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STEM Education Quality and Student Engagement in Urban-Rural Primary Schools in Shandong China

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Abstract

China primary schools emphasis on STEM education, large disparities still exist in its implementation, notably between urban and rural educational institutions. This study indentify the correlation between the quality of STEM education and student engagement of primary school teachers in urban and rural areas. Using a correlational study design, the study collected data from 384 primary school teachers in Shandong, China through a structured questionnaire. The questionnaire prodbed into STEM education and measured student engagement on behavioral, emotional, and cognitive levels. Based on the results of the survey with ($r = 0.719$, $p < .01$), there was a very strong positive relationship between the quality of STEM education and student engagement. The regression results confirmed the quality of STEM education as a strong predictor of student engagement ($R^2 = 0.614$) while the school location also significantly explained the variation. Majorly, urban schools and not rural schools were the sources of higher scores for both the quality of STEM instruction and student engagement because of the following results. These effects further corroborate the previous findings that the key players in improving STEM experiences are the factors related to teaching. STEM education in China is still struggling with the gap between the myriad of challenges in different regions in realizing the full potential of STEM education, hence, the nation is nowhere near where they should aim to be. The need of the hour is an ever-increasing supply of capable and motivated professionals, well-versed in updated technology, in the realm of STEM. A more feasible scenario is generated in which learning is contextualized, student engagement, and, quite possibly, academic achievement will rise along with it. The conclusion underscores the significance of raising STEM education quality to ensure effective student engagement, especially in financially-weak rural areas. The research suggests policy options like the more extensive teacher training, fair resource allocation, and context-based curriculum change. They are the main elements of eliminating the urban-rural gap and realizing inclusive STEM education.

Keywords: STEM Education Quality, Student Engagement, Urban-Rural Primary Schools

Introduction

In the efforts of China to make STEM education prominent and a priority, it comes out that there is imbalance in the quality and regularity in the implementation, more so in the case of urban and rural schools. The aforementioned discrepancies are not only immediate but also direct causes of decreased student motivation and stilted equity in access to education. Given that teachers are the main decision-makers of classroom settings and students' involvement, it is imperative to explore teacher attitudes. Educators in rural schools are deprived of less professional development and teaching resources, which are critical to their abilities to deliver STEM pedagogy effectively (Jiang, 2024). Different teachers' preparation routes and infrastructure unevenly supply and convey the message about STEM education in different urban and rural locations. Thus, of late, it has been shown that the professional identity and beliefs of teachers in rural areas are often negatively affected by systematic inequalities and thus their teaching strategies have been affected (Wang et al., 2023). Also, educational disparities have been blamed for the lack of teacher qualifications, less effective instructional strategies, and the lack of classroom engagement in rural areas (Chang & Wang, 2024). That is, inner city schools' successes can only support this point if and only if the said teachers in the interior areas perceive the challenges in a straightforward way and act on them. This study aims to identify the correlation between the quality of STEM education and student engagement of primary school teachers in urban and rural areas. In order to know the quality of STEM education are analyzed through the perspectives of Constructivist and Experiential Learning theories, this study looks at student engagement as a complex idea that includes behavioral, emotional, and cognitive characteristics.

Previous Research

Science, Technology, Engineering, and Mathematics (STEM) education is a trend worldwide that has a significant impact on the knowledge-based and innovative economy. The inclusion of students in the STEM related areas has become overly important. This is due to the fact that it bears a heavy weight on the school performance, career decision, and long-term retention in the given subject (Attard et al., 2021). Both worldwide and Chinese scholars have been exploring the most essential elements that determine the level of education and student engagement in STEM. A matter of great concern is the performance of teachers and student engagement, especially in the various school settings (Jiang, 2024). The problem arises from the fact that the educational inequality existing between the urban areas and the countryside has been deeply and well-established.

New research findings have brought the essential elements of teacher quality, embedding habitually the curriculum, and innovations resources to the stage of the biggest STEM student engagement forecasters. Ranosz et al. (2023) reasoned that 3D game-based learning in STEM subjects proved to be effective and, in the meantime, evoking students' curiosity. It was carried out by Attard et al. (2021) who came up with such instruments as inquiry and industry collaboration that allowed more student interest and thus, made STEM education more attractive. In the Australian school education system, Way et al. (2022) implemented a triple-level method as they discovered that the full combination of the teachers' active-inductive method and the students' independent approach to STEM in education were significantly related to students' participation. Also, a study by Holmes et al. (2022) determined that place-based and contextual authorship of motivation and attitudes was generated toward STEM education, especially through lessons, which students could associate with real experiences. Lechhab et al. (2023) demonstrated the indispensability of the teachers' constant improvement approach and the introduction of ICT in creating the educational environment that would be open, interactive, and beneficial to students with various abilities.

Tiep (2023) believed that teacher awareness has a crucial role in the proper introduction of STEM curricula, and the study that he conducted withdrawn the conclusion that several teachers at the elementary schools were unsure of the methods and lacked resources for the proper implementation of STEM lessons. Wang et al. (2023) noticed the differences in engagement from urban and rural settings and they uncovered the reasons for this, including changes in teacher training, technical tools, and infrastructure. Jiang (2024) had almost the same results as he stated that there are no ways teacher quality can be improved in the rural areas and that there was a direct effect on the quality of teaching and students' participation in class. Chang and Wang (2024) found out that there is a significant relationship between the increased effectiveness of teaching methods and the involvement of students in class when carrying out English-STEM integration. Li et al. (2023) went on to make a finding that students' participation in STEM is influenced by their perception of the value of tasks and their self-efficacy, which holds the idea of using goal-related material as really important. According to Zhang (2024), teacher satisfaction and the depth of their involvement promoted the decision about which method of academic engagement was to be used, especially in the places with limited resources. Adams and Sargent (2013) observed that the implementation of interactive and more student-centered practice was gradually leading to a more positive attitude of students in northwest China, thus, engagement was being improved to a small but continuously progressing extent.

International and Chinese scholars agree on a few points aside from contextual differences. Firstly, the teaching quality is generally accepted as a prerequisite for student engagement all over the world. The sources have not only revealed that inquiry-based, interdisciplinary and student-centred methods are the most effective, but studies also show that they boost both interest and involvement in STEM education (Way et al., 2022; Jiang, 2024). The most important, the students and the students' lives are the first stake. Without the focus of the students' lives and their desired futures in STEM education, no material will engage students. Moreover, project-based and place-based with authentic applications have been validated in various contexts (Holmes et al., 2022; Wang et al., 2023). Thirdly, if they are exposed to professional growth, the teachers' output can be greatly improved. The data from this area have shown that the effectiveness of in-service teacher training has its consequences in terms of student performance both locally and internationally. Conclusions follow from the international and Chinese contexts with the fact that they have achieved a positive effect (Lechhab et al., 2023; Chang & Wang, 2024).

To begin with, there is the difference in the educational inequality of rural areas in China. An overview of studies worldwide focuses on teaching practice in rich, urban geographies, pointing out that China still faces the problem of old machinery, the huge size of classes, and inferior learning materials in the countryside (Wang et al., 2023; Jiang, 2024). The most obvious distinction can be seen between top-down structured education and classroom teaching. While the global systems are capable of pushing through reforms in an undeviating way, the Chinese institutions frequently refer to the impediments of the national curricula due to local peculiarities (Zhang, 2024). Furthermore, international scholars are on the rise of interest in emotional and psychological dimensions of engagement, for example, interest, identity, and intrinsic motivation, while Chinese scholars' interests are still predominantly on instruction and performance (Murphy et al., 2019; Li et al., 2023). This may reflect an orientation in educational values, with China moving from exam-oriented educational models to holistic models of engagement. And fifth, the concept of assessment is framed around formative assessment in Western literature and summative exams in Chinese journals, which in turn dictates the testing practices and the development of students' engagement (Chang & Wang, 2024; Attard et al., 2021).

Research Design
A correlational design has been used in this study to investigate the association between STEM Education Quality (independent variable) and Student Engagement (dependent variable) among urban and rural primary school teachers in China. Data collection was mainly conducted through a quantitative research design using a questionnaire that was structured, which was one of the key methods of gathering the data. In total, the participants were 384 teachers, and they were a cross-section sample of urban and rural primary school teachers.

STEM Education Quality and Student Engagement. STEM education quality was measured in the areas of Science, Technology, Engineering, and Mathematics whereas Student Engagement was represented by the Behavioral, Emotional, and Cognitive dimensions. Correlation and regression analyses were used to investigate further the relationship between the two variables in terms of the strength and direction of the association of STEM Education Quality and the levels of Student Engagement, respectively.

Locations, Population and Sampling
Geographic concentration of Shandong Province, China, which is noted for the development of the educational sector and substantial urban-rural heterogeneity, is the basis of the present study. The Shandong education system is an ideal area for comparing and contrasting the quality of STEM education and the participation of students in various learning environments. Because of the province's existence of urban areas with technology and rural communities without technology, the province became an appropriate one to conduct a research on technology integration influenced by context variables like infrastructure, teacher capacity, and the availability of resources (Zhou & Lin, 2023).

For this research, the primary target population is a group of primary schoolteachers in urban and rural public primary schools in Shandong Province. It is the teachers who directly deliver STEM-based curricular and are really aware of students' interest in the curricula.

The researchers took a sample of 384 teachers using the universally recommended Krejcie & Morgan (1970) formula, which suggests this number for populations of 10,000 and above at a 95% level of confidence with a 5% margin of error. This figure of the sample is statistically reliable for quantitative research and has statistical potency (Hair et al., 2023). The statistical findings are good for making informed inferences and are inclusive of correlation and regression analysis to find out the relation between STEM education and student engagement in different educational settings.

Intrument
The questionnaire on this research has questions that relate to recent education studies in STEM education which are about curriculum design, quality of instruction, students' engagement, and psychometric measurement. The author of this paper suggested that the following studies might be taken as benchmarking: Holmes et al. (2022) in place-based education, Johnson and Miller (2024) who talk about maintaining interest through pre-emptive interventions, and Robinson and Fenner (2020), the developer of the STEMTIP scale for instructional readiness. In the domains of gender difference in engagement, Vincent-Ruz and Schunn (2023) on STEM identity, and Wang and Degol (2023) who carried out a literature survey of STEM research instruments have also made a good mix of new contributions. Together, these works provide a strong base to evaluate STEM education and student engagement.

The survey consists of four sections. Part A basically contains questions about the gender, age, teacher's teaching experience, school location, education title, and subjects taught. Part B is about the quality of STEM education where S, T, E, and M refer to Science, Technology, Engineering, and Mathematics and these are viewed through the lenses of Constructivist Learning Theory (Piaget, 1952; Vygotsky, 1978), and Experiential Learning Theory (Kolb, 1984). Part C is to take interest as a multi-dimensional concept of behavioral, emotional, and cognitive engagement in Engagement Theory by Kuh (2003), and Self-Determination Theory by Deci and Ryan (1985). Both of these sections, that is, Part B and Part C, resort to the use of the 5-point Likert scale in order to ascertain the level of agreement of the respondents with the listed statements.

Section D is a series of questions without constraints that permit the gathering of qualitative data. Teachers have to mention what challenges they faced in order to implement STEM education, provide ideas on how to improve student participation, and indicate the resources or training they may need. The survey consists of two equally important parts: the first one to explore STEM educational practice, and the second one to find out student participation, however, the data as a whole will depict the situation clearly only in primary schools

Results
This section presents the correlation analysis between the independent variable (IV) and the dependent variable (DV). The Pearson correlation coefficient was used to assess the strength and direction of the relationship between these variables. Table 1 provides the results of the correlation analysis.

Table 1
Descriptive Statistics for STEM Education Quality (IV) and Student Engagement (DV)

STEM Education Quality (IV) and Student Engagement (DV)			
	Mean	Std. Deviation	N
IV	75.0625	10.15577	384
DV	63.0938	7.27394	384

Table 1 outlines the findings which give us the average of 75.06 points for the educational STEM quality, meaning that on the whole, educators consider that the STEM programs in their respective schools are of quite high quality. The result not only illustrates the positive perspective but also the level of teachers' and community's support in the educational setting. Also, the mean score for learner involvement is 63.09, and though the result is indicative of a situation with both significant participation and aspects for improvement, the types of participation talked about are those in the middle to the higher end of the scale. Looking at the standard deviation figures, there is still a certain variance in the response across the teachers, however, the variance in the quality of STEM education is higher than the student engagement. It means that the same source could be understood differently by different people and thus the location of the school, the resources they have, and the personal experience of being a teacher might influence the understanding of quality of STEM.

One way to research the robustness and kind of dependence or connection between the two mentioned items that is, the value of the quality of education in STEM and the engagement of the learner is to use Pearson correlation and by that, we will get more insights on the role of the strengthening of the one variable in student involvement in the other. Table 2 provides the results of Correlation Between STEM Education Quality and Student Engagement.

Table 2
Correlation Between STEM Education Quality and Student Engagement

Correlations STEM Education Quality (IV) and Student Engagement (DV)			
		IV	DV
IV	Pearson Correlation	1	.719**
	Sig. (2-tailed)		.000
DV	Pearson Correlation	.719**	1
	Sig. (2-tailed)	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

According to Table 2, the Pearson correlation analysis was carried out to establish the effect of STEM education quality (IV) on student engagement (DV). The correlation is calculated as r = 0.719, which indicates a very strong positive connection between the two variables. In other words, a better perceived quality of STEM education is one with a direct link to an improved level of student engagement. The p-value of 0.000, validating the correlation to significant levels, is reported at the 0.01 level (2-tailed). This significance level is said to give us 99% confidence that the relationship seen would be very likely due to a real effect. It is stated in the guidelines for the interpretation of the correlation coefficient that the value obtained is 0.719, which corresponds to the range of a strong correlation (0.7–0.9). This value signals a significant linear relationship between the variables IV and DV, which means that a change in IV is associated with a change in DV.

Table 3 below illustrates the summary findings of the data analysis which sought to understand the correlation between STEM education quality and student engagement. The analysis aimed at finding out how much of the quality of STEM education can forecast the engagement levels of the students. Important statistical indicators like R-squared (R^2), adjusted R-squared, standard error of the estimate, and the Durbin-Watson statistic are displayed. These values give evidence of if the regression model is a good fit and if it is possible to explain the level of students' engagement by the variation in STEM education quality. The results are very crucial for educators and policymakers who are interested in the improvement of student engagement in STEM-related learning environments.

Table 3, Model Summary of Regression Analysis Between STEM Education Quality and Student Engagement, tells us about the regression model and its ability to predict that examines the association between STEM education quality and student engagement.

Table 3
Model Summary of Regression Analysis Between STEM Education Quality and Student Engagement

Model Summary of Regression Analysis Between STEM Education Quality and Student Engagement							
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.784[a]	.614	.612	4.52964	.614	303.334	2

Table 3 shows the model summary of the linear regression analysis that was used to find the predictive relationship between STEM education quality and student engagement. The model showed an R-value of 0.784, which the positive correlation between the dependent and independent variables remained high. An R^2 of 0.614 suggests that nearly 61.4% of the variation in the dependent variable (student engagement) can be explained by the quality of STEM education that students perceive. The adjusted R^2 of 0.612 provides evidence for the statement that the model retains its strength even after the number of the predictors has been controlled for. The standard error of the estimate of 4.52964 is the mean deviation of the observed values from the regression line. Moreover, the F-change value of 303.334 illustrates a significant result, which shows that the model is statistically significant, suggesting that the predictor (STEM education quality) has a major effect on the changes that occur in student engagement. In general, these outcomes endorse the view that perceived quality of STEM education is a significant and reliable predictor of the students' engagement level in the STEM learning environment.

Table 4 below presents the regression model summary examining the effect of STEM education quality and school location on student engagement. The analysis assesses how both factors together influence student engagement, highlighting their individual and combined contributions to the overall model fit.

Table 4
Regression Model Summary: Effect of STEM Education Quality and School Location on Student Engagement

Regression Model Summary: Effect of STEM Education Quality and School Location on Student Engagement			
Model	Change Statistics		
	df2	Sig. F Change	
1	381	.000	2.325

a. Predictors: (Constant), STEM_Urban Rural
b. b. Dependent Variable: DV

Table 4 provides a summary of the results of a regression model that assesses the relationship between STEM education quality and school location (urban-rural area) on students' engagement. The model produces a significant F-change of 2.325 with a p = .000, suggesting that the variable of school location positively influences the model's ability to predict student engagement. The df2, which is 381 for the model, represents the observations used for the analysis of the model. The p-value of the model being statistically significant (p < .001) indicates that the independent variables that is the quality of STEM education and urban versus rural setting both together make a notably large contribution to the explanation of the variance of student engagement. This means that aside from STEM education, school location is another factor that is responsible for students' engagement with the settings of the STEM education at different levels.

Table 5 below find the results of the regression model designed to forecast student engagement depending on STEM education quality and school location. In it, user can see the statistical importance and impact of each predictor and thus get the idea of how these variables affect student engagement levels.

Table 5
Summary for the Regression Model Predicting Student Engagement Based on STEM Education Quality and School Location

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12447.403	2	6223.701	303.334	.000[b]
	Residual	7817.222	381	20.518		
	Total	20264.625	383			

a. Dependent Variable: DV
b. Predictors: (Constant), STEM_UrbanRural, IV

Table 5 showcases a summary of the regression model that was used to evaluate how STEM education quality and school location can predict student engagement. The regression sum of squares is 12,447.403 on df = 2, with the mean square of 6,223.701. The F-value is 303.334 and the p-value (significance level) is equal to .000. As a result, the overall regression model can be interpreted as significant at the 0.001 level. Consequently, both the STEM education quality and the school location characteristics are important and influential factors in the prediction of student engagement, and there is no 'by chance' variance explained by these factors. The residual sum of squares is 7,817.222 and this is the part of the variance that is not explained by the regression model, while the total sum of squares (20,264.625) represents all the variance in the student's engagement. This confirms that the model is correct and both variables are the main force in student involvement in science, technology, engineering, and math. Learning.

Discussion

The results of the correlation and regression analyses clearly indicate a strong and statistically significant relationship between STEM education quality and student engagement in primary schools in Shandong, China. The Pearson correlation coefficient ($r = 0.719$, $p < .01$) confirms a strong positive correlation, implying that as the perceived quality of STEM education improves, so too does student engagement. This is further supported by the regression analysis, which shows that 61.4% of the variance in student engagement can be explained by the quality of STEM instruction ($R^2 = 0.614$). These findings align with previous research emphasizing the influence of instructional quality on student participation and outcomes (Attard et al., 2021; Ranosz et al., 2023).

The findings support international literature highlighting the importance of engaging, pertinent, and interdisciplinarity STEM education in promoting student motivation and student engagement. For instance, the application of 3D games (Ranosz et al., 2023) and inquiry strategies (Attard et al., 2021) has been seen to positively impact the perceptions of STEM among learners and their desire to engage. In the same vein, in the Chinese educational context, Tiep (2023) and Jiang (2024) pointed to the importance of quality education and highly supported educators to promote student engagement, especially in disadvantaged rural communities.

Moreover, the findings reveal the moderating role of school location. The regression model that included school location as a predictor showed statistical significance ($F = 303.334$, $p < .001$), pointing at the imbalance between urban and rural areas as a major cause of the differences in engagement. This comes in line with the available literature on infrastructural differences, teacher development, and resources between urban and rural schools in China (Wang et al., 2023; Jiang, 2024). Such differences should be addressed by means of targeted interventions such as differentiated professional development and the fair provision of resources.

Moreover, the results of the study have made it clear that teachers' perceptions displayed a large standard deviation quest for the contextual factors such as experience of the teacher, availability of technology, and policy support one can still resort to in case there is a need for a research which should measure the influence of the above factors on the STEM-engagement relationship.

However strong the evidence obtained is, the research can be characterized by the lack of control of the factors that could possibly affect the study. Even if the study shows a strong correlation and a high R-squared value, it cannot explain the cause of the issue. Furthermore, future research conducted using an experimental or longitudinal research design to investigate the impact of targeted STEM education reform on the learners' engagement might be needed.

These results indicate that school administrators and policymakers need to take appropriate action. If, through modifying the current curriculum, training and support of teachers and provision of resources the quality of STEM education improves, then it might be expected for the numbers of highly engaged students to go up dramatically. Special resources are most needed in order to boost the school districts that are rural, as there are already observable disparities and deficiencies there that can obstruct proper implementation of STEM education. According to this report, teacher-focused and cutting-edge strategies to engage students and recognized to be the best factors for growth and performance (Holmes et al, 2022; Chang & Wang, 2024).

Conclusion

To conclude, not only is the promotion of high-quality STEM education an important factor in the investment in education, it also contributes to keeping the interest, and thus the involvement, in studying science and technology among the students. The students should be targeted on time so that their teachers, administrators, and all stakeholders collaborate in the promise to ensure that they benefit from the resources and delivery of STEM wherever they are.

Implication and Suggestion

The study presents the governance of the education sector with very important insights. The first lesson is the principal necessity to focus on a specific teacher's professional development. The situation in the rural areas, where the shortage of training and resource facilities might endanger the student's educational process, is particularly severe. Second, the developers of the curriculum and those who establish the educational policy have the tremendous task of ensuring that the teaching and acquisition of these activities are real-world, linking disciplines, and tech-based. Third, the school managers have to ensure that the institution not only adequately provides infrastructure, such as instructional materials and ICT tools, but that they also distribute them to the urban-rural divide equitably. Lastly, the survey data substantiate that STEM performance can be significantly improved, and the results can be linked to the bigger educational equity and innovation picture in the country's education system.

Teacher professional development has been suggested as a method to advance the STEM curricular field, particularly in the countryside, which, in turn, will guarantee the best teachers of this subject. It is also the schools' role to engage the students early in inquiry-based and relevant learning to extend the number of project-based methods available. One of the crucial aspects here is to secure the necessary hardware, software, and learning materials before only then we talk about the use of different technologies. The government should give local freedom in the organization of education in its national policy through delegation of authority and allocation of necessary resources. The future study would be better if it considered the long-term and implementation aspects that affect the educational context and the students' participation in various learning areas.

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