education, classroom confidence, and job satisfaction—were examined in relation to student performance in mathematics, science, and reading.

Table 3: Correlations Between Teacher Quality and Student Scores

Variable	Years of Teaching Experience	Formal Education Level	Confidence inTeaching Science	Teacher Career Satisfaction	Mathematics Score	Science Score	Reading Score
Years of Teaching Experience	1.000	-.214**	.000	-.006**	.098**	.123**	.142**
Formal Education Level	-.214**	1.000	.030**	.058**	.185**	.201**	.195**
Confidence in Teaching Science	.000	.030**	1.000	.228**	-.126**	-.092**	-.106**
Teacher Career Satisfaction	-.006**	.058**	.228**	1.000	.006**	.041**	.042**

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Mathematics Score	.098**	.185**	-.126**	.006**	1.000	.912**	.891**
Science Score	.123**	.201**	-.092**	.041**	.912**	1.000	.936**
Reading Score	.142**	.195**	-.106**	.042**	.891**	.936**	1.000
Note: Correlation is significant at the 0.01 level (2-tailed)							

Table 3 highlights significant correlations, with formal education showing the strongest positive links to student scores (r = .185 to .201), while confidence in teaching science unexpectedly correlates negatively (r = -.092 to -.126). The high inter-subject correlations (r = .912 between math and science) suggest shared instructional influences.

The regression analyses explained in Table 4, provide key insights into the relationship between teacher quality indicators and student academic performance across mathematics, science, and reading. Teaching experience emerges as a positive predictor of student performance, especially in mathematics and science. Regression analysis demonstrates a significant positive correlation between years of teaching experience and student achievement. In science and mathematics, students taught by more experienced teachers tend to perform better, particularly when teachers have at least five years of experience.

The formal education level of teachers also plays a critical role in student outcomes. Correlation analysis indicates that teachers with a Bachelor's or Master's degree contribute to higher student scores across all subjects. Regression analysis further supports this relationship, with formal education showing a stronger impact on reading ($\beta = 0.236$, $p < 0.01$) compared to science ($\beta = 0.153$, $p < 0.01$) and mathematics ($\beta = 0.149$, $p < 0.01$). This suggests that teachers with higher qualifications are better equipped to deliver effective instruction and facilitate student comprehension, particularly in literacy-based subjects.

Teacher confidence is another influential factor, but its relationship with student performance varies by subject. While higher confidence in mathematics teaching is associated with improved student outcomes ($\beta = 0.066$, $p < 0.01$), confidence in science teaching shows a negative correlation with student performance ($\beta = -0.140$, $p < 0.01$). This unexpected result may indicate potential overconfidence among teachers or mismatches in instructional strategies. The findings suggest that while confidence is generally beneficial, excessive confidence in certain subjects may not always translate into improved student learning.

Job satisfaction exhibits a complex relationship with student achievement. While satisfied teachers tend to demonstrate higher motivation and engagement, the direct impact on student test scores is weak. Correlation analysis reveals a slight positive relationship between job satisfaction and reading ($r = 0.042$, $p < 0.01$), science ($r = 0.041$, $p < 0.01$), and mathematics ($r = 0.006$, $p < 0.01$). However, regression analysis unexpectedly indicates negative beta values across all subjects, suggesting that teachers with higher job satisfaction may be assigned to more challenging classrooms or that dissatisfied teachers compensate with increased effort.

Subject-specific findings reinforce the role of teacher quality in mathematics and science achievement. The strong correlation between science and mathematics scores ($r = 0.912$, $p < 0.01$) underscores the shared instructional challenges and opportunities in STEM education. Additionally, contextual factors such as school resources and parental involvement can moderate the effects of teacher quality, emphasizing the need for holistic educational policies that support both teacher development and broader learning environments.

Table 4: Standardized Regression Coefficients for Teacher Quality Predictors

Variable	Mathematics (β)	Science (β)	Reading (β)
Years of Teaching Experience	0.056	0.118	0.197
Formal Education Level	0.149	0.153	0.236
Job Satisfaction	-0.043	-0.055	-0.027
Confidence in Teaching Mathematics	0.066	0.019	N/A
Confidence in Teaching Science	-0.140	-0.083	N/A

The variance explained in below, remains modest, with R^2 values of 3.9% for both mathematics and science, and 7.5% for reading, implying that other additional factors, such as instructional strategies and school resources, contribute to student success. The high inter-

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subject correlations (r = 0.912 between mathematics and science) indicate overlapping instructional influences, further emphasizing the need for an integrated approach to teacher development.

Table 5: Regression analysis summary

	Model Summary	ANOVA
Mathematics	R = .196, R^2 = .039, Adjusted R^2 = .039, Std. Error = 90.98580	F (5, 104918) = 842.214, p < .001
Science	R = .198, R^2 = .039, Adjusted R^2 = .039, Std. Error = 94.29467	F (5, 104918) = 854.399, p < .001
Reading	R = .274, R^2 = .075, Adjusted R^2 = .075, Std. Error = 114.75549	F (3, 281186) = 7626.084, p < .001

V. IMPLICATIONS AND RECOMMENDATIONS:

The strong correlation between teachers' formal education and student achievement underscores the need for stricter qualification requirements. Policies should prioritize advanced training and continuous professional development to maintain teaching effectiveness. While experience positively impacts learning, diminishing returns suggest that structured career-long training is essential. The negative relationship between job satisfaction and student performance suggests that working conditions, such as workload and support systems, require attention to sustain teacher motivation. Additionally, the unexpected negative effect of confidence in teaching science suggests that training programs must focus on subject-specific competencies rather than generalized confidence.

Teachers with higher education levels should leverage their expertise to create engaging, conceptually rich lessons, particularly in science and mathematics. Veteran teachers can play a key role in mentoring early-career educators, facilitating professional knowledge sharing. Given the weak correlation between job satisfaction and student outcomes, maintaining a positive, supportive classroom environment remains crucial. Teachers should also critically assess their teaching methods, seek feedback, and adopt evidence-based strategies to improve instructional effectiveness, particularly in science, where confidence does not necessarily translate to student success.

5.1 Implications for Future Research:

The regression models' moderate explanatory power (3.9% for science and math, 7.5% for reading) suggests that teacher quality is just one component of the whole picture. There is a need for more thorough models because unmeasured factors like class size, school resources, or student motivation probably have a big role. The TIMSS data's nested structure, which places students within classes and schools, emphasizes the value of multilevel modeling in dividing variance across levels. This topic has been largely explored but still needs further research to fully identify contextual impacts.

The detrimental impact of science teaching confidence and work satisfaction demands qualitative examination through interviews or classroom observations to find deficiencies in training or teaching methods. Mixed-method approaches are necessary because systemic variables like policy demands or a lack of autonomy can cause problems with job satisfaction. Strong cross-subject correlations (such as 0.912 between science and math) point to common instructional factors and emphasize the need for more research on teacher collaboration or curriculum integration. Analysis of how the consequences of teacher quality differ by nation's infrastructure or socioeconomic level is made possible by TIMSS's worldwide reach. The significance of teacher quality in education could be better understood by using comparative and longitudinal research to pinpoint best practices and elucidate the long-term effects of experience and professional growth.

5.2 Recommendations:

The are several suggestions for educational stakeholders, in light of the implications: improve teacher educational standards, encourage the development and retention of teachers, create ways to improve job satisfaction and confidence, and adjust instructional strategies. Finally, the study recommends extended research activities including qualitative technique to focus into happiness and self-esteem, and comparable studies to find scalable solutions.

VI. CONCLUSION:

In order to present a worldwide perspective, this research paper has examined the relationship between teacher quality and student

academic performance using data fromTIMSS. Student performance in reading, science, and math was analyzed in relation to formal education level, years of teaching experience, confidence in teaching, and job satisfaction. Their significance in improving learning is confirmed by key studies that show increased degrees and experience have a favourable impact on outcomes, with reading showing a noticeable strength. The unexpectedly negative correlations between job satisfaction and confidence in teaching science, however, draw attention to problems and point to possible training or workplace support deficiencies. These findings highlight the complexity of teacher quality and how it affects different disciplines differently.

These findings have important ramificationsfor educational systems around the globe. In order to optimize teacher effectiveness, they promote stricter certification requirements and retention tactics. They also highlight the necessity of providing focused assistance to boost confidence and satisfaction. A holistic approach is encouraged by the models' low explanatory power, which implies that other factors, including school resources, also important. Future investigations that address global disparities, such as multilevel and longitudinal studies, can expand on these findings. This study promotes optimal teaching approaches to improve student success and educational equity, laying the groundwork for evidence-based reforms.

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