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Bandura's self-efficacy sources as predictors of algebra problem-solving ability: Evidence from Ghanaian senior high school students

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Abstract

Algebra problem-solving ability is a central indicator of students' mathematical competence yet students persistently struggle to solve algebra problems. The study therefore, investigated the extent to which Bandura's sources of self-efficacy individually and jointly predict algebra problem-solving ability among senior high school students in Kumasi Metropolitan, Ghana. A cross-sectional survey design with predictive focus was adopted to sample 614 students from five public senior high schools using multi-stage sampling techniques. The study was guided by two research questions and two corresponding null hypotheses. Data were collected using two instruments: Self-efficacy sources scale questionnaire (SESS) and algebra problem-solving ability test (APSAT). All instruments were face validated by four experts, and construct validated by exploratory factor analysis, with KMO values above 0.70. Reliability was determined using Cronbach's alpha for SESS and APSAT, yielding coefficients of 0.818 and 0.792 respectively. The results revealed that the four sources of self-efficacy jointly predicted algebra problem-solving ability to a statistically significant extent ($R = .411$, $R^2 = .169$, $F(4, 609) = 30.99$, $p < .001$), accounting for 16.9% of the variance. Physiological and affective states emerged as a significant negative predictor ($\beta = -.328$, $p < .001$), while social persuasion was a significant positive predictor ($\beta = .142$, $p < .005$). Mastery and vicarious experiences were not statistically significant. The findings emphasise the importance of emotional supportive and efficacy-enhancing instructional practices in mathematics education. Recommendations were made for stakeholders to adopt anxiety-reduction strategies and constructive encouragement, with teachers serving as authentic voices of social persuasion to enhance students' self-efficacy in algebra problem-solving.

Keywords: Algebra Problem-Solving Ability, Bandura's Sources of Self-Efficacy, Physiological and Affective States, Kumasi Metropolitan, Senior High School Students, Social Persuasion.

Introduction

The importance of mathematics as a subject lies in its ability to develop problem-solving abilities (Awuah & Ogbonnaya, 2020; National Teaching Council, 2023; OECD, 2023). Beyond its academic value, mathematics serves as a tool to train students in problem-solving and enhances their thinking abilities, enabling them to solve real-life problems they face daily. According to Awuah (2018), with the 4th industrial revolution facing the world now, the acquisition of requisite problem-solving skills has become more important than ever. In view of this, those who lack the requisite problem-solving abilities may find it challenging to adapt to and thrive in this highly competitive environment. The mathematics problem-solving ability itself is not only a goal in mathematics education, but also something very meaningful in daily life (Pintér, 2012).

Within the Core Mathematics curriculum, algebra occupies a particularly critical position in the development of abstract reasoning and problem-solving abilities. Algebra provides tools for representing relationships, modelling real-world situations, and solving complex problems using symbolic language (Salah, 2025). Many real-life problems can be addressed through algebra, which is a branch of mathematics that uses symbols and arithmetic operations to represent and solve problems (Usman & Mussa, 2025). For example, Owusu-Mensah et al. (2020) demonstrated the practical relevance of algebra through their model of the dynamics COVID-19 transmission through algebraic and fractional-order equations and evaluated the effectiveness of intervention strategies. In the practical realm, the principles of algebra play a key role in technologies such as cryptography, secure communications, coding theory, and computer science algorithms (Salah, 2025). The importance of

algebraic problem-solving in mathematics cannot be overstated.

Despite the significance of algebra problem-solving abilities, many high school students face challenges with algebra, resulting in lower academic performance and increased mathematics anxiety (Ali & Das, 2024; Mediana & Hinacay, 2025). In Ghana, similar concerns have been documented, with persistent challenges observed in students' algebraic learning, working process and problem-solving performance at the senior high school level (Asiedu-Addo & Yidana, 2018; Baidoo, 2025; Hissan & Ntow, 2021). These challenges are often accompanied by negative emotional experiences, including anxiety, fear of failure, and low self-confidence, which may further affect students' engagement and achievement in algebra (Clemente et al., 2024; Pajares & Miller, 1994). This suggests that students' difficulties in algebra problem-solving may not be adequately explained by cognitive skills and instructional practices alone, highlighting the need to consider affective and psychological factors.

To address these challenges, numerous innovative solutions have been proposed to enhance urban students' problem-solving abilities in algebra. Among them are ethnomathematics, cooperative learning approach (Pope, 2016), cognitive training programs, and metacognition (Boz, 2024). While these approaches target instructional and cognitive dimensions of learning, in a globalized world dominated by social media, students' self-perceptions of their academic abilities represent a critical psychological determinant of their problem-solving success.

Among the psychological factors, mathematics self-efficacy has emerged as a critical construct in educational psychology, influencing students' engagement, performance, and persistence in mathematics-related tasks (Bandura, 1986; Clemente et al., 2024; Pajares & Miller, 1994). Bandura's social cognitive theory posits that self-efficacy is the belief in one's capabilities to organize and execute the course of actions required to attain a specific goal (Bandura, 1986). It is formed from four sources: mastery experiences, vicarious experiences, social persuasions, and physiological and affective states (Zakariya, 2022). Mathematics self-efficacy is the student's confidence in solving mathematics tasks. It has been robustly linked to mathematics performance with high-mathematics self-efficacy learners engaging more persistently and performing better than their low self-efficacy peers (Zakariya, 2022). For example, extensive evidence shows mathematics self-efficacy predicts achievement more strongly than anxiety or even prior knowledge (Zakariya, 2022). Students with higher mathematics self-efficacy tend to demonstrate greater persistence, effort, and problem-solving skills in mathematics tasks (Clemente et al., 2024). It is therefore crucial to explore and analyse senior high school students' self-efficacy in demonstrating algebraic reasoning and using various mathematics symbols to translate statements and real-life situations into mathematical models (Widyawati et al., 2018). Drawing on Bandura's social cognitive theory, several empirical studies report that students' beliefs in their capabilities significantly influence their engagement, persistence, and success in solving algebraic problems (Hissan & Ntow, 2021). Yang et al. (2024) reported that self-efficacy robustly predicted achievement and improved performance across different grade levels.

Despite this acknowledged significance, relatively few studies explicitly tie Bandura's four sources of efficacy to algebra problem-solving ability. In Africa, high school students face algebra difficulties due to limited resources, low motivation, and teacher readiness (Hissan & Ntow, 2021). Self-efficacy interventions, such as guided practice, peer modelling, and verbal encouragement, improve confidence and problem-solving persistence (Zakariya, 2022). In Kumasi metro, Oppong-Gyebi et al. (2023) found that 5.3% increase in mathematics performance was associated with higher self-efficacy. Yet these studies are limited to overall self-efficacy rather than disaggregating it into its underlying sources. As a result, there is limited understanding of how different self-efficacy sources shape students' algebra problem-solving ability within the Ghanaian senior high school context.

This gap in the literature constrains efforts to design targeted instructional strategies that address not only cognitive skills but also the affective state of algebra problem-solving difficulties. Therefore, there is a need for empirical research that examines how Bandura's self-efficacy sources jointly and individually predict algebra problem-solving ability among senior high school students. Enhancing self-efficacy can reduce math anxiety, improve persistence, and prepare students for STEM and real-life problem-solving challenges.

Theoretical Review

According to Bandura (1977), individuals' self-efficacy judgments arise from four types of information: Mastery experiences, vicarious experiences, social persuasion, and physiological and affective states. Mastery experiences refer to one's own past successes or failures on a task; success boosts efficacy whereas failure undermines it (Usher

& Pajares,2009; Zakariya, 2022). Vicarious experiences come from observing others (models) perform the task: seeing similar peers succeed can raise one's confidence, although social comparison may make this effect modest (Schunk & DiBenedetto, 2020; Zakariya, 2022). Social persuasions involve verbal encouragement or feedback from teachers, peers, or parents; timely praise or incentive can enhance confidence whiles negative remarks from others can undermine it in the face of challenges (Schunk & DiBenedetto, 2020; Zakariya, 2022). Finally, physiological and affective states reflect emotional and physical reactions during the task: low anxiety, positive mood, and calmness lead learners to judge themselves as more capable, whereas stress or fatigue diminishes efficacy (Bandura, 1986; Zakariya, 2022). In the literature, mastery experiences are mostly considered the most powerful source of self-efficacy (Bandura,1986; Usher & Pajares,2009; Zakariya, 2022). This is supported by evidence: mastery-based interventions (for example step-by-step practice) systematically improve mathematics confidence and performance, and correlational studies often find mastery self-efficacy the strongest predictor of achievement (Usher & Pajares,2009; Zakariya, 2022). Vicarious experiences can boost confidence by modelling strategies, but meta-analyses show its impact is usually smaller than mastery (Zakariya, 2022). Theoretical work explains this by social comparison dynamics: learners may discount models who seem too different. Overall, theory and empirical studies predict that all four sources should relate to algebra problem-solving ability.

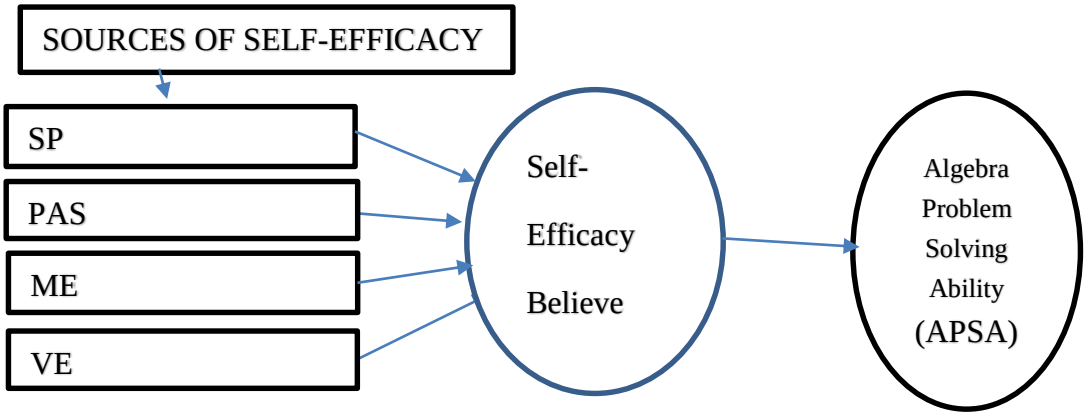

Figure 1 Conceptual Framework of This Study

Figure 1 represents the conceptual framework guiding the study. PAS = Physiological and affective states, SP = Social persuasion, VE = Vicarious experiences, ME = Mastery experiences, APSA = Algebra problem-solving ability.

Research Questions:

1. To what extent do the Bandura's sources of self-efficacy individually predict students' algebra problem-solving ability among senior high school year 2 students?
2. To what extent do the Bandura's sources of self-efficacy jointly predict students' algebra problem-solving ability among senior high school year 2 students?

Null Hypotheses:

H_{01}: Bandura's self-efficacy sources do not make a significant individual contribution to the prediction of algebra problem-solving ability among senior high school year 2 students.

H_{02}: Bandura's self-efficacy sources do not make a significant joint prediction of algebra problem-solving ability among senior high school year 2 students

Method

This study adopted a quantitative cross-sectional survey research design with a correlational and predictive focus to collect data at a single point in time using an adapted self-efficacy questionnaire and teacher-made algebra problem-solving ability test. The survey design was appropriate because it allowed for efficient data collection from a large sample of students without manipulating the study variables and to generalise findings from the sample to the study setting (Creswell & Creswell, 2023).

The sample size for this study was 614 students. This number was determined scientifically

to ensure accuracy and reliability using the formula proposed by Miller and Brewer (2003). Formula: $n = \frac{N}{1+ N\alpha^2}$, where, N = target population (4,795 senior high school year 2 students), n = minimum sample size, and α = significant level (0.05). This approach considers a 95% confidence level and a 5% margin of error. Since the study focused on human participants. $n = \frac{4,795}{1+4,795\ (0.05^2)} = 369.2 = 369$. Based on this formula, a minimum sample size of 369 respondents was required for the study. However, the researchers utilised a sample of 614 students, exceeding the minimum requirement. Increasing sample size beyond the minimum is recommended in correlational and predictive studies to enhance statistical power, reduce sampling error, and improve the stability of regression estimates (Creswell & Creswell, 2018).

Multi-stage sampling technique was used to select five public schools within the Kumasi Metropolitan Assemble in three stages. In Stage One, public Senior High Schools were treated as clusters; although all fourteen schools were approached, only five granted timely access (1 Category A, 3 Category B, and 1 Category C), while the rest were unavailable due to examinations and academic schedules. In Stage Two, students were stratified by programme (General Arts, General Science, Business, Home Economics, and Visual Arts) to reduce within-group variability and improve precision (Fraenkel et al., 2019). In Stage Three, simple random sampling was applied using a blind lottery method, where students drew papers and those with identifiers were selected. Sample sizes were proportionally allocated across programmes, with full inclusion where enrolment was below 20. This ensures randomness, fairness, and reduced selection bias.

The Bandura's Self-Efficacy Sources Scale (SESS) and the Algebra Problem-Solving Ability Test (APSAT) were the two major instruments used in the study. The sources of self-efficacy used were derived from the mathematics problem-solving efficacy scale (MPES) developed by Dagdag et al. (2020) which consists of a 5-point Likert scale questionnaire. To ensure that the self-efficacy was measured task specifically, the terminology of mathematics was changed to algebra in the MPES. All sources of Bandura's self-efficacy consisted of 5 items to keep the number of items equally distributed across all sources.

A researcher designed achievement test was used to assess students' algebra problem solving ability. This test was geared towards the algebra problem solving skills of the second-year students of the Ghanaian Senior High School Mathematics Curriculum (NaCCA, 2023). The assessment consisted of 10 items: from recall to extended reasoning problems, with all items aligned to Webb's Depth of Knowledge framework. The cognitive test did not contain any multiple-choice questions. This decision was deliberate, as multiple-choice formats may encourage guessing and limit insight into students' reasoning processes. Research has shown that open-ended and task-based items are more effective for assessing problem-solving ability because they require learners to construct responses and demonstrate reasoning explicitly (Flanagan et al., 2009). The test framework followed Pólya's four-stage model. Four of the APSAT items were adapted from WASSCE Core Mathematics past questions to enhance construct and content validity and reliability of the instrument.

The validity of each self-efficacy source was supported by a pilot study (n=28) yielding subscale reliability coefficients from 0.653 to 0.787 and the joint self-efficacy sources mean have reliability of 0.818, indicating good reliability. According to Hair et al. (2019), alpha values above 0.70 are generally acceptable for applied social science research, while slightly lower values ($\alpha \geq 0.60$) may be tolerated in exploratory or context-adapted scales The APSAT was developed to measure students' achievements in algebra problem solving abilities across four sub-topics: algebraic expressions/factorization, linear equations/inequalities, and word problems involving linear/ simultaneous equations, and word problems involving quadratic equations. Pilot testing confirmed reliability (r = 0.792), while the main study yielded an alpha of 0.747. The construct validity for both scales was established through expert review and Exploratory Factor Analysis (EFA), with all constructs exceeding KMO values of 0.70, indicating good sampling adequacy and sufficient shared variance among items (Hair et al., 2019).

Data analysis was performed using IBM SPSS Statistics Version 20 (IBM Corp., 2011) through standard multiple linear regression. According to Creswell and Creswell (2018), the necessary assumptions must be evaluated prior to model estimation to enhance credibility and validity of results. Linearity and homoscedasticity were assessed via scatterplots of standardized residuals against predicted values. The results showed a random distribution of points around zero with no systematic patterns, confirming that the linear relationship assumption holds and that error variance is consistent across all levels (Pallant, 2020; Field, 2013). The Durbin–Watson statistic was computed to test for independence of errors, yielding a value of 1.530. As this falls within the acceptable range of 1.5

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to 2.5, it indicates that autocorrelation is not a concern in this model (Field, 2013). Furthermore, multicollinearity was examined using Tolerance and Variance Inflation Factor (VIF) values. Tolerance scores ranged from 0.518 to 0.865, exceeding the minimum threshold of 0.20. VIF values ranged from 1.154 to 1.929, which are well below the cutoff point of 5. These figures confirm that the predictor variables are sufficiently independent and do not exhibit problematic overlap (Hair et al., 2019; Pallant, 2020). To interpret the strength of relationships and the practical significance of results, effect size magnitudes were classified using the widely accepted standards established by Cohen. According to Cohen (1988), the multiple correlation coefficients (R) are classified as $0.10 \leq R \leq 0.29$ indicate weak positive relationship, $0.30 \leq R \leq 0.49$ indicate moderate positive relationship, and $0.50 \leq R \leq 1.0$ indicate strong positive relationship. For regression model effect size (f^2), calculated as $f^2 = \frac{R^2}{1-R^2}$: $0.00 \leq f^2 \leq 0.02$ indicates small effect size, $0.03 \leq f^2 \leq 0.34$ indicates moderate effect size and $f^2 \geq 0.35$ indicates large effect size.

Results

Table 1. Summary of regression analysis of Bandura's self-efficacy sources predicting APSA

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	9.356	2.066		4.530	.000
	PAS	-2.517	.305	-.328	8.263	.000
	SP	1.434	.485	.142	2.956	.003
	VE	-.772	.406	-.087	-1.899	.058
	ME	.798	.465	.088	1.714	.087

Table 1 represents SPSS analysis of the regression coefficients of the sources of self-efficacy. In summary, the social (verbal) persuasion significantly and positively predicted algebra problem-solving ability (β = 0.142, t = 2.956, p = 0.003). Physiological and affective states significantly and negatively predicted algebra problem-solving ability (β = −0.328, t = −8.263, p < .001). Mastery experience did not significantly predict algebra problem-solving ability (β = 0.088, t = 1.714, p = 0.087). Vicarious experience also did not significantly predict algebra problem-solving ability (β = −0.087, t = −1.899, p = 0.058).

The standard multiple regression equation using the unstandardized coefficients B:

APSA = 9.356 − 2.517(PAS) + 1.434(SP) − 0.772(VE) + 0.798(ME) + ε

Table 2: Regression analysis of the extent of Bandura's sources of self-efficacy jointly predicting algebra problem-solving ability among senior high school year 2 students

Model	R	R Square	Adjusted R Square	Change Statistics					Durbin-Watson
				R Square Change	F Change	df 1	df2	Sig. F Change	
1	.411	.169	.164	.169	30.994	4	609	.000	1.530

Table 2 shows that the combined sources of self-efficacy produced a multiple correlation coefficient of R = .411, with a coefficient of determination of $R^2 = .169$. This indicates a moderate positive predictive relationship. The R^2 value of .169 suggests that 16.9% of the variation in students'

algebra problem-solving ability is explained by the combined influence of mastery experience, vicarious experience, social persuasion, and physiological and affective states, while the remaining 83.1% of variation is due to other factors not included in this model. Moreover, the effect size (f^2 = 0.203) represents moderate effect size which suggests that the predictive power of this model is not only theoretically significant but also practically meaningful. Hence, interventions that improve self-efficacy sources can be expected to produce visible improvements in students' algebra problem-solving ability.

Table 3: Analysis of variance of the extent of Bandura's sources of self-efficacy jointly predicting algebra problem-solving ability among senior high school year 2 students.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4644.916	4	1161.229	30.994	.000[b]
	Residual	22817.265	609	37.467		
	Total	27462.181	613			

a. Dependent Variable: Algebra problem-solving ability
b. Predictors: (Constant), mastery experience, physiological and affective states, vicarious experience, social persuasion.

Table 3 shows that the combined sources of self-efficacy significantly predict senior high school year 2 students algebra problem-solving ability, F (4, 609) = 30.994, p = .000. Since the p-value (.000) is below the 0.05 significance level, the null hypothesis is rejected and we conclude that the combined Bandura's self-efficacy sources significantly predict algebra problem-solving ability among senior high school year 2 students.

Discussion

Although the full theoretical model was retained for discussion purposes, a reduced model including only significant predictors explained less variance (R^2 = 0.132 compared to 0.169). The non-significant variables contribute to the model through shared variance with the significant variables as the four sources operate together in real learning context. Moreover, while excluding mastery and vicarious experiences enhances the parsimony of the model, it leads to the loss of information, which significantly compromises its explanatory power and theoretical completeness.

The findings of the present study indicate that social (verbal) persuasion is the strongest positive self-efficacy source significantly predicting algebra problem-solving ability among senior high school year 2 students. The results highlight the influential role of teacher feedback, encouragement, and classroom discourse in shaping students' confidence in algebra problem-solving. This result aligns with empirical studies across contexts, which have demonstrated that praise, encouragement, and constructive feedback from teachers significantly enhance students' confidence and performance in mathematics (Dagdag et al., 2021; Appiah et al., 2022; Oppong-Gyebi et al., 2023).

Physiological and affective states emerged as a significant negative predictor, indicating that higher anxiety and emotional distress are associated with lower achievement. These results align with existing studies that negative emotions can limit cognitive resources and overall effectiveness (Clemente et al., 2024; Pajares & Miller, 1994; Hissan & Ntow, 2021). Theoretically, individuals interpret physiological arousal as cues of competence; however, excessive stress undermines persistence and cognitive ability (Bandura, 1986; Zakariya, 2022).

The strong influence could be because of mathematics anxiety that is common in Ghanaian context, exacerbated by instruction that emphasizes correctness over exploratory learning (Asiedu-Addo & Yidana, 2018; Mediana & Hinacay, 2025).

As there was no significant relationship between performance and mastery experiences, contrary to theory, but there was a positive correlation between mastery experience and outcomes. This means that success in the past may have an impact on performance but may also share this impact with other variables that are also important and their impact becomes lesser than success when used independently in the model. This implies that, in order to build efficacy beliefs, mastery experiences must be meaningful, progressive and conceptually based.

In the same way, vicarious experience failed to significantly predict, which is in line with research that shows that the influence of vicarious experience can also be indirect and context dependent (Zakariya, 2022). This suggests that observing others solve problems does not directly improve students' ability to do so. Observational learning is effective only when students can relate to the model and understand

the reasoning involved (Schunk & DiBenedetto, 2020).

Despite its contributions, the study has several limitations. The cross-sectional design limits causal interpretation of the findings. In addition, reliance on self-report measures may have introduced response bias. Furthermore, the study was also limited to selected senior high schools in Kumasi metropolitan reducing the generalisability of the results to other contexts.

Conclusions and Implications

The study reveals that the self-efficacy sources jointly predicted algebra problem-solving ability. The unexplained 83% of variance highlights the importance of confounding variables. Moreover, the results show that students self-efficacy in algebra problem-solving is context dependent. The results also suggest that senior high school year 2 students failure in algebra problem-solving is associated with how anxious they feel and lack of supportive encouragement while their previous achievement and peer-modelling do not significantly translate into problem-solving confidence. These findings indicate that enhancing algebra problem-solving abilities require interventions that integrate psychological, quality instruction, and systemic approaches in mathematics education.

Recommendations

Algebra problem-solving activities should be active and an opportunity for students to ask for feedback from peers and instructors in a positive way, and to work on ways to deal with mathematics anxiety. Teachers should foster learners' positive emotions in the class, alleviate anxiety and promote growth mindset. Frequent, clear and constructive feedback for improving confidence and understanding should be given by teachers. Educational authorities must provide professional training, which involves academic and emotional learning. Future research can be extended to other grade levels and contexts, and use the mixed-method design or structural equation model to investigate the development of sources of self-efficacy in mathematics education.

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