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Teacher Credentials, Students' Efforts and Aspirations as Determinants of Learning Achievement in Mathematics and Science

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Abstract. This study examined the relationship between teacher credentials, student efforts, aspirations, perceptions, and learning achievements in mathematics and science. Using cross-sectional data from 4,081 students and 1,000 teachers across 150 schools in 92 districts in Ghana, the ordinary least squares method was applied. The findings highlighted several key factors influencing student achievement. Teacher experience was found to have a significant impact on student performance, highlighting the importance of retaining experienced educators. Teacher qualifications and subject-fitness also showed modest effects, with professional development training enhancing the impact of teacher qualifications. This indicates that professional development training not only improves teaching skills but also complements teachers' educational backgrounds. On the student side, the study emphasized the critical role of effort, aspirations, and positive attitudes toward learning in determining achievement. These findings stressed the need to foster a motivating environment in which students set high aspirations, commit to personal study, and maintain a positive outlook toward their subjects. Based on these results, the study recommended that the National Teaching Council and the Ghana Education Service design targeted professional development programs tailored to teachers' qualifications and needs. This approach would enhance the effectiveness of professional development training and ensure that teachers are equipped with both content knowledge and pedagogical strategies. Furthermore, the findings provided actionable evidence for policymakers and educators aiming to improve learning outcomes in science and mathematics. By addressing both teacher-related and student-related factors, targeted

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interventions can better support academic performance and long-term educational success.

Keywords: teacher credentials; professional development training; subject-fit teacher; teaching experience; student performance

1. Introduction

Teachers are critical determinants of students' learning outcomes. Teachers influence how students regard themselves and participate in classroom activities (Thomas & Nair, 2023). Teachers select, design, and conduct the experiences of learners (Bosch et al., 2025; Rasuli et al., 2023). To a large extent, the experiences and achievements of learners, therefore, depend upon the teacher's effectiveness in the art of conducting learner's experiences. The overall quality and effectiveness of the teacher is a function of the talent and training received. The quality of a teacher is characterized by educational qualification, the training received, and the teacher's knowledge of the subject matter. It is also characterized by the teacher's ability to recognize individual students as learners, as the teacher is expected to build on the learners' strengths (Blömeke et al., 2016).

Many studies have demonstrated a substantial correlation between teacher quality and student accomplishment and learning outcomes, relying on indices such as subject knowledge, experience, training, qualifications, or general intellectual ability (Blömeke et al., 2016; Hanushek et al., 2004). If an experienced professional teacher is carrying out their tasks and obligations and other conditions are held constant, there is a greater possibility that pupils will achieve success. The majority of the pedagogical practices that teachers employ when instructing students in a classroom depend on their content knowledge, pedagogical knowledge, and abilities (Borko, 2004; Wilmot, 2008).

Despite a favorable pupil-teacher ratio of 16.02 as of 2018 and high proportions of trained teachers (77.11% as of 2018) at secondary schools in Ghana, there are poor returns in learning measured in terms of pass rate, particularly in mathematics and the science subjects (UNESCO, Institute for Statistics, 2019). For many years, the failure rate in mathematics and science has been high at Senior High School (SHS) level (Azure, 2015). The Chief Examiners' report of the West African Examination Council (WAEC) indicated that the performance of students in science is not encouraging (WAEC, 2017).

Because of the persistent poor performance of students in mathematics and science, the Ministry of Education (MOE) and the Ghana Education Service (GES) have prioritized improving the quality and effectiveness of teachers. A significant focus has been placed on evaluating teachers' classroom performance to determine their effectiveness in fulfilling their roles. However, research examining how factors such

as teacher subject-fitness, pedagogical skills, teaching techniques, and teaching experience affect student performance in mathematics and science in Ghana is limited. Furthermore, studies exploring how teacher and student characteristics jointly influence the performance of secondary school students in these subjects are scarce. It is worth highlighting that Blömeke and others (2016) identified key teacher credentials including teachers' education qualifications, teaching experience, subject content knowledge, pedagogical knowledge, and pedagogical content knowledge as crucial to students' learning outcomes. Similarly, Blömeke and Delaney (2012) emphasized that teachers' subject-fitness, content knowledge in mathematics, and strong educational credentials combined with pedagogical content knowledge enhance instructional quality and improve student achievement.

This study aimed to investigate how teacher and student characteristics influence the achievement of secondary school students in mathematics and science in Ghana. The specific objectives guiding the study are as follows:

1. To examine how various dimensions of teacher quality affect students' performance in mathematics and science.
2. To assess the impact of students' characteristics on their performance in mathematics and science.
3. To explore the role of classroom management in students' achievement in mathematics and science.

2. Literature Review

In Ghana, the education system has three education levels: basic, secondary, and tertiary. Basic education covers 11 years, and students complete this level by taking the Basic Education Certificate Examination (BECE), which qualifies them to transition to secondary school education. Secondary level education involves general education (SHS) and vocational (Technical SHS and vocational institutes). Secondary level education lasts three (3) years and is completed with students writing the West Africa Senior School Certificate Examination (WASSCE) (MoE, 2018). The WASSCE is conducted by the WAEC. The WAEC is a non-profit organization established by the governments of the Gambia, Ghana, Liberia, Nigeria, and Sierra Leone. The regional examination body serves to harmonize and standardize pre-university assessment procedures within and among the member countries (WAEC, 2024).

Over the years, the performance of SHS students has been of concern. Student performance in the terminal standardized WASSCE has generally been inconsistent (WAEC, 2017). The WAEC Chief Examiner's report attributed the inconsistency to include ill-preparation for the examination and poor understanding of scientific principles (WAEC, 2017). The report further suggested that teachers should make the teaching of mathematics and science lively and interesting in order for students to appreciate the concepts and topics in the syllabus. These reasons may be a

reflection of teachers' poor pedagogical skills and the lack of effort and poor attitude toward studies on the part of students, an interplay of teachers and student factors associated with students' performance.

The study is guided by the McIlrath and Huitt (1995) model of school learning, which follows a systems theory framework. The systems theory framework views learning as an interconnected and dynamic process involving various factors at different levels. This framework emphasizes the interaction between inputs (e.g., student and teacher characteristics), processes (e.g., instructional practices), and outputs (e.g., student performance and achievement). The model integrates elements of behavioral, cognitive, and constructivist theories, focusing on how these components influence student learning within the school environment. By taking a systems approach, the model highlights the importance of both internal factors (e.g., motivation and prior knowledge) and external factors (e.g., teacher quality and classroom environment) in shaping educational outcomes.

The McIlrath and Huitt (1995) model considers both teacher and student behaviors and recognizes that the success of any educational process depends on what teachers provide and how students engage with it. The actions of both teachers and students in the classroom are influenced, to some extent, by the qualities and characteristics that they bring to the teaching and learning process. The McIlrath and Huitt model shows input and output as the beginning and the end of the teaching/learning process. Teacher and students' characteristics are labeled input variables while student performance is defined as output. Subcategories of teacher characteristics include planning, management, and instruction delivery. The second subcategory of student input consists of characteristics such as study habits, age, motivation, and emotional, cognitive, and character development, all of which are important in the relationship (McIlrath & Huitt, 1995). A good measure or proxy for cognitive ability is a student's prior performance at the end of one academic year, which often becomes a characteristic at the beginning of the next academic year. A third subcategory comprises parental education and family expectations for student performance, which have also been shown to be good predictors of student performance.

A number of studies have investigated teacher qualification, teacher training, and teacher teaching experience in relation to students' performance. Woessmann (2004) suggests that the teacher as an input in the education production equation is the principal factor. Carroll (2005) agrees but added that there are significant differences among teachers in terms of methods of teaching and skills. A study by Siemon et al. (2001) on the effectiveness of mathematics teachers observed significant differences within schools in student achievement. Similarly, Sullivan and McDonough (2002) found evidence that students from similar backgrounds

have different experiences at school, and this could only be associated with differences among the teachers.

Carroll (2005) argues that the key factor regarding teachers is not the level of their formal qualification but their depth of knowledge of the subject matter. This is because an important role of the teacher is to provide students with learning environments that are responsive to their needs (Anthony & Walshaw, 2009). It is in this regard that Ankoma et al. (2005) posit that the teacher's role is not limited to selecting subject content based on students' age, needs, interests, abilities, and aptitudes but also involves choosing appropriate teaching techniques and resources to enhance classroom learning. An effective teacher, therefore, is one who can use a variety of tools and representations to support students' cognitive development (Anthony & Walshaw, 2009).

It is widely known that teacher qualification and professional development are important determinants of student achievement. However, studies that hypothesize teachers' qualification have not reached a consensus on the direction and effect on learning outcomes. For example, Darling-Hammond (2000) indicates that a teacher's master's degree has no influence on students' academic performance. Myrberg (2007) also suggests that a master's degree does not assure teacher competence in the delivery of mathematics content. The works of Yara and Otieno (2010) and Hill (2010) are among the few studies that argue that the quality and level of education of a teacher directly affects their understanding, knowledge, and subject matter delivery.

Teacher training is one of the main determinants of quality teaching and learning outcomes. Naoreen et al. (2011) assert that trained teachers are able to produce better results than untrained teachers, and well-trained teachers depict better content knowledge and skillful delivery of mathematics and science subjects. In addition to a teacher's initial training, ongoing professional development that is focused on specific subjects is crucial in determining student performance. For example, in-service training for mathematics and science teachers plays a key role in enhancing their effectiveness.

Bjekić et al. (2008) argue that beyond the basic training that teachers receive in colleges and universities, ongoing professional development is crucial for effective teaching. Similarly, Ochieng et al. (2016) found that teacher training had a positive impact on students' mathematics performance in Kenyan public secondary schools. The quality of pre-service training combined with ongoing professional development (e.g., in-service training) is, therefore, strongly linked to student achievement and overall school performance. Such professional training not only refreshes teachers' content knowledge but also enhances their competence, leading to improved student outcomes.

Another ingredient of teacher quality is the subject-fitness of the teacher. Subject-fitness of a teacher is defined as a teacher teaching the specific subject that they studied in school, especially at the higher education level. In other words, a teacher who is subject-fit to teach a particular subject is one who studied the particular subject at the terminal level that qualified the person to teach at the level they have been engaged to teach. This variable is particularly important at the SHS level where students are expected to begin to prepare for university education. Subject-fit teachers are more likely to have higher content knowledge in the particular subject area than one who has not studied the subject as a cognate area but is merely teaching it because no specialist is available (Sancassani, 2023). Ball (2000) suggests that teachers with strong content knowledge are better equipped to create opportunities that enhance student learning and engagement and to address diverse learning needs in the classroom.

An educator's teaching experience can be measured by the total number of years the teacher has worked as a teacher and by the number of years spent teaching a specific subject. Darling-Hammond (2000) observed that teachers with many years of experience are generally more effective than those with less than three years of experience. Furthermore, Rice (2010) suggests that experience enhances teachers' knowledge, skills, effectiveness, and productivity in achieving desired outcomes. Similarly, Ochieng et al. (2016) found that teachers' experience has a significant positive impact on student performance, indicating that more experienced teachers tend to achieve better results than their less experienced counterparts.

3.0 Methodology

3.1 Research Design and Study Participants

The design used for this study was an exploratory cross-sectional design. This design was appropriate, as the primary goal was to explore and gain insights into the role of teacher credentials and student characteristics in influencing learning outcomes. The study was not intended to test any specific hypotheses or to establish any causal relationships. The interest was to identify relationships and suggest directions for further research. A cross-sectional quantitative survey of senior high schools was, therefore, conducted to collect data for the analysis. The survey was conducted in 150 schools in 92 districts across Ghana. The analysis was based on the data that was collected from 4,081 students and 1,000 teachers.

3.2 Research Instrument

Two separate survey questionnaires were developed, tested, and used to collect the data from the teachers and students. Information collected from the teachers included background information, educational attainment, teaching experience, and pedagogical skills. Other items included professional development training (PDT). The student questionnaire collected information such as students' perceptions about

mathematics and science, their perception of the importance of studying mathematics and science for future academic progression, and their assessment of the difficulty of mathematics and science. Another section covered students' perceptions of teachers in terms of skills and the methods employed in teaching. Items in this section included teachers' punctuality to class, their level of preparedness for lessons, and their use of relatable examples during teaching. The learning outcomes for students in mathematics and science were measured using a multiple-choice item test (20 objectives each) that had been developed and tested. All instruments were piloted, and the protocol was reviewed and approved by the Ethics Committee for the Humanities† of the University of Ghana.

3.3 Data Collection Process

The data was collected using the Computer Assisted Personal Interviewing (CAPI) approach. The CAPI is a survey method in which interviewers use electronic devices (e.g., tablets or laptops) to collect data during face-to-face interviews. This offers several advantages, including reducing errors by incorporating validation checks, skip patterns, and prompts directly into the survey software. It also facilitates the immediate review of responses, helping to identify inconsistencies or missing data during the interview. The survey questionnaire was adapted to the CAPI using the CSPro application for survey data collection and management mounted on android tablets. Fieldworkers underwent thorough training to enable them to understand the content and purpose of each item on the questionnaire and how to use the CAPI efficiently and effectively.

3.4 Data Analysis

3.4.1 Estimation Technique

A regression model was used to explore the relationship between teacher credentials and student characteristics and students' performance in mathematics and science. The general form of the linear regression model was given as follows:

$$Y_i = \alpha_i + \beta X_i + \varepsilon_i Y_i = \alpha_i + \beta X_i + \varepsilon_i \quad (1)$$

where Y represents the dependent variable (test scores in mathematics and science) in the model, X denotes the set of explanatory or independent variables in the estimation model, $\alpha_i \alpha_i$ is a constant, β β is a parameter to be estimated, $\varepsilon_i \varepsilon_i$ is the error term, and i denotes individual student respondents. The empirical analysis followed the model of Ochieng et al. (2016). The model was specified as follows:

$$Perf_i = \beta_0 + \beta_1 TrQual_i + \beta_2 PDT_i + \beta_3 Exp_i + \beta_4 SubjFit_i + \beta_5 TTechn_i + \beta_6 BECE_i + \beta_7 Effort_i + \beta_8 Asp_i + \beta_9 Perc_i + \beta_{10} Sex_i + \beta_{11} Form_i$$

† Protocol approval number: *ECG 007/16-17.*

$$Perf_i = \beta_0 + \beta_1 vTrQual_i + \beta_2 vStudent_i + \varepsilon_1$$
$$Perf_i = \beta_0 + \beta_1 vTrQual_i + \beta_2 vStudent_i + \varepsilon_1 \quad (2)$$

where '*Perf*' denotes the test scores (in terms of percentages) in mathematics and science, and 'v*Teacher*' is a vector of teacher characteristics containing items such as educational qualification (*TrQual*), participation in professional development training (*PDT*), teaching experience (*Exp*), and subject-fitness (*SubjFit*). '*TrQual*' denotes the educational qualification of the teachers.

The minimum qualification among the teachers in the study was a vocational/technical certificate, and the highest was a postgraduate degree. '*PDT*' is a dummy variable that denotes whether or not the teacher received any training in professional development for mathematics and science in the preceding year, '*Exp*' denotes years of teaching the subject at the secondary level, '*SubjFit*' is a dummy variable that takes the value '1' if the teacher teaches a subject that they studied at a higher level of education.

'*TTechn*' was the score of nine (9) items assessing teachers' teaching methods and techniques. Respondents responded to the nine items with a five-point Likert scale, anchored by 1 (never) and 5 (always in every lesson). The index was calculated using the overall mean score of the nine items. A higher mean score (4.5–5) suggested that students *perceive* that teachers always employ appropriate class management techniques. Conversely, a lower mean score (1–1.4) indicated that the students perceive that the teachers never employ appropriate class management techniques.

The vector of student characteristics (*vStudent*) contained items such as sex (*Sex*), prior performance (*BECE*), form or level of student (*Form*), number of hours the student spent on personal studies (*Effort*), aspiration for higher education (*Asp*), and student's perceptions of mathematics and science (*Perc*). '*BECE*' was the grade (results) obtained by the student in the BECE. The grade determined the quality of the BECE results and was a measure of the student's prior achievement. Students were graded on a nine-point scale (Stanine system) where grade '1' was the highest performance and grade '9' was the lowest. '*Effort*' was a variable that measured the number of hours a student spent per week on personal studies (including working on assignments), and '*Asp*' denoted the educational aspiration of the student. Students were asked to indicate the highest level of education that they aspired to reach. The options ranged from stopping after completing SHS to PhD. '*Perc*' was the score of eight (8) items measuring students' perceptions and attitudes toward mathematics and science. This index was calculated using the overall mean score of the eight items. Higher mean scores (3.5–4) suggested that students strongly agreed with the statements and that they had positive attitudes toward mathematics and science. Conversely, lower mean scores (1–1.4) indicated that the students strongly

disagreed with the statement, suggesting that they had negative attitudes toward mathematics and science. '*Sex*' and '*Form*' were dummy variables that signified the student's gender and SHS level, respectively. The βs were the estimated parameters of interest. In a second formulation, interactive terms were added to the base model to examine a possible heterogeneous effect of some of the policy variables (PDT, subject-fitness, and educational qualification).

4. Results

4.1 Descriptive Statistics of Respondents

Table 1 shows the descriptive statistics of the study sample (students and teachers). The student sample consisted of 51% males and 49% females. The average test score of the students was 23.8% and 38.2% for mathematics and science, respectively. The male students scored 25.4% in mathematics and 40.1% in science, while the female students scored 22.1% and 36% in mathematics and science, respectively. In terms of the scores for the SHS level, SHS 2 students scored 25.6% in mathematics and 41.3% in science, while SHS 1 students scored 23.1% and 36.9% in mathematics and science, respectively.

The minimum or best expected aggregate score was six ones (i.e., grade 1 in six subjects), an average score of 36 (i.e., grade 6 in six subjects), or the poor aggregate score of 56 (i.e., grade 9 in six subjects), which was the maximum based on the Stanine grading system. The average BECE aggregate was 26 (out of a probable 6), which was quite high and suggested that on average, most of the students entered the surveyed SHSs with poor BECE results. Students spent on average, 13 hours per week on personal studies (including working on assignments).

About 25% of the students aspired to reach diploma level, 51% aimed to attain a bachelor's degree, 16% aimed to attain a master's degree, and 7% aimed to reach PhD level. The data showed that students' perceptions or attitudes toward mathematics and science was 3.02 and 3.07, respectively, which suggests that students generally have a positive attitude toward mathematics and science. The attitude of male students (3.06 and 3.09 toward mathematics and science, respectively) was not significantly different from that of the female students (2.97 and 3.05 toward mathematics and science, respectively).

The teacher sample consisted of 1,030 teachers, with 93% being males and 7% being females. The majority of the teachers (87.96%) had attained a bachelor's degree, while about 11% had a postgraduate degree. About 38% of the teachers had 3 years or less teaching experience, 49% had taught between 4 years and 10 years at the secondary level, and about 13% had over 10 years of teaching experience at the secondary level. The data showed that 76.5% of the teachers had studied the subject that they were teaching as a major course, 7.38% had combined this subject with another subject, 10.49% had studied the subject that they were teaching as a minor

course, and 5.63% did not study the subject that they were teaching at the higher level but may have studied a related subject.

The results of the teachers who had participated in PDT showed that about 31.26% of the teachers had participated in GES organized training programs while 65.24% of the teachers had participated in school-based in-service training programs. Students were asked to assess the methods and techniques of their mathematics and science teachers. The results indicated that on average, mathematics and science teachers often (4.31 and 4.33, respectively) employ good and appropriate classroom management techniques.

The index of the students' assessment of teachers regarding their methods and techniques (*TTechn*) of teaching was 4.31 and 4.33, respectively, suggesting that learners are satisfied with the teachers' approaches to classroom management. In terms of *PDT*, the data showed that 65% of the teachers had received PDT over the previous 12 months. For teachers' highest educational qualification, 88% of the teachers had attained a bachelor's degree, while 11% had a master's degree. The average years of experience in teaching at the secondary level (*Exp.* was about six years. For the subject-fitness (*SubjFit*) of teachers, 84% of the teachers had studied the subject that they were teaching as either a major or a combined course.

Table 1: Summary statistics of teachers and students' characteristics

Variables	*Mean*	*SD*	*Min*	*Max*	*N*
Dependent variable					
Mathematics test score	23.83	11.36	0	90	4,071
Science test score	38.23	14.48	0	90	4,071
Student characteristics					
BECE	26.15	7.56	6	52	4,057
Effort	12.66	6.99	0	30	4,069
Asp (Diploma)	0.25	0.43	0	1	4,069
Asp (Degree)	0.51	0.50	0	1	4,069
Asp (Master's Degree)	0.16	0.36	0	1	4,069
Asp (PHD)	0.07	0.26	0	1	4,069
Perc (Mathematics)	3.02	0.33	1.63	4	4,069
Perc (Science)	3.07	0.34	1.38	4	4,069
Sex	0.49	0.50	0	1	4,070
Form	0.30	0.46	0	1	4,071
Teacher characteristics					
PDT	0.65	0.48	0	1	4,071
TrQual (Bachelor's)	0.88	0.33	0	1	4,071
TrQual (Postgrad.)	0.11	0.31	0	1	4,071
Exp	5.77	4.42	0	32	4,071
SubjFit	0.84	0.37	0	1	4,071
TTechn (Mathematics)	4.31	0.63	1	5	4,069
TTechn (Science)	4.33	0.65	1	5	4,069
Interactive terms					
PDT_Fit	0.54	0.50	0	1	4,071
PDT_TrQual (PDT+Bachelor's)	0.56	0.50	0	1	4,071
PDT_TrQual (PDT+Master's)	0.08	0.27	0	1	4,071
TrQual_Fit (Bachelor's+SubjFit)	0.74	0.44	0	1	4,071
TrQual_Fit (Master's+SubjFit)	0.09	0.28	0	1	4,071

BECE: Basic Education Certificate Examination; Asp: Aspiration for higher education; Perc: Student perception of mathematics and science; PDT: Professional development training; TrQual: Educational qualification; Exp: Teaching experience; SubjFit: Subject-fitness; TTechn: Effect of classroom management techniques

4.2 Regression Results and Discussions

4.2.1 Teacher Credentials and Students' Performance

Table 2 presents the regression results showing the various dimensions of teacher quality and the relationship with students' performance. Models 1 and 2 depict only the effect of the classroom management techniques (*TTechn*) employed by the

teachers on students' performance, while models 3 and 4 include other teacher and student characteristic variables. The results (models 1 and 2) show that classroom management techniques employed by mathematics and science teachers have a positive and significant effect on students' test scores. Moreover, in models 3 and 4, the effect of the deployment of appropriate classroom management techniques remained statistically significant and unaffected by the inclusion of other variables; the significance of classroom management techniques employed by science teachers lost its significance.

The results in models 3 and 4 show that the educational qualification of teachers (possession of a bachelor's degree) has an insignificant effect on students' test scores. This suggests that there is no significant difference between teachers with a bachelor's degree and teachers with lower qualifications (Vocational/Technical Certificate, a Post-Secondary qualification, or a Diploma). Holding a postgraduate degree had a modest effect on performance (2.98%) in science, but there was no significant effect on the test scores in mathematics. On the contrary, teaching experience had a positive and significant effect on the test scores. Thus, an additional year of teaching at the secondary level was associated with a 0.12% increase in test scores for both mathematics and science. In terms of the effect of PDT on the test scores for performance in mathematics and science, the analysis did not show any significant difference between teachers who participated in PDT (in-service training) in the last two years and those who did not participate in PDT. Subject-fitness of the teacher was also found not to have any significant effect on students' test scores.

4.2.2 Students Characteristics and Learning Achievement

In respect of the learner variables, the results indicated that the BECE grade had a negative and significant impact on the students' test scores. This suggests that students with a higher aggregate at the BECE scored 0.22% and 0.38% less in mathematics and science, respectively than students with a lower aggregate in the BECE (good performance). Presented in reverse order, this means that high-performing students continue to perform better at the secondary level than low-performing students. Additionally, more hours spent by students per week on personal studies was positively associated with higher performance in the mathematics test score. More hours spent on personal studies led to an increase in the mathematics test score by 0.05%. However, performance in science was unaffected by the number of hours that students spent per week on personal studies. The possible explanation for this result is that studying science is not so much about the time spent but more about the availability of the right equipment to practice, visualize, and experiment.

The results on students' educational aspirations revealed elevations in performance along the lines of the educational ladder such that students who had higher

aspirations performed significantly better than those with lower aspirations. The mathematics test scores for students who aspire to reach a diploma, master's, or PhD rose linearly (2.35%, 3.85%, and 5.76%) above that of students who aspire to end their education at SHS level. In relation to performance in science, there was no significant difference between students with diploma aspirations and students with SHS aspirations. However, students with aspirations toward a first degree scored 3.84% more in the science test than students who aspire to end their education at SHS level. However, students with high educational aspirations of a master's or PhD performed 3.83% and 5.76% higher in mathematics, respectively and 5.29% and 10.46% higher in science, respectively than students who aspired to end their education at SHS level. These results suggested that the higher the educational aspirations of students, the higher their performance in mathematics and science. In terms of a student's perception and attitude toward mathematics and science, there was a positive and significant relationship between performance and having a positive perception and attitude toward mathematics and science. Having a positive perception and attitude toward mathematics and science was positively and significantly associated with higher performance (models 3 and 4).

Table 2: Determinants of teacher effectiveness on students' performance (independent effect)

Dependent variables	Math.	Science	Math.	Science
	(1)	(2)	(3)	(4)
Explanatory variables				
PDT			0.0119	0.490
			(0.361)	(0.450)
TrQual (Bachelor's)			0.837	2.223
			(1.478)	(1.538)
TrQual (Postgraduate)			1.116	2.979*
			(1.573)	(1.659)
Exp			0.129***	0.109**
			(0.0453)	(0.0534)
SubjFit			0.286	-0.109
			(0.460)	(0.574)
TTechn	1.188***	0.704*	0.533**	0.0833
	(0.270)	(0.361)	(0.266)	(0.331)
Grade			-0.223***	-0.383***
			(0.0245)	(0.0302)
Efforts			0.0502**	0.0491
			(0.0255)	(0.0320)
Asp (Diploma)			2.345*	2.306
			(1.360)	(1.528)
Asp (Bachelor's)			2.128	3.837**
			(1.336)	(1.495)
Asp (Master's)			3.834***	5.294***
			(1.399)	(1.564)
Asp (PHD)			5.762***	10.46***
			(1.552)	(1.724)
Perc			3.689***	4.083***
			(0.552)	(0.663)
Sex			-2.615***	-3.366***
			(0.349)	(0.434)
Form			0.957**	1.977***
			(0.404)	(0.504)
Constant	18.71***	35.18***	12.06***	28.54***
			0.0119	0.490
Observations	4,069	4,069	4057	4057
Prob > *F*	0.000	0.000	0.000	0.000
F Statistics	19.35	3.80	20.53	37.36

BECE: Basic Education Certificate Examination; Asp: Aspiration for higher education; Perc: Student perception of mathematics and science; PDT: Professional development training; TrQual: Educational qualification; Exp: Teaching experience; SubjFit: Subject-fitness; TTechn: Effect of classroom management techniques

Note: Robust standard error in parentheses; *, **, and *** correspond to 10%, 5%, and 1% significance level, respectively.

4.2.3 The Interactive Effect of Teacher Credentials on Student Performance

The estimated models using the ordinary least squares (OLS) estimator indicated that the *F* statistics were highly significant at the 1% level (*Prob* > *F* = 0.000). This suggests that overall, the estimated models were statistically significant. Most of the findings of this study are consistent with both theoretical and empirical literature. Table 3 presents the outcome of the inclusion of interaction terms. The interaction terms served as a robustness check for the independent effect model. Models 5 and 6 showed the interactive effect of in-service training and subject-fitness of a teacher, while models 7 and 8 depicted the interactive effect of in-service training and educational qualification of teachers. Furthermore, models 9 and 10 presented the interactive effect of teacher's qualification and the subject-fitness of teachers. The interaction terms were independently added to the empirical model to avoid the problem of collinearity among the variables.

As shown in Table 3 (models 5 and 6), the interactive term for whether or not a teacher participated in PDT and the status of the teacher's subject-fitness had no significant effect on students' performance. However, the results of models 7 and 8 revealed that the interactive term for *PDT* with educational qualification (*PDT_Qual*) had a positive and significant effect on students' performance. Using the coefficients of *PDT* (8.071), *PDT#Bachelor's* (7.884), and *PDT#Master's* (10.99) in Model 7 and the bachelor's degree and postgraduate degree values of *TrQual* (1 and 2, respectively), the conditional effect of PDT on students' performance in mathematics was positive for teachers with a postgraduate degree relative to teachers with a lower qualification. This result suggests that holding all other factors constant, PDT combined with educational qualification (postgraduate degree) enhances teachers' competence and student performance in mathematics.

Table 3: Determinants of teacher effectiveness on students' performance (interactive effect)

Dependent Variables	**Math.**	**Science**	**Math.**	**Science**	**Math.**	**Science**
	(5)	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Explanatory Variables						
PDT	-0.192	0.353	-8.071***	-8.176***	0.0113	0.470
	(0.850)	(1.081)	(3.028)	(2.974)	(0.361)	(0.451)
TrQual (Bachelor's)	0.832	2.220	-4.320*	-3.337	4.407**	1.284
	(1.477)	(1.539)	(2.544)	(2.402)	(2.244)	(2.754)
TrQual (Post Grad.)	1.107	2.973*	-6.302**	-4.672*	3.307	-1.283
	(1.572)	(1.660)	(2.709)	(2.628)	(2.548)	(3.052)
Exp	0.129***	0.110**	0.135***	0.117**	0.131***	0.111**
	(0.0453)	(0.0535)	(0.0453)	(0.0535)	(0.0452)	(0.0534)
SubFit	0.132	-0.213	0.261	-0.135	4.764*	-1.899
	(0.720)	(0.927)	(0.460)	(0.575)	(2.835)	(3.243)
TTechn	0.531**	0.0826	0.553**	0.112	0.539**	0.0719

Dependent Variables	Math.	Science	Math.	Science	Math.	Science
	(5)	(6)	(7)	(8)	(9)	(10)
Explanatory Variables						
	(0.266)	(0.332)	(0.266)	(0.331)	(0.266)	(0.331)
BECE	-0.223***	-0.383***	-0.223***	-0.384***	-0.224***	-0.385***
	(0.0245)	(0.0303)	(0.0245)	(0.0302)	(0.0245)	(0.0303)
Effort	0.0503**	0.0492	0.0492*	0.0480	0.0510**	0.0498
	(0.0255)	(0.0321)	(0.0254)	(0.0320)	(0.0255)	(0.0320)
Asp (Diploma)	2.350*	2.309	2.478*	2.444	2.353*	2.295
	(1.361)	(1.527)	(1.366)	(1.548)	(1.359)	(1.542)
Asp (Bachelor's)	2.131	3.839**	2.234*	3.947***	2.138	3.818**
	(1.337)	(1.494)	(1.342)	(1.515)	(1.335)	(1.509)
Asp (Master's)	3.838***	5.296***	3.936***	5.407***	3.862***	5.288***
	(1.400)	(1.564)	(1.405)	(1.582)	(1.399)	(1.578)
Asp (PHD)	5.759***	10.45***	5.824***	10.52***	5.772***	10.41***
	(1.552)	(1.725)	(1.556)	(1.739)	(1.551)	(1.737)
Perc	3.694***	4.086***	3.725***	4.096***	3.681***	4.095***
	(0.552)	(0.663)	(0.552)	(0.663)	(0.551)	(0.662)
Sex	-2.617***	-3.368***	-2.613***	-3.369***	-2.612***	-3.343***
	(0.349)	(0.435)	(0.348)	(0.434)	(0.349)	(0.434)
Form	0.956**	1.977***	1.010**	2.030***	0.952**	1.993***
	(0.405)	(0.504)	(0.405)	(0.505)	(0.404)	(0.504)
PDT#Fit	0.242	0.163				
	(0.928)	(1.176)				
PDT#Bachelor's			7.884***	8.498***		
			(3.045)	(3.003)		
PDT#Master's			10.99***	11.37***		
			(3.234)	(3.254)		
Bachelor's#SubjFit					-4.776	1.329
					(2.875)	(3.300)
Master's#SubjFit					-3.108	5.380
					(3.174)	(3.605)
Constant	12.18***	28.62***	17.03***	33.92***	8.728***	29.91***
	(2.800)	(3.434)	(3.367)	(3.832)	(3.221)	(4.052)
Observations	4,069	4,069	4,069	4,069	4,069	4,069
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
***F* Statistics**	22.74	29.19	23.58	29.86	24.37	29.97

BECE: Basic Education Certificate Examination; Asp: Aspiration for higher education; Perc: Student perception of mathematics and science; PDT: Professional development training; TrQual: Educational qualification; Exp: Teaching experience; SubjFit: Subject-fitness; TTechn: Effect of classroom management techniques

Note: Robust standard error in parentheses; *, **, and *** correspond to 10%, 5%, and 1% significance level, respectively

Similarly, using the coefficients of *PDT* (-8.176), *PDT#Bachelor's* (8.498), and PDT#Master's (11.37) in Model 8 and the bachelor's degree and postgraduate degree values of Tr*Qual* (1 and 2, respectively), the result of the conditional effect of

teacher training on students' performance in science was positive for teachers with either a bachelor's degree or a postgraduate degree, unlike teachers with a Vocational/Technical Certificate, a Post-Secondary qualification or a Diploma. This result suggests that holding all other factors constant, a qualified teacher with a bachelor's degree or a postgraduate degree who received additional PDT enhances student performance in science to a larger extent than teachers with lower qualifications who received additional PDT.

Furthermore, using the coefficients of *TrQual* (-4.230 and -6.302 for bachelor's degree and postgraduate degree, respectively) and *PDT#Bachelor's* (7.884) and *PDT#Master's* (10.99) in Model 7, the results indicated that the conditional effect of educational qualification (bachelor's degree and postgraduate degree) on students' performance in mathematics was positive whereas it was negative for teachers without any in-service training when all other factors were held constant. Finally, the interactive terms *Bachelor's##Fit* and *Master's#Fit* (teachers' educational qualification and subject-fitness) had no significant effect on the mathematics and science test scores. This result indicates that there was no significant differential effect on the test scores with teachers with higher academic qualifications (bachelor's degree and postgraduate degree) who were subject fit and teachers with higher academic qualifications (bachelor's degree and postgraduate degree) who were not subject fit.

5. Discussion

The study found that the classroom management techniques employed by the mathematics and science teachers and their teaching experience had a positive and significant effect on students' test scores. The study also found that the teachers' educational qualification, their participation in PDT (in-service training), and their subject-fitness had no significant effect on the students' test scores. However, when PDT (in-service training) interacted with educational qualification, it had a positive and significant effect on the students' performance. In terms of the student credentials, the study found that students who had lower grades (performed well) in BECE continued to perform well in mathematics and science at secondary school. Similarly, hours spent by students per week on personal studies was positively associated with higher performance in the mathematics test scores. Students' aspirations had a positive and significant effect on their test scores; students who aspired to higher education performed better than those who wanted to end their education at secondary school. Students' perceptions and attitudes toward mathematics and science had an effect on the test scores. Therefore, having a positive perception and attitude toward mathematics and science increases performance.

The success of any educational process depends on both what teachers provide and how well students engage with it. The behavior of both teachers and students in the

classroom is influenced by the characteristics and qualities they bring to the teaching and learning process, and this ultimately affects classroom dynamics and academic performance (Maulana et al., 2023; Opdenakker, 2023). The study's findings indicate that professional development support, educational qualifications, teaching experience, teaching techniques, and subject expertise are crucial policy variables.

5.1 Teacher Teaching Techniques

As asserted by Opdenakker (2023), the classroom management technique of teachers (keeping the class under control) plays an important role in the outcome of students' learning. The independent model (exclusion of control variables) showed that the classroom management techniques employed by the mathematics and science teachers had a positive and significant effect on students' test scores in mathematics and science. The implication from this finding is that teaching techniques (pedagogical skills) are crucial for nurturing learning in students.

Consequently, the estimations showed that classroom management techniques employed by the mathematics teachers was positively associated with student performance. This aligns with the prior expectation that teachers with strong skills use a variety of representations and tools to support students' mathematical development (Anthony & Walshaw, 2009; Tacadena, 2021). However, although the assessment of the classroom management techniques of the science teachers was equally high, this variable did not seem to be associated with improved performance in science. This is, however, consistent with Anamuah-Mensah and Benneh (2010) who suggested that the lack of integrated science teachers in Ghana and the low competencies among teachers are the result of their poor instructional approaches. Nonetheless, it is also possible to attribute the result to the fact that teaching mathematics and science requires different approaches. While classroom management techniques may be positive and enhance learning in mathematics, learning science requires not only classroom management techniques but also equipment that may not be available or adequately provided in Ghana. Additional professional development support training would enhance science teachers' pedagogical needs while provision of the requisite equipment would enhance the teaching and learning of science and have an impact on performance.

5.2 Professional Development Training

Rasuli et al. (2023) posit that teachers' planning and management is important in preparing for classroom interaction and keeping the class under control. Teacher training equips teachers with the planning and management techniques required in the classroom. Contrary to expectation, teachers' professional development support training alone had no effect on mathematics and science test scores. Hence, there are no significant differential effects on test scores whether a teacher receives professional development support training or not.

This result is inconsistent with that of Ochieng et al. (2016) who posit that the quality and the level of in-service training significantly influence student achievement. However, the current study found a heterogeneity effect of PDT on students' performance. The interaction between teacher PDT and teacher qualification was positively associated with students' outcomes in mathematics and science. This result suggests that the conditional effect of PDT on students' performance in mathematics and science is positive when teachers have higher qualifications. Similarly, Goldhaber and Brewer (2000) found a positive relationship between in-service training and students' achievement in mathematics—but not in science. Moreover, Rowan et al. (1997) presented similar findings and conclusions regarding PDT provision and student performance in both science and mathematics.

This result suggests two probabilities. Firstly, the lack of the significant effect found in the first model may be attributed to inadequacy of the training received by the teachers. On average, 31.26% of teachers reported participating in GES organized training for mathematics only once in the last 12 months. This may be inadequate to have a significant effect on teaching and learning outcomes. Secondly the results suggest that PDT may be more useful for teachers who have higher academic qualifications. These people may be called "professionally trainable". Knowledge of this is important for targeting professional development support with discriminated packages or targeting higher qualification holders for efficiency.

5.3 Educational Qualification

Another teacher characteristic in the teaching/learning process is the educational qualification of teachers. Nilsen and Gustafsson (2016) posit that teachers' instruction is essential in guiding the learning process. The quality of the teacher's instruction in the teaching and learning process stems partly from the educational qualification of the teacher. In the first ideation, the results showed that holding either a bachelor's degree or a lower qualification had no significant effect on test scores. Holding a postgraduate degree, however, had a modest effect on science test scores. These findings are similar to the findings of Buddin and Zamarro (2009) that teachers who are more qualified academically and professionally (advanced level teachers) do not necessarily show excellent results.

However, the interaction between teacher qualification (postgraduate degree) and PDT showed a positive association with the students' test scores. This suggests a conditional effect of educational qualification on students' performance in mathematics for teachers with a postgraduate degree compared to teachers with a Vocational/Technical Certificate, a Post-Secondary qualification or a Diploma (Higher National Diploma [HND]). However, compared to teachers with lower qualifications, the conditional effect of educational qualification on students'

performance in science was positive when the teachers held either a bachelor's degree or a postgraduate degree. The implication of this is that PDT is more effective in terms of influencing learning outcomes if the training is provided for teachers with the appropriate higher qualification (postgraduate degree). This is consistent with the study by Bjekić et al. (2008) who assert that other than the basic training that teachers receive in colleges and universities, continuous professional training and development is essential in teaching.

5.4 Subject-Fitness

Subject-fitness of a teacher plays a vital role in classroom behavior and student performance. However, in this study (independent model), the subject-fitness of mathematics and science teachers did not show any significant effect on student test scores. The result indicated that there were no significant differences between mathematics and science teachers who studied mathematics and science at the higher level of education and teachers teaching mathematics and science whose higher degree was neither mathematics nor science. This result is similar to the findings of Zuzovsky (2009) who showed that teachers' subject-specific specialization does not have a significant impact on students' performance. However, in the interactive model, the effect of subject-fitness of the mathematics teacher on students' performance was positive. Thus, specialization (major) in mathematics at the higher level may enhance teacher effectiveness, which will ultimately lead to increased student performance.

5.5 Teaching Experience

As expected, teaching experience (years of experience at the secondary level) was positively associated with student performance in mathematics and science. This suggests that years of teaching at the secondary level was associated with an increase in positive learning outcomes for mathematics and science. The average teaching experience at the secondary school level was about six years. Hence, an additional year of teaching at the secondary level is associated with an increase in the students' test scores in mathematics and science of 0.13% and 0.11%, respectively. This result conforms to prior expectations that experience gained by teachers over time enhances their knowledge, skills, work effectiveness, and productivity in improving student performance (Rice, 2010). The result is also consistent with the study by Ochieng et al. (2016) that more experienced teachers deliver better results than less experienced teachers.

5.6 Student Perceptions and Attitudes

In addition to the significant and relevant effect of teacher effectiveness variables on test scores in mathematics and science, which were of primary importance in this study, the analyses also yielded interesting results with respect to the second input subcategory as posited by Nilsen and Gustafsson (2016). This includes all the students' descriptions that might have had an influence on the teaching/learning

process and student performance. The perceptions and attitudes toward mathematics and science were used as student characteristics in this study. Student's perceptions and attitudes toward mathematics and science were positively related to students' performance. Positive and higher perceptions and attitudes toward mathematics and science were associated with an increase in the students' test score by 3.7% and 4.1% respectively. This result suggests that student's performance partly depends on their views and attitudes toward the subjects. This is similar to the suggestion by Hwang and Son (2021) that positive attitude and higher aspiration in mathematics and science serve as intrinsic motivation to learn the subjects and are thus associated with high performance.

6. Conclusion

This study sought to investigate how teacher credentials and students' characteristics (their perceptions and attitudes) affect the achievement of secondary school students in mathematics and science. The study highlighted that teacher classroom management techniques, academic qualifications, PDT, years of experience, and subject-fitness are key attributes of teacher quality. These factors, combined with students' educational aspirations, personal study efforts, and positive attitudes toward subjects, significantly influence students' performance. The findings provide valuable evidence for designing interventions to improve learning outcomes. First, the study demonstrates the need for targeted PDT for teachers. Professional development training is most effective in teachers with the requisite educational qualifications, as these trainings are designed to enhance pedagogy rather than build foundational content knowledge. Targeted PDT in the long term will increase teachers' pedagogical content knowledge and general pedagogical knowledge (actual and perceived) and hence, instruction quality. Teachers with lower qualifications are less likely to benefit significantly from such training.

Second, the study underscores the importance of classroom management techniques in improving student achievement. Regular monitoring and assessment of teachers' classroom practices are recommended. Headmasters should adopt instructional or pedagogical leadership approaches to ensure that teachers employ effective classroom management strategies. Third, subject-fitness is a critical determinant of student performance. Subject-fit teachers deliver lessons in a more practical way, enabling the learners to understand and appreciate the lessons and keeping the learners engaged in the learning process. It is recommended that the GES prioritize recruiting science and mathematics teachers who have specialized in these subjects at higher education levels. This study also raises questions for further research. While PDT alone showed no direct impact on learning outcomes, exploring the content, delivery methods, and cost-effectiveness of such training is necessary. Additionally, future studies could benefit from longitudinal data to provide deeper insights into these dynamics over time.

7. Limitations of the study

Although students' socioeconomic status is key in determining learning outcomes, the current study did not include household socioeconomic status as a student characteristic. Similarly, the study failed to explore the role that parents and peers play in students' learning outcomes in mathematics. However, these limitations do not in any way affect the relevance of the relationships that were established. The study, however, recommends future studies to include these variables.

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