



Teacher characteristics do not predict self-efficacy for learner-centered instruction in science and mathematics: A null finding from Zambian teacher education

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Citation: Mapulanga, T., & Jita, L. C. (2026). Teacher characteristics do not predict self-efficacy for learner-centered instruction in science and mathematics: A null finding from Zambian teacher education. *European Journal of Science and Mathematics Education*, 14(4), 629-643. <https://doi.org/10.30935/scimath/19500>

ARTICLE INFO

Received: 24 Jan 2026

Accepted: 15 Aug 2026

ABSTRACT

Learner-centered instruction is widely promoted in science and mathematics education. Yet, the extent to which teacher demographic characteristics shape self-efficacy for such practices in developing-country contexts, particularly within university-based teacher education programs in Zambia, remains underexplored. This study examined the self-efficacy for learner-centered instruction among 257 pre-service and in-service science and mathematics teachers enrolled in university-based teacher education programs in Zambia. The study employed a cross-sectional survey design to investigate whether demographic characteristics collectively predict self-efficacy for learner-centered instructional practices. Descriptive findings indicated consistently high self-efficacy across demographic groups. However, multiple linear regression analysis revealed that age, gender, teaching experience, qualification, category of teacher, and subject specialization did not significantly predict teachers' self-efficacy beliefs. The regression model was not significant, $F(7,249) = 1.33$, $p = 0.237$, and explained only 3.6% of the variance in self-efficacy ($R^2 = 0.036$). Post-hoc power analysis indicated insufficient power to detect small effects (achieved power ≈ 0.35). These findings tentatively suggest that professional learning experiences may warrant greater attention than demographic characteristics in future better-powered longitudinal research. Implications for the design of STEM teacher education curricula are discussed.

Keywords: teacher characteristics, teacher self-efficacy, learner-centered instruction, secondary school teachers, science instruction, mathematics instruction, teacher education

INTRODUCTION

Teachers' self-efficacy beliefs may impact the teaching strategies they employ in the classroom (Künsting et al., 2016; Yildiz, 2022). Self-efficacy is defined as the conviction that one can carry out the necessary actions to achieve specific goals (Klassen & Tze, 2014). According to Tschannen-Moran and Hoy (2001), a teacher's efficacy belief is an assessment of his or her capacity to achieve the intended results of student learning and engagement. Therefore, teachers' self-efficacy is a belief in their (teachers') capability to effectively plan and enact teaching activities necessary to achieve educational aims, especially facilitating students' learning. Olawale and Hendricks (2024) assert that teachers use instructional practices they perceive they can successfully employ. Furthermore, teachers with high self-efficacy are more likely to use instructional practices that promote students' learning (Bottomley et al., 2024). There are three main dimensions of teachers' self-efficacy: effectiveness for classroom management, efficacy for student engagement, and

efficacy for instructional practices (Tschannen-Moran & Hoy, 2001, 2007). However, due to their influence on the teaching-learning process, the current study focused on the effectiveness of instructional strategies and student engagement.

The strong correlation between teachers' self-efficacy beliefs, their teaching practices, and students' academic success justifies the focus on these factors (Holzberger & Prestele, 2021; Zee & Koomen, 2016). Instructional practices refer to the techniques, procedures, or exercises that teachers can employ to teach. Specific examples of instructional practices include assessing students, activating their prior knowledge, conducting experiments, providing clear examples and representations, clearly explaining content, utilizing a variety of teaching materials and strategies, assigning homework and assignments, using multiple assessment methods, and connecting concepts to real-world situations (Karamane et al., 2023; Wisniewski et al., 2020). These practices reflect learner-centered pedagogy, which emphasizes active engagement, conceptual understanding, and real-world application. The instructional practices that teachers use in their classes can have a great influence on the success of the teaching-learning process (Auerbach & Andrews, 2018; Freeman et al., 2014).

Learner-centered instruction in science and mathematics places unique demands on teachers, requiring them to facilitate open-ended inquiry, manage productive discourse around problem-solving, and adapt to students' diverse mathematical and scientific conceptions. Consequently, self-efficacy for these practices is not merely a general pedagogical belief but is deeply intertwined with teachers' confidence in their discipline-specific knowledge and pedagogical reasoning. In science education, learner-centered approaches often involve inquiry-based experimentation and evidence-based reasoning, while in mathematics, they emphasize problem-solving, conceptual understanding, and mathematical discourse. These subject-specific demands highlight the importance of situating learner-centered instruction within disciplinary pedagogical traditions. If learner-centered instruction in STEM requires discipline-specific pedagogical reasoning, then subject specialization might emerge as a predictor of self-efficacy for learner-centered instruction.

These instructional practices are derived from the teachers' professional knowledge domain, known as (general) pedagogical knowledge (Gess-Newsome et al., 2019; Shulman, 1986). According to Freeman et al. (2014), instructional practices that engage learners actively tend to be associated with increased academic performance among students. In many education systems, learner-centered pedagogy is primarily introduced, modeled, and legitimized through initial teacher education and continuing professional development, making teacher education contexts central to the development of instructional self-efficacy. Thus, it is essential to investigate teacher self-efficacy beliefs for learner-centered instructional practices within science and mathematics teacher education contexts, where such pedagogical approaches are explicitly promoted and developed.

Self-efficacy is thought to be shaped by teacher characteristics such as professional training, teaching experience, and academic qualifications through social persuasion, mastery experiences, and vicarious learning (Mohammed & Luguterah, 2024; Tschannen-Moran & Hoy, 2007). It has been argued that teachers who believe they are capable are more likely to implement learner-centered instructional strategies, effectively manage classrooms, and support diverse learners (Lipka et al., 2025; Tschannen-Moran & Hoy, 2001), all of which lead to increased student engagement and academic achievement. Teacher characteristics have long been viewed as important inputs in the teaching-learning process. Research in teacher effectiveness theory suggests that characteristics such as teaching experience, subject specialization, and professional qualifications influence how teachers interpret curricula, select instructional strategies, and respond to learners' needs (Darling-Hammond et al., 2017). However, contemporary scholarship cautions against assuming direct or deterministic relationships between demographic characteristics and instructional quality since results in this area are mixed (Choy et al., 2013; Mohammed & Luguterah, 2024; Park et al., 2020; Suprayogi et al., 2017). In this context, teacher characteristics matter not because of their inherent qualities but because of how they interact with teachers' beliefs, knowledge, and context. For example, teaching experience may enhance instructional effectiveness only when it provides opportunities for reflective practice and pedagogical growth. Similarly, academic qualifications contribute to instructional quality when they are aligned with pedagogical competence rather than content knowledge alone (Darling-Hammond et al., 2017).

While emerging research in Zambia, where learner-centered instruction is encouraged, has begun to document teacher self-efficacy for learner-centered instruction (Mapulanga et al., 2025), much of this work provides descriptive patterns and group comparisons, with limited attention to the extent to which commonly examined demographic variables meaningfully predict these beliefs when analyzed collectively. Additionally, much of the existing research examines demographic influences on teacher self-efficacy without sufficiently considering the role of shared teacher education experiences that may mediate or mitigate such differences. Consequently, there remains a need to move beyond surface-level comparison towards a deeper examination of the factors that genuinely account for variation in self-efficacy for learner-centered science and mathematics instruction in teacher education contexts. Therefore, the present study addresses this gap by evaluating whether commonly examined demographic characteristics (such as gender, age, teaching experience, qualification, category, and specialization) meaningfully predict teachers' self-efficacy for learner-centered instruction within shared teacher education contexts, where professional learning experiences may attenuate demographic differences.

In Zambia, where teacher education programs typically combine coursework, school-based teaching practice, and for in-service teachers, upgrading pathways are aimed at strengthening pedagogical competence. National curriculum reforms emphasize learner-centered pedagogy, encouraging inquiry-based learning, problem-solving, and learner engagement in science and mathematics classrooms. However, these approaches are often implemented in contexts characterized by large class sizes, limited instructional resources, and examination-oriented systems. These structural conditions shape how learner-centered pedagogy is enacted and may influence the development of teachers' self-efficacy within teacher education programs. Thus, there exists tension between policy mandates for learner-centered instruction and classroom realities of large classes and limited resources. This study contributes to this discourse by exploring the following research questions:

1. Do demographic characteristics collectively predict teacher self-efficacy beliefs?
2. How much unique variance does each account for?

Examining pre-service and in-service teachers who are concurrently engaged in university-based teacher education or upgrading programs provides a unique opportunity to explore self-efficacy development within relatively shared professional learning environments. Therefore, this study interrogates the assumed relevance of demographic characteristics within teacher education contexts that emphasize common pedagogical preparation.

Significance of the Study

This study makes several contributions to the literature on teacher self-efficacy and learner-centered science and mathematics instruction, particularly within developing-world contexts. First, it advances theoretical understanding by demonstrating that teacher self-efficacy for learner-centered instruction is not strongly predicted by commonly examined demographic factors when these variables are analyzed collectively. Within the specific context of Zambian teacher education programs, and given the limitations of a cross-sectional convenience sample, this study finds no evidence that demographic characteristics predict teacher self-efficacy. This preliminary evidence questions whether demographic determinism is a useful frame in such settings, pending replication with more representative designs. From a teacher education perspective, understanding what does not explain teachers' instructional confidence is as important as identifying what does, particularly in university-based programs designed to support pedagogical reform.

Second, the study operationalizes teacher self-efficacy at a practice-specific level, focusing on learner-centered instructional practices and student engagement. This approach aligns with contemporary calls to conceptualize self-efficacy as context- and task-specific rather than as a generalized personal trait, thereby offering a more precise analytical lens for examining instructional beliefs in science and mathematics education. Third, by drawing on data from a sub-Saharan African context undergoing significant curriculum reform towards learner-centered pedagogy, this study provides a critical test of whether findings from predominantly Western, resource-rich contexts hold under different systemic conditions. Furthermore, by drawing on data from both pre-service and in-service teachers across multiple universities in Zambia, the findings extend the geographical and contextual scope of self-efficacy research and enhance its relevance to

education systems undergoing curriculum reforms that emphasize learner-centered pedagogy. Finally, the study provides practical and policy-relevant insights by highlighting the limited explanatory power of demographic characteristics in relation to professional learning conditions.

Theoretical Framing

This study is grounded in the literature on teacher effectiveness and learner-centered instruction, conceptualizing educational outcomes as the result of multiple inputs, including teacher characteristics, school conditions, and learner attributes (Hanushek & Rivkin, 2010). Teacher-related variables are treated as key schooling inputs, although their effects on student learning are typically indirect and operate through instructional practices and teacher-related cognitive and motivational factors. While early studies often focused on observable teacher demographic characteristics such as qualification, years of experience, and certification, more recent research highlights the mediating role of instructional practices and teacher self-efficacy (Ekstam et al., 2017; Künsting et al., 2016; Yildirim & Sidekli, 2018). Furthermore, evidence continues to show that these structural variables explain only limited variation in instructional quality and student achievement (Hanushek & Rivkin, 2010; Klassen & Tze, 2014).

Contemporary meta-analytic work further confirms that demographic characteristics tend to have weak and inconsistent associations with teacher effectiveness outcomes, with teaching experience showing only modest context-dependent effects (Klassen & Tze, 2014; Zee & Koomen, 2016). This has reinforced the shift toward more proximal determinants of teaching quality, particularly instructional practices and teacher self-efficacy. Research shows that teacher self-efficacy is positively associated with instructional quality, classroom management, and teacher persistence, although its effects on student achievement are generally indirect and mediated through instructional practice (Künsting et al., 2016; Lipka et al., 2025; Yoon & Goddard, 2023). However, the present study did not directly measure instructional behavior but only tested the demographics and self-efficacy path, and not the full mediation.

The study is also situated within the literature on learner-centered instruction, which emphasizes inquiry, collaboration, formative assessment, and active student engagement. These approaches place substantial cognitive and pedagogical demands on teachers, requiring adaptive decision making and confidence, and implementing complex instructional strategies. Recent evidence continues to show that learner-centered and active learning approaches improve student outcomes in science and mathematics, particularly in higher education and secondary STEM contexts (Freeman et al., 2014; Rabgay, 2018; Weitzel & Blank, 2020). However, their effectiveness depends heavily on teachers' pedagogical preparedness and instructional confidence (Altintas & Kozaner Yenigül, 2020; Holzberger & Prestele, 2021). The current study explores teachers' self-efficacy in enacting learner-centered instruction in science and mathematics classrooms.

Within this framework, the study examined demographic and professional characteristics—gender, age, teaching experience, qualification level, teacher category, and subject specialization—conceptualised as distal structural inputs in the educational production process. These variables may shape instructional outcomes indirectly by influencing access to training opportunities, exposure to classroom practice, and development of subject-specific pedagogical knowledge. For example, teaching experience may contribute to accumulated instructional expertise, while higher qualifications may reflect greater exposure to pedagogical theory and structured professional learning.

Recent research continues to suggest that such structural characteristics have limited direct predictive power compared to instructional and belief-based variables (Hanushek & Rivkin, 2010; Klassen & Tze, 2014). However, consistent with the teacher effectiveness literature, these structural characteristics are not assumed to exert strong direct effects on instructional capability. Instead, their influence is expected to be mediated through teacher self-efficacy, which functions as a key proximal determinant of instructional behavior. Accordingly, this study examines whether teacher demographic and professional characteristics significantly predict self-efficacy for learner-centered science and mathematics instruction. By focusing on self-efficacy as an intermediate outcome, the study moves beyond simplistic demographic explanations of teacher effectiveness and aligns with contemporary research emphasizing the importance of psychological and instructional mechanisms in shaping teaching quality and student learning outcomes.

METHODOLOGY

Research Approach and Design

This quantitative research employed a cross-sectional survey design in which data were collected at a single point in time (Creswell, 2014). This approach captures teachers' self-efficacy beliefs at a single point in time and does not permit causal inferences. However, it was preferred because it enabled data collection from a relatively large sample, thereby providing insights from a large number of participants.

Instrument

An online seven-point Likert-scale survey questionnaire, modified from the literature (Hodges et al., 2016; Mapulanga et al., 2022), was utilized in this study. The questionnaire items pertain to two traditional aspects of self-efficacy (Tschannen-Moran & Hoy, 2001, 2007): five items on efficacy for student involvement and 20 items on efficacy for instructional strategies. Efficacy for instructional strategies measures teachers' confidence in their ability to employ a range of instructional practices that support student learning. On the other hand, efficacy for student engagement measures teachers' beliefs in their ability to inspire students and actively engage them in the learning process.

The items were phrased in terms of self-efficacy beliefs; all items begin with "I can ...", and end with specific instructional practices that are learner-centered ([Appendix A](#) shows the scale items used in this study). The questionnaire consisted of two parts: Part A required respondents to provide their demographic information, i.e., age, gender, category of teachers, highest qualification, qualification being pursued, teaching experience, and specialization (D1 to D7), and in Part B, participants were asked to respond to 25 questions on their self-efficacy views regarding the use of learner-centered instructional practices. Participants were required to select answers on a scale of 1 to 7, with 1 representing "not at all confident," 2 representing "slightly confident," 3 representing "somewhat confident," 4 representing "moderately confident," 5 representing "fairly confident," 6 representing "very confident," and 7 representing "completely confident." The seven-point Likert scale was preferred because it provided high response variability, allowed for distinction between levels of teacher self-efficacy, captured more nuanced responses by offering teachers more response options to reflect their self-efficacy levels, and provided greater adaptability and statistical power due to the larger number of response items (Ibrahim, 2025).

To determine the content validity of the questionnaire, the researchers reviewed the theoretical literature on self-efficacy instructional strategies in scientific and mathematical learning contexts. The content validity of the original questionnaire (with thirty items) was assessed by a panel of four experts (two in science education, two in mathematics education). They independently rated each item for its relevance to the construct of learner-centered instruction, its clarity for the target population, and its alignment with the Zambian secondary school curriculum. Based on the panel's review, six items were reworded for clarity, and five items were removed due to interrater agreement of less than 75% (Waltner et al., 2019). Cronbach's alpha was used to evaluate the scale's internal consistency and dependability. The scale's overall reliability ($\alpha = 0.944$) is above the suggested thresholds (Taber, 2018), supporting the use of the composite self-efficacy score in further analyses (Tschannen-Moran & Hoy, 2001). The high internal consistency indicates that the items measure a common underlying construct and supports the aggregation of item responses (DeVellis & Thorpe, 2021). The use of a composite self-efficacy score is further justified by the conceptualization of teacher self-efficacy as a domain-specific and theoretically coherent construct, where multiple items capture closely related aspects of perceived instructional capability (Tschannen-Moran & Hoy, 2001). In scale development research, when items demonstrate strong internal consistency and conceptual alignment, it is appropriate to combine them into a single composite score to provide a parsimonious and reliable representation of the construct (DeVellis & Thorpe, 2021; Hair et al., 2019). Therefore, the aggregation of item responses into a composite score representing teachers' self-efficacy for learner-centered science and mathematics education is methodologically appropriate.

Participant Selection and Data Collection Procedure

Due to the practical challenges of accessing a nationally representative sample of teachers enrolled in upgrading programs, a convenience sampling strategy was employed. The questionnaire link was distributed

via official and semi-official WhatsApp groups used by students in the participating universities' faculties of education. Program coordinators and class representatives were asked to share the link and reminder messages. A total of 257 complete responses were received. Because the total number of students actively monitoring these WhatsApp groups at the time of data collection is unknown, a precise response rate cannot be calculated. This represents a significant limitation, as the sample may over-represent teachers who are more digitally connected and already engaged with teacher education programs, which could influence the reported levels of self-efficacy.

Data Analysis

The data were exported to a Microsoft Excel sheet and screened. Then, the data were imported into SPSS version 25 for analysis. Given the study's focus on teachers' overall perceived capability to implement learner-centered science and mathematics instruction, item responses were aggregated into a single composite self-efficacy score. The use of a composite measure was guided by the strong internal consistency of the scale ($\alpha = 0.944$) and the conceptual overlap among the instructional dimensions assessed. A mean score was computed to retain the original response scale and facilitate interpretability across respondents (DeVellis & Thorpe, 2021). However, although high internal consistency suggests substantial shared variance across items, Cronbach's alpha does not establish uni-dimensionality. Therefore, the composite score should be interpreted as representing overall self-efficacy rather than empirically distinct subdimensions of teacher efficacy. However, we note that collapsing potentially distinct dimensions of self-efficacy into a single score may obscure differential relationships between teacher characteristics and specific efficacy domains. This approach is consistent with prior research that treats self-efficacy as a composite construct when examining predictors rather than their dimensional differences (Tschannen-Moran & Hoy, 2001). The data were checked for normality, and the results indicated significant deviation from normality ($W = 0.852, p < 0.001$). The analysis involved computing descriptive (mean and standard deviation) and inferential statistics (Multiple linear regression). The decision to proceed with inferential statistical analysis is based on Norman (2010), who asserts that inferential (parametric) statistical analyses tend to be robust regardless of violations of assumptions of normality for t-tests and ANOVA tests, and by extension to regression analysis. However, the extension to regression analysis needs to be validated in the context of multiple regression with uneven subgroups. Multiple linear regression analysis was employed to examine the extent to which teacher demographic characteristics collectively and uniquely predict self-efficacy beliefs regarding learner-centered science and mathematics instruction. Regression analysis enables the simultaneous assessment of multiple predictors while controlling for interrelationships among them (Islam, 2020). This approach is particularly appropriate given that demographic characteristics such as age, teaching experience, qualification, and teacher category are theoretically and empirically correlated. By estimating the unique contribution of each predictor, the analysis allows for a more precise evaluation of commonly assumed demographic effects. It avoids inflated or misleading conclusions that may arise from bivariate or group-level analyses. Although a composite self-efficacy score was used in the present analysis, it is acknowledged that instructional strategies and student engagement represent distinct dimensions of teacher self-efficacy. Analyzing these dimensions separately may reveal more nuanced relationships and is recommended for future research. Furthermore, the aggregation was considered appropriate for the study's focus on identifying general predictors of instructional self-efficacy rather than examining dimension-specific differences.

Despite some demographic categories containing relatively small subgroup sizes (e.g., PhD and certain specializations), these variables were retained in the regression analysis model to preserve the conceptual completeness of the analysis and to reflect the full diversity of participants' professional backgrounds. However, the small sample sizes in these categories may reduce statistical power and lead to less stable parameter estimates. Accordingly, findings related to these groups should be interpreted cautiously. This decision was supported by the results of a sensitivity test, which showed that the findings qualitatively remained unchanged. Although collapsing categories was considered, doing so risked obscuring meaningful distinctions between qualification levels and specializations relevant to this study.

Table 1. M scores of teachers' self-efficacy beliefs across demographic characteristics

Variable		N	M	SD
1. Category of teachers	Pre-service	71	5.67	0.72
	In-service	186	5.81	0.78
2. Gender	Male	184	5.79	0.79
	Female	72	5.72	0.69
3. Specialization	Biology education	38	5.79	0.56
	Chemistry education	19	5.63	0.75
	Physics education	12	5.63	1.52
	Mathematics education	86	5.86	0.63
	Biology and chemistry education	63	5.73	0.91
	Mathematics and biology education	39	5.73	0.64
4. Highest qualification	Master's degree	2*	6.02	0.48
	Bachelor's degree	58	5.74	0.84
	Diploma	162	5.80	0.77
	School certificate	35	5.67	0.61
5. Qualification pursued	Diploma	2*	5.34	0.48
	Bachelor's degree	219	5.79	0.69
	Master's degree	33	5.79	0.81
	PhD	3*	4.35	2.91
6. Teaching experience	0	59	5.77	0.76
	1-5	100	5.90	0.58
	6-10	46	5.64	0.99
	11-15	27	5.86	0.79
	16-20	18	5.92	0.73
	21 and above	7*	5.31	1.20
7. Age (years)	25 and below	51	5.71	0.62
	26-30	53	5.87	0.76
	31-35	72	5.76	0.83
	36-40	34	5.83	0.80
	41-45	35	5.70	0.82
	46 and above	12	5.77	0.76

* Interpret with caution due to small sample size

RESULTS

Teachers' Self-Efficacy Levels Across Demographic Characteristics

Teachers' self-efficacy for enacting learner-centered instructional practices was determined through descriptive statistics (means and standard deviation) for each demographic characteristic. The level of self-efficacy beliefs was determined following Mapulanga et al. (2025) as follows: 6.50-7.00 = very high confidence; 5.50-6.49 = high confidence; 4.5-5.49 = somewhat high confidence; 3.50-4.49 = moderate confidence; 2.50-3.49 = somewhat low confidence; 1.50-2.49 = low confidence, and 1.00-1.49 = very low confidence.

The descriptive statistics on teachers' self-efficacy beliefs across demographic factors are shown in **Table 1**. Overall, mean scores ranged from 5.31 to 6.02 on the seven-point scale. Mean values were similar across teacher category, gender, subject specialization, qualification, teaching experience, and age groups. Subgroups with small samples (*) are included in **Table 1** and should be interpreted with caution.

Predicting Teachers' Self-Efficacy Beliefs Using Demographic Characteristics

A multiple linear regression analysis was performed using SPSS version 25 to determine whether demographic characteristics (specialization, teaching experience, gender, the certification sought, age, highest qualification, and category) significantly predicted the teachers' average self-efficacy beyond the descriptive differences observed across groups. Diagnostic tests were performed before running the regression analysis to evaluate multicollinearity using tolerance and variance inflation factor (VIF) values and to confirm the assumptions of normality, linearity, and homoscedasticity using residual plots (Islam, 2020). The VIF values above 3 indicate moderate multicollinearity. The VIF values remained below commonly cited thresholds (5-10), indicating moderate but acceptable multicollinearity. There were no indications of these presumptions being violated. Although the regression diagnostic did not indicate severe multicollinearity, the moderated

Table 2. Multiple regression predicting teachers' average self-efficacy scores

Model	Coefficients			t	Sig.	95.0% CI for B		Correlations			Collinearity statistics	
	B	SE	β			LB	UB	Zero-under	Partial	Part	Tolerance	VIF
(Constant)	6.678	.454		14.694	.000	5.783	7.573					
Gender	-.071	.106	-.042	-.667	.506	-.280	.138	-.048	-.042	-.041	.962	1.039
Age	-.008	.049	-.015	-.161	.872	-.104	.088	-.016	-.010	-.010	.455	2.198
Category	-.149	.204	-.087	-.733	.464	-.550	.252	-.080	-.046	-.046	.272	3.676
Teaching experience	-.066	.043	-.173	-1.549	.123	-.151	.018	-.128	-.098	-.096	.309	3.233
Highest qualification	.107	.083	.144	1.290	.198	-.056	.270	-.056	.081	.080	.310	3.230
Qualification pursued	-.252	.134	-.133	-1.884	.061	-.516	.011	-.092	-.119	-.117	.776	1.288
Specialization	-.011	.024	-.028	-.446	.656	-.059	.037	-.012	-.028	-.028	.958	1.044

Note. SE: Standard error; CI: Confidence interval; LB: Lower bound; & UB: Upper bound

Table 3. Sensitivity multiple regression results

Model	Coefficients			t	Sig.	95.0% CI for B		Correlations			Collinearity statistics	
	B	SE	β			LB	UB	Zero-under	Partial	Part	Tolerance	VIF
(Constant)	6.193	.459		13.485	.000	5.288	7.097					
Gender	-.015	.103	-.010	-.151	.880	-.218	.187	-.025	-.010	-.010	.979	1.021
Age	-.069	.050	-.128	-1.395	.164	-.167	.029	-.011	-.092	-.090	.497	2.013
Category	-.176	.187	-.116	-.939	.349	-.545	.193	-.116	-.062	-.061	.278	3.599
Teaching experience	-.050	.042	-.145	-1.197	.232	-.132	.032	-.148	-.079	-.078	.286	3.491
Highest qualification	.031	.079	.046	.390	.697	-.125	.187	-.075	.026	.025	.299	3.347
Qualification pursued	.087	.151	.042	.574	.567	-.212	.385	.051	.038	.037	.800	1.250
Specialization	-.012	.024	-.035	-.527	.599	-.059	.034	-.046	-.035	-.034	.955	1.048

Note. SE: Standard error; CI: Confidence interval; LB: Lower bound; & UB: Upper bound

VIF observed for some predictors suggests that standard errors may have been inflated, thereby reducing the precision of coefficient estimates and limiting the ability to detect small effects. Consequently, non-significant findings should be interpreted cautiously. In addition, some demographic categories contained very small subgroup sizes, particularly the PhD category ($n = 3$), which exhibited substantial variability in self-efficacy scores. Estimates associated with such sparse subgroups are therefore unlikely to be stable or generalizable, and future studies may exclude them for primary analyses. A sensitivity test was conducted to assess the robustness of the findings.

Table 2 presents the results of the multiple linear regression analysis, showing the regression model, regression coefficients (B), standard errors, standardized coefficients (β), t-values, and confidence intervals for each predictor. The results indicate that the total regression model was not significant, $F(7, 249) = 1.33$, $p = 0.237$. Approximately 3.6% of the variation in self-efficacy was explained by the model ($R^2 = 0.036$, adjusted $R^2 = 0.009$). The Durbin-Watson statistic (1.67) revealed that there was no discernible autocorrelation in the residuals. None of the individual predictors reached statistical significance at the $p < 0.05$ level. Despite approaching significance ($p = 0.061$), the qualification pursued did not reach the standard alpha threshold of 0.05.

A post-hoc power analysis indicates that this study had insufficient power to detect small effects (achieved power ≈ 0.35 for $f^2 = 0.02$). Thus, null findings should not be interpreted as evidence of absence, but rather as absence of strong evidence under the current design

Sensitivity Analysis

A robustness check was conducted to assess the sensitivity of the estimated results by excluding subgroups with $n < 10$ and re-estimating the regression model. The sample size was reduced from 257 to 237 after exclusion of the subgroups PhD, Master's, age 46 years and above, teaching experience 21 years and above, and qualification diploma. **Table 3** shows that the results remained qualitatively unchanged, with coefficients showing similar magnitude and direction and no meaningful change in statistical significance. One exemption is the variable qualification pursued. In the baseline model, this variable is marginally significant ($p = 0.061$) but became statistically non-significant in the trimmed sample ($p = 0.567$), with a reduction in coefficient magnitude and a change in sign. The instability of the qualification pursued coefficient following subgroup exclusion suggests that the observed association may be influenced by sparse subgroup representation. This suggests that the weak baseline association may be sensitive to small samples (n) and

should be interpreted with caution. However, it should be noted that the larger subgroups drive the main findings and that inferences about rare demographic categories may be unreliable and should be interpreted cautiously. Overall, the results confirm that the main findings are not driven by extreme observations and are stable to the removal of potentially influential data points.

DISCUSSION

Participants' self-efficacy beliefs ranged from moderate to high, with most teachers reporting strong confidence in learner-centered science and mathematics instruction. Across demographic categories, self-efficacy scores were generally similar, suggesting limited variability in perceived instructional capability within the sample. This pattern may partly reflect the tendency for self-efficacy measures to produce positively skewed self-assessments. At the same time, the findings suggest that teachers within these university-based teacher education and upgrading programs generally perceive themselves as capable of implementing learner-centered instructional approaches despite the practical challenges often associated with science and mathematics teaching.

The study found no statistically significant evidence that demographic characteristics, gender, age, teaching experience, qualification, teacher category, or subject specialization predict teacher self-efficacy. The regression model explained only a small proportion of the variance in self-efficacy, indicating that these variables, when considered collectively, had limited explanatory power within the sample. These findings are broadly consistent with teacher effectiveness research, suggesting that observable demographic characteristics often show weak or inconsistent relationships with teacher beliefs and instructional outcomes (Hanushek & Rivkin, 2010; Klassen & Tze, 2014). Similarly, prior research suggests that self-efficacy is more closely associated with experiential and contextual influences than with stable demographic attributes (Zee & Koomen, 2016).

However, the null findings should be interpreted cautiously. The low explained variance suggests that demographic variables account for only a limited proportion of variance in self-efficacy in this context. In addition, the study had limited statistical power to detect small effects, increasing the possibility of Type II error (Cohen, 1992; Maxwell, 2004). Consequently, the absence of statistically significant relationships should not be interpreted as evidence of no association, but rather as insufficient evidence to detect potentially small effects within the current design. It is therefore possible that modest relationships between some demographic characteristics and self-efficacy exist but were not detectable under the present analytical conditions. Given the low power and restricted range, the null finding is equally consistent with the absence of a true relationship, the presence of a small relationship that this study could not detect, or the suppression of demographic variation by the sampling method.

Although minor descriptive differences were observed across gender, qualification, and teacher category, these differences did not translate into statistically significant effects. Overall, self-efficacy scores were relatively similar across groups, indicating a generally consistent pattern of perceived instructional confidence. For example, teachers with higher qualifications showed slightly higher mean self-efficacy scores descriptively, although these differences were small and statistically non-significant. The relative similarity of responses may partly reflect the shared teacher education and upgrading context from which participants were drawn, although program-level factors were not directly measured in this study.

The findings are partially consistent with studies reporting weak or non-significant relationships between teacher characteristics and self-efficacy (Klassen et al., 2011; Park et al., 2020), but in contrast with studies reporting differences associated with teaching experience and qualifications (Choy et al., 2013; Mohammed & Luguterah, 2024; Suprayogi et al., 2017). Similarly, some studies have reported higher self-efficacy among teachers with greater experience or advanced qualifications (Holzberger & Prestele, 2021; Sellami et al., 2025), while others have found gender-related differences in STEM teaching contexts (Bottomley et al., 2024). These inconsistencies may reflect contextual differences, measurement approaches, and whether self-efficacy is conceptualised as a general belief or as a practice-specific construct. The present findings suggest that when self-efficacy is examined in relation to specific learner-centered instructional practices, demographic characteristics may have limited explanatory power. This may be particularly relevant in contexts where teachers are exposed to similar pedagogical expectations and professional preparation experiences.

The relatively low proportion of explained variance further suggests that important influences on teacher self-efficacy were not captured in the present model. Prior research indicates that factors such as professional support, instructional feedback, collegial interactions, and school context may be associated with self-efficacy development (Yoon & Goddard, 2023; Zhou et al., 2023). However, these factors were not measured in the current study and therefore cannot be empirically evaluated here. In addition, the relative homogeneity of the sample may have constrained variability in both predictor and outcome variables, thereby reducing the likelihood of detecting statistically significant relationships. This finding highlights the complexity of teacher self-efficacy and suggests that demographic characteristics alone are unlikely to provide a comprehensive explanation for differences in teachers' instructional confidence.

One possible but untested explanation for the null findings is that teachers enrolled in similar teacher education and upgrading programs may have been exposed to comparable pedagogical experiences, expectations, and learning environments, potentially contributing to more similar levels of self-efficacy across participants. Shared exposure to learner-centered instructional approaches, supervised teaching practice, and professional interaction within these programs may have contributed to this pattern. However, this interpretation remains speculative because the present study did not directly assess program characteristics, instructional quality, or contextual learning conditions. Future research should examine these program-level factors directly to determine their relationship with teachers' self-efficacy.

The findings support perspectives in the teacher effectiveness and teacher learning literature, which suggest that instructional confidence develops through professional experiences, feedback, and contextual interactions rather than demographic characteristics alone (Zee & Koomen, 2016). From this perspective, demographic characteristics may function as indirect or distal indicators rather than direct predictors of self-efficacy. At the same time, the results do not imply that demographic characteristics are universally unimportant, but rather that their influence may depend on contextual and experiential conditions not captured in the present study.

Overall, the findings suggest that demographic characteristics have limited explanatory power for teachers' self-efficacy in learner-centered science and mathematics instruction within this sample. However, the results should be interpreted as indicating insufficient evidence of strong relationships rather than evidence of absence. The combination of low explained variance, limited statistical power, and sample homogeneity suggests that more comprehensive and context-sensitive models are needed to better understand the determinants of teacher self-efficacy. Future studies incorporating contextual, instructional, and institutional variables may provide a more complete understanding of how teachers' self-efficacy develops within science and mathematics education.

Several limitations should be considered when interpreting these findings. Firstly, reliance on self-reported data may introduce social desirability bias. Secondly, the cross-sectional design using participants recruited through WhatsApp and an online survey introduces coverage bias, which limits causal inference. Teachers without reliable internet access and smartphones were less likely to be represented in the sample. Third, the relatively homogeneous sample of teachers engaged in similar training contexts may have restricted variability in key variables. Fourthly, the use of a composite self-efficacy score without formal factor-analytic validation of the instrument's dimensional structure limits conclusions regarding the dimensional structure of the self-efficacy measure. It is possible that the instrument captures multiple related dimensions of teacher self-efficacy, such as efficacy for instructional strategies and efficacy for student engagement. Collapsing these dimensions into a single composite measure may have obscured differential relationships between teacher characteristics and specific aspects of self-efficacy. Fifth, the limited statistical power increases the possibility that small but meaningful effects were not detected (Cohen, 1992; Maxwell, 2004). However, the findings are useful as they provide an overall picture of teachers' self-efficacy beliefs, which can serve as a foundation for planning large-scale research to enhance science and mathematics teaching. The study's findings are further strengthened by using an instrument that demonstrates very high internal consistency among its items.

CONCLUSIONS AND RECOMMENDATIONS

The study contributes to teacher education research by providing empirical support for theoretical claims that professional learning conditions, rather than demographic attributes, are more proximal determinants

of teachers' instructional beliefs. The findings indicate that teachers generally reported high confidence in their capacity to enact learner-centered. Importantly, the study did not find evidence that commonly examined demographic characteristics significantly predicted teachers' self-efficacy beliefs. This questions the assumption that demographic factors are central determinants of instructional confidence and instead supports theoretical perspectives that emphasize the role of professional learning experiences and instructional contexts in shaping self-efficacy. By providing robust psychometric evidence and empirical findings from a Global South-country context, this study refines existing understandings of teacher self-efficacy and contributes a validated framework for future research on learner-centered pedagogy in science and mathematics instruction. The findings suggest that professional learning experiences and instructional contexts may play an important role in shaping self-efficacy beliefs, although these factors were not directly measured in the present study.

Within the context of shared teacher education programs, professional learning experiences may be more proximal influences, though causal confirmation requires longitudinal and experimental designs. These findings encourage a shift away from demographic explanations of instructional confidence toward more dynamic, practice-oriented models of teacher development. In doing so, the study offers both theoretical refinement and practical guidance for strengthening learner-centered pedagogy in secondary school education. However, the null findings should be interpreted with caution, given the low statistical power, restricted variability associated with the sampling approach, and the absence of dimensional validation for the adapted instrument.

Based on the study's findings, the following recommendations are proposed for policy, practice, and future research. First, Zambian teacher education programs should audit their current curricula to assess the quantity and quality of practice-based mastery experiences they provide, such as micro-teaching, lesson study, and supervised classroom practice with feedback. Secondly, initial and continuing science and mathematics teacher education programs should prioritize sustained instructional coaching, classroom observation, and feedback, as these experiences may be more influential than demographic background in shaping instructional self-efficacy. Thirdly, longitudinal and mixed-methods designs are recommended to examine how self-efficacy evolves over time and how professional learning experiences, school culture, and policy reforms shape these beliefs. In addition, professional development initiatives should be context-responsive, addressing the specific challenges and opportunities within local secondary school environments.

Future research in the Zambian context should employ longitudinal designs to track how self-efficacy evolves as teachers move through their programs and into their early years of independent teaching. Such designs could help disentangle the effects of the program from the effects of prior experience. Given the null findings, research should also ensure adequate statistical power and larger samples ($N \geq 500$) for detecting small effects with seven predictors. Furthermore, future research should integrate self-efficacy measures with classroom observation data and student learning outcomes to better understand the mechanisms through which self-efficacy influences instructional quality. Future studies should employ exploratory or confirmatory factor analysis to evaluate the dimensional structure of the scale and examine whether predictors operate differently across subdomains of teacher self-efficacy. Furthermore, professional development should address large class sizes (typically 50-60 students) by modelling learner-centered strategies that work in crowded, resource-limited classrooms, such as think-pair-share with locally made materials. Additionally, the study recommends future research to replicate this design to increase confidence in genuinely null effects.

Author contributions: **TM:** conceptualization, data curation, formal analysis, methodology, writing – original draft, writing – review & editing; **LCJ:** conceptualization, methodology, supervision, writing – original draft, writing – review & editing. Both authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Acknowledgments: The authors would like to thank the SANRAL chair, faculty of education, University of the Free State for the technical support.

Ethics declaration: This study was approved by the Ethics Committee of DMI St. Eugene University (protocol number: REG/EST/011242/AD-246). In addition, researchers obtained permits to conduct this research at the three universities in Zambia. Furthermore, it was ensured that they voluntarily participated in the study after being clearly informed of the survey's purpose. Additionally, researchers informed the participants that they were free to participate or withdraw from the study without any adverse consequences. Furthermore, authors confirm that (a) informed consent was

obtained from participants or that participant data has been fully anonymized, and (b) the platform(s)' data redistribution policies were complied with. The participants gave written informed consent.

AI statement: During the preparation of this work, the authors used ChatGPT to improve language clarity and readability. Following the use of this tool, the authors critically reviewed and edited the content as necessary and took full responsibility for the integrity and accuracy of the final text in the manuscript.

Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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APPENDIX A

Table A1. Questionnaire items

No	Item
1	I can help my pupils formulate science/math questions and investigations when beginning a new topic/real-world problem/challenge.
2	I can help my pupils identify and address their science/math misconceptions through exploration and reflection.
3	I can help my pupils identify patterns or trends in data from investigations/experiments/research/activities they conduct.
4	I can help my pupils connect what they have learned to real-world situations/problems.
5	I can help my pupils identify and extract critical information from a given challenge/scenario/observation of phenomena.
6	I can help my pupils engage with and learn from each other when they share the results of their investigations/research/group activities.
7	I can assist my pupils in establishing the relationship between the topics they learn and other subjects.
8	I can help my pupils connect the evidence they gather during an investigation/ experiment/ activity to the claims they make.
9	I can help pupils perform activities (such as demonstration/ experiment, simulation, animation, and display of teaching aids) specific to the topics being learned.
10	I can give examples from daily life experiences to explain science/math concepts.
11	During the term, I can use different assessment methods such as assignments, projects, classroom and homework exercises, tests, and experiments to assess pupils' learning.
12	I can ask questions that reveal how much my students know about the topics I teach.
13	I can ask questions that evaluate how much my students have learned about the science/math topic.
14	I can use topic-specific teaching aids such as figures, diagrams, simulations, models, and drawings.
15	I can help my pupils conduct group investigations/experiments/activities to reveal science/math concepts.
16	I can assist pupils to use the knowledge they learn in further topics/concepts/subjects
17	I can help pupils use the scientific/math content they learn when supporting their claims.
18	I can help my pupils present the results of their investigations/experiments/activities to the class with posters or other media.
19	I can help my pupils connect science/math content with their previous investigations, giving scientific/mathematical meaning to the investigations.
20	I can help my pupils use claims, evidence, and reasoning to discuss science/math concepts.
21	I can help my pupils solve problems, even if they are solving them differently than I would solve them.
22	I can warn my students about the topics/concepts they may find difficult to learn.
23	I can let my pupils struggle with concepts and activities during the learning process by refraining from providing immediate answers or solutions.
24	I can immediately notice why my students have difficulty learning a topic.
25	I can immediately notice when my students have difficulty learning a topic/concept.

