

Geometry Anxiety among Senior High School Students: Examining the Roles of Perceived Spatial Visualization Ability, Geometry Self-Efficacy, and Perceived Geometry Classroom Learning Environment.

Abstract:

Geometry anxiety is a domain-specific affective experience, yet limited evidence explains how students' perceived spatial capability, geometry self-efficacy, and classroom learning environment operate together in relation to it. This cross-sectional correlational study examined 500 Form Two students from a public Senior High/Technical School in the Sekyere South District of Ghana. Participants were selected using simple random sampling and completed a 40-item questionnaire measuring perceived spatial visualization ability (PSVA), geometry self-efficacy (GSE), perceived geometry classroom learning environment (PGCLE), and geometry anxiety (GA). Confirmatory factor analysis and structural equation modelling were conducted using maximum likelihood estimation. The four-factor measurement model showed strong fit, $\chi^2(734) = 844.508$, $p = .003$, CFI = .994, TLI = .994, RMSEA = .017, 90% CI [.011, .023]. PSVA ($\beta = .495$) and PGCLE ($\beta = .410$) were positively associated with GSE, whereas PSVA ($\beta = -.174$), PGCLE ($\beta = -.168$), and GSE ($\beta = -.585$) were negatively associated with GA. GSE showed significant negative indirect associations from PSVA to GA ($\beta = -.289$, 95% bias-corrected CI [-.346, -.237]) and from PGCLE to GA ($\beta = -.240$, 95% bias-corrected CI [-.294, -.193]). Geometry self-efficacy was strongly associated with lower geometry anxiety and statistically accounted for part of the relationships of perceived spatial capability and classroom environment with anxiety. Because the study was cross-sectional and conducted in one school, the findings are interpreted as associations rather than causal effects.

Keywords: geometry anxiety; perceived spatial visualization ability; geometry self-efficacy; classroom learning environment; structural equation modelling

Introduction

Geometry requires students to interpret diagrams, reason about spatial relationships, visualize transformations, and mentally manipulate geometric information. These demands make spatial processes especially relevant to geometry learning (Ünlü & Ertekin, 2017). Geometry learning is also affective and motivational: students' beliefs about their capabilities and their experiences in the classroom can shape how they approach geometry tasks. Geometry anxiety refers to worry, tension, fear, or uneasiness associated with geometry-related situations. It is usefully distinguished from general mathematics anxiety because geometry has domain-specific representational and spatial demands, and a dedicated geometry-anxiety measure has been developed for secondary-school students (Sağlam et al., 2011). Recent geometry research continues to link anxiety with other geometry-learning characteristics and outcomes (Ünlü & Ertekin, 2017).

One potential correlate of geometry anxiety is perceived spatial visualization ability (PSVA), defined here as students' perceptions of their capability to mentally represent, manipulate, rotate, and transform spatial information relevant to geometry. PSVA is not an objective spatial-performance score. This distinction matters because actual spatial ability, perceived spatial ability, and spatial anxiety are related but distinguishable constructs (Sokolowski et al., 2019). Research using objective

spatial measures has connected spatial visualization with geometry self-efficacy and anxiety-related outcomes (Dursun, 2010; Ünlü & Ertekin, 2017), while self-report research has demonstrated that perceived spatial capability can be studied as a distinct construct (Turgut, 2015).

Geometry self-efficacy (GSE) concerns students' beliefs about their capability to successfully perform geometry-related tasks. It is broader than PSVA: PSVA concerns perceived capability for spatial-visualization operations, whereas GSE concerns confidence across geometry tasks. Geometry self-efficacy has been established as an important construct in geometry learning (Cantürk-Günhan & Başer, 2007; Erkek & Işıksal-Bostan, 2015; Ünlü & Ertekin, 2017). Broader mathematics evidence also shows a consistent negative relationship between mathematics anxiety and competence beliefs such as self-efficacy (Du et al., 2021; Li et al., 2021; Živković et al., 2023).

Students' affective experiences also develop within a classroom context. Perceived geometry classroom learning environment (PGCLE) refers to students' perceptions of social, instructional, and interpersonal conditions such as teacher support, participation, cooperation, task focus, and fairness. Classroom-environment research has identified these as meaningful psychosocial dimensions (Dorman, 2008), and geometry-specific work has shown that geometry classrooms can be examined as psychosocial learning environments (Kuzle, 2023). In Ghana, students' perceptions of mathematics classroom environments have been studied at the junior-high level (Wilmot et al., 2018), and recent Senior High School evidence links classroom management and pedagogical practices with mathematics anxiety (Azuuga et al., 2026). However, these Ghanaian studies address mathematics generally rather than an integrated model of geometry-specific anxiety.

The literature therefore supports relationships among spatial processes, self-efficacy, classroom experiences, and anxiety, but provides limited evidence on how PSVA, GSE, and PGCLE operate together in relation to geometry anxiety among Ghanaian Senior High School students. In particular, it remains unclear whether GSE statistically accounts for part of the associations of PSVA and PGCLE with geometry anxiety. The present study addresses this geometry-specific explanatory gap using structural equation modelling.

Theoretical and Conceptual Framework

The study is anchored primarily in Pekrun's Control-Value Theory of Achievement Emotions (CVT) and supported by Bandura's self-efficacy framework. CVT proposes that achievement emotions such as anxiety are closely associated with learners' appraisals of control and value in achievement situations (Pekrun, 2006, 2024). In the present model, geometry anxiety is the achievement emotion; PSVA represents a specific perceived capability relevant to spatially demanding geometry tasks; and PGCLE represents a contextual condition that may be associated with students' competence beliefs and emotional experiences. Bandura's (1997) account of self-efficacy complements this framework by emphasizing beliefs about one's capability to perform particular tasks. Accordingly, GSE is positioned as a broader geometry-related competence belief and as a statistical intermediary linking PSVA and PGCLE with geometry anxiety.

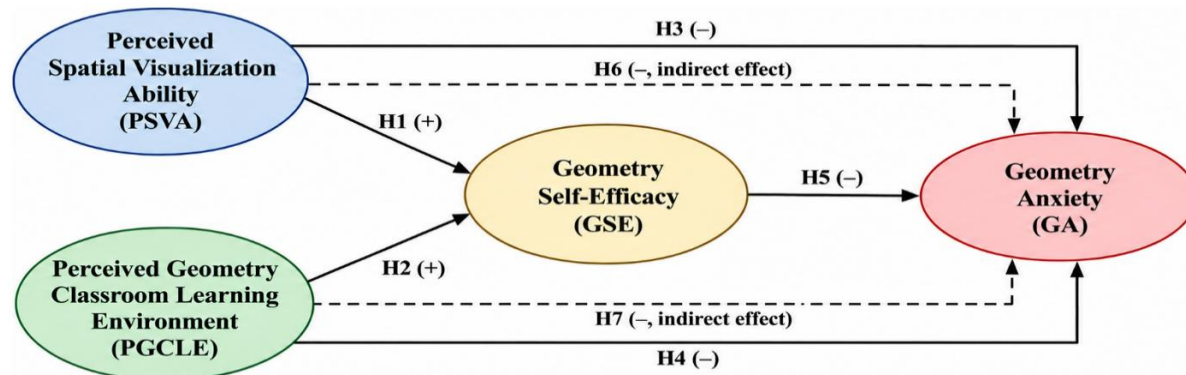


Figure 1. Conceptual framework and hypothesized relationships.

Note. PSVA = perceived spatial visualization ability; GSE = geometry self-efficacy; PGCLE = perceived geometry classroom learning environment; GA = geometry anxiety. Solid arrows represent direct hypotheses; dashed paths represent hypothesized indirect relationships through GSE. Directions shown are a priori hypotheses, not empirical findings.

Hypotheses

H1. PSVA is positively associated with GSE.

H2. PGCLE is positively associated with GSE.

H3. PSVA is negatively associated with GA.

H4. PGCLE is negatively associated with GA.

H5. GSE is negatively associated with GA.

H6. PSVA has a negative indirect association with GA through GSE.

H7. PGCLE has a negative indirect association with GA through GSE.

Materials and Methods

Research Design and Setting

A quantitative cross-sectional correlational design was used to examine associations among PSVA, GSE, PGCLE, and GA. The study was conducted in a public Senior High/Technical School in the Sekyere South District of the Ashanti Region, Ghana. The target population comprised 1,223 Form Two students enrolled in General Science, General Arts, Business, Agricultural Science, Home Economics, Visual Arts, and Technical programmes. Structural equation modelling (SEM) was used to evaluate the measurement model and the hypothesized direct and indirect relationships (Kline, 2023). Because the design was cross-sectional and non-experimental, directional paths were interpreted as theory-specified associations rather than established causal effects.

Participants and Sampling

Simple random sampling was used to select participants from the eligible Form Two student population. The final sample comprised 500 students. Programme membership in the achieved sample was General Science (n = 67), General Arts (n = 104), Business (n = 94), Agricultural Science (n = 56), Home Economics (n = 60), Visual Arts (n = 51), and Technical (n = 68). Programme quotas

were not fixed because sampling was not stratified by programme. Sample adequacy for SEM was considered in relation to model complexity and estimation stability rather than a universal rule of thumb, because SEM sample requirements vary with loadings, structural effects, model complexity, and other data characteristics (Wolf et al., 2013).

Instrument

Data were collected with a structured questionnaire containing demographic items and 40 substantive items, with 10 indicators for each latent construct. PSVA items assessed perceived capability to mentally represent, rotate, manipulate, and transform spatial information and were informed by self-report spatial-ability literature (Turgut, 2015). GSE items assessed confidence in understanding and performing geometry tasks and were informed by geometry self-efficacy research (Cantürk-Günhan & Başer, 2007). PGCLE items assessed teacher support, participation, peer cooperation, task-focused learning, and fairness, drawing on classroom-environment dimensions represented in the WIHIC tradition (Dorman, 2008). GA items assessed nervousness, tension, worry, and apprehension in geometry learning and assessment contexts and were informed by geometry-anxiety research (Sağlam et al., 2011).

PSVA and GA items used a five-point agreement format from 1 (Strongly disagree) to 5 (Strongly agree). GSE items used five confidence categories from 1 (Not at all confident) to 5 (Completely confident), and PGCLE items used five frequency categories from 1 (Almost never) to 5 (Almost always). The questionnaire was reviewed by the research supervisor for content relevance, clarity, and construct alignment. Internal structure was subsequently evaluated through CFA. Reliability and convergent evidence were assessed using Cronbach's alpha, composite reliability (CR), standardized loadings, and average variance extracted (AVE). Discriminant evidence was examined using the Fornell-Larcker comparison (Fornell & Larcker, 1981) and the heterotrait-monotrait ratio (HTMT; Henseler et al., 2015).

Data Collection and Ethical Considerations

Ethical approval for the study was obtained from the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development Institutional Review Board (AAMUSTED-IRB), Ghana, prior to data collection. The IRB did not issue a formal approval number for the study. Permission to conduct the research within the school was also obtained from the headmaster and relevant school authorities. For participants below 18 years of age, the IRB-approved procedure permitted school-authority permission together with student assent in place of parental or guardian consent. Students aged 18 years or older provided informed consent. All participants were informed about the purpose of the study, the voluntary nature of participation, confidentiality and anonymity of their responses, and their right to decline or withdraw without penalty. No personally identifying information was included in the analytical dataset, and findings were reported only in aggregate form.

Data Analysis

The dataset was screened before substantive analysis. All 500 respondent IDs were unique, no item responses were missing, and all 40 substantive items fell within the intended 1-5 response range. Individual items, rather than precomputed scale means, were used as latent-variable indicators.

CFA and SEM were performed in IBM SPSS Amos using maximum likelihood (ML) estimation. The five-category indicators were treated as approximately continuous. This choice was made transparently because simulation studies show that performance of continuous-variable estimators with ordered categories depends on the number of categories and distributional conditions, while ordinal estimators can be preferable under other conditions (Li, 2016; Rhemtulla et al., 2012). Item distributions were inspected and did not show pronounced skewness. Model evaluation considered χ^2 , χ^2/df , CFI, TLI, and RMSEA with its 90% confidence interval, together with parameter plausibility rather than treating fit cut-offs as mechanical pass/fail rules (Kline, 2023).

The CFA specified four correlated factors, each measured by 10 indicators. The structural model then specified PSVA and PGCLE as exogenous variables predicting GSE and GA, with GSE predicting GA and PSVA covarying with PGCLE. Indirect effects through GSE were evaluated using 5,000 bootstrap resamples and 95% bias-corrected confidence intervals. An indirect effect was considered statistically supported when its bootstrap interval excluded zero. Because all variables were measured at one time point, mediation was interpreted as a statistical indirect association rather than a temporal or causal mechanism.

Results

Participant Characteristics

The final analytical sample consisted of 500 students: 258 males (51.6%) and 242 females (48.4%). Most were aged 16-17 years (60.8%), followed by 18 years and above (27.8%) and 14-15 years (11.4%). All seven programmes were represented (Table 1).

Table 1. Participant characteristics (N = 500)

Characteristic	n	%
Gender		
Male	258	51.6
Female	242	48.4
Age group		
14-15 years	57	11.4
16-17 years	304	60.8
18 years and above	139	27.8
Programme		
General Science	67	13.4
General Arts	104	20.8
Business	94	18.8
Agricultural Science	56	11.2
Home Economics	60	12.0
Visual Arts	51	10.2

Characteristic	n	%
Technical	68	13.6

Measurement Model

The four-factor CFA converged successfully and yielded $\chi^2 (734) = 844.508$, $p = .003$, $\chi^2/df = 1.151$, CFI = .994, TLI = .994, IFI = .994, and RMSEA = .017, 90% CI [.011, .023]. Standardized loadings ranged from .809 to .876 for PSVA, .777 to .876 for GSE, .818 to .864 for PGCLE, and .817 to .876 for GA.

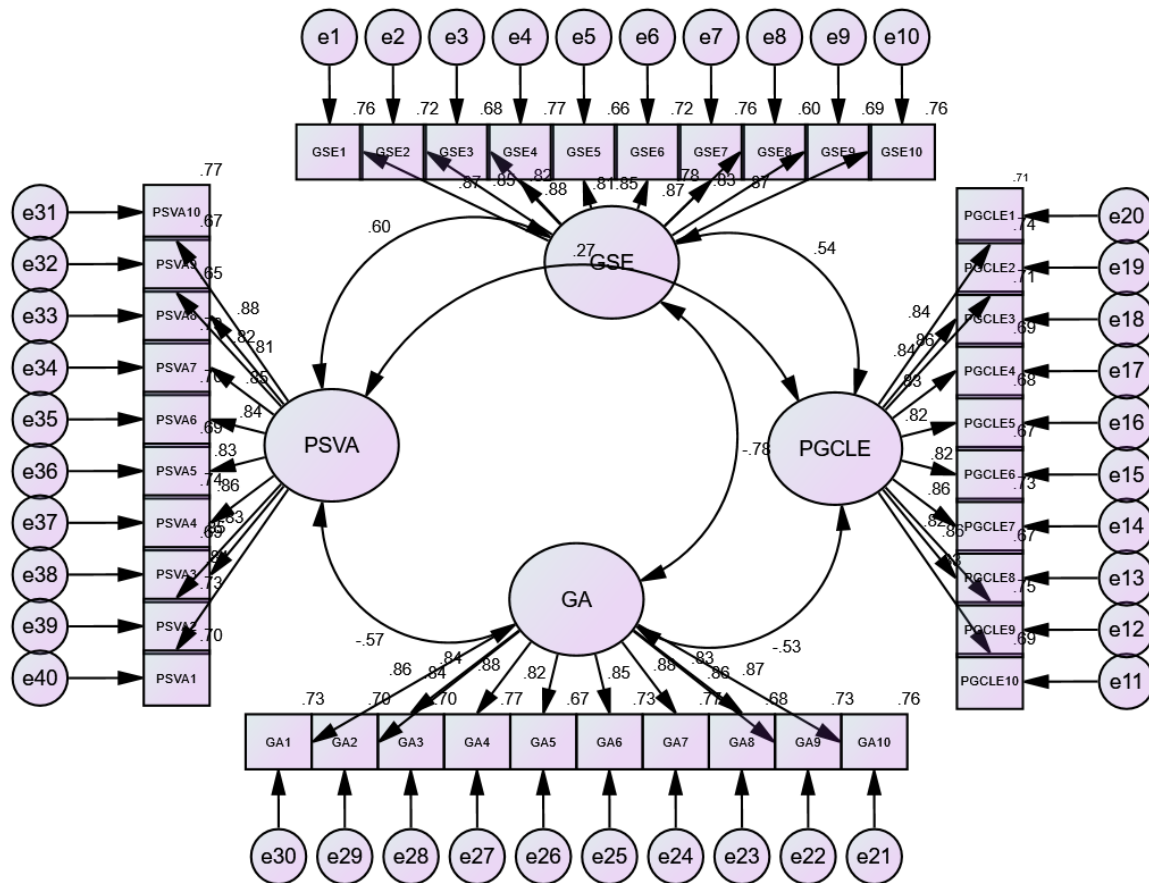


Figure 2. Confirmatory factor analysis of the four-factor measurement model.

Note. Values shown are standardized estimates. PSVA = perceived spatial visualization ability; GSE = geometry self-efficacy; PGCLE = perceived geometry classroom learning environment; GA = geometry anxiety.

Table 2. Reliability and convergent evidence for the measurement model

Construct	Loading range	α	CR	AVE	$\sqrt{\text{AVE}}$
PSVA	.809-.876	.960	.960	.708	.841
GSE	.777-.876	.961	.961	.711	.843
PGCLE	.818-.864	.960	.960	.704	.839
GA	.817-.876	.963	.963	.725	.851

As shown in Table 2, internal-consistency and composite-reliability estimates were high, and AVE exceeded .50 for each construct. The square root of AVE for each construct also exceeded its absolute latent correlations with the other constructs. HTMT estimates ranged from .272 to .782; all point estimates and their 90% bootstrap upper bounds were below .85 (Table 3). These results support the empirical distinctiveness of the four constructs, while the very high reliability coefficients also warrant attention to possible item redundancy in future scale refinement.

Table 3. HTMT estimates with 90% bootstrap confidence intervals

Construct pair	HTMT	90% CI
PSVA-GSE	.605	[.553, .654]
PSVA-PGCLE	.272	[.201, .341]
PSVA-GA	.576	[.521, .626]
GSE-PGCLE	.541	[.484, .597]
GSE-GA	.782	[.748, .813]
PGCLE-GA	.532	[.474, .587]

Structural Model and Hypothesis Testing

The structural model converged and reproduced the CFA global fit: $\chi^2(734) = 844.508$, $p = .003$, $\chi^2/df = 1.151$, CFI = .994, TLI = .994, and RMSEA = .017, 90% CI [.011, .023]. The identical global fit is expected because the structural relations among the four latent variables are just-identified at the latent level; therefore, the hypotheses were evaluated from the structural coefficients and bootstrap intervals rather than from changes in global fit. All five direct paths were statistically significant and in the hypothesized directions (Table 4).

Table 4. Structural path estimates

Hyp.	Path	B	SE	β	95% BC CI for β	p
H1	PSVA $\rightarrow$ GSE	.498	.039	.495	[.429, .555]	< .001
H2	PGCLE $\rightarrow$ GSE	.445	.041	.410	[.341, .476]	< .001

Hyp.	Path	B	SE	β	95% BC CI for β	p
H3	PSVA $\rightarrow$ GA	-.175	.038	-.174	[-.248, -.099]	< .001
H4	PGCLE $\rightarrow$ GA	-.181	.039	-.168	[-.236, -.099]	< .001
H5	GSE $\rightarrow$ GA	-.582	.048	-.585	[-.659, -.506]	< .001

PSVA and PGCLE jointly accounted for 52.2% of the variance in GSE ($R^2 = .522$). PSVA, PGCLE, and GSE jointly accounted for 64.7% of the variance in GA ($R^2 = .647$). These R^2 values describe variance accounted for in the fitted sample and are not causal proportions.

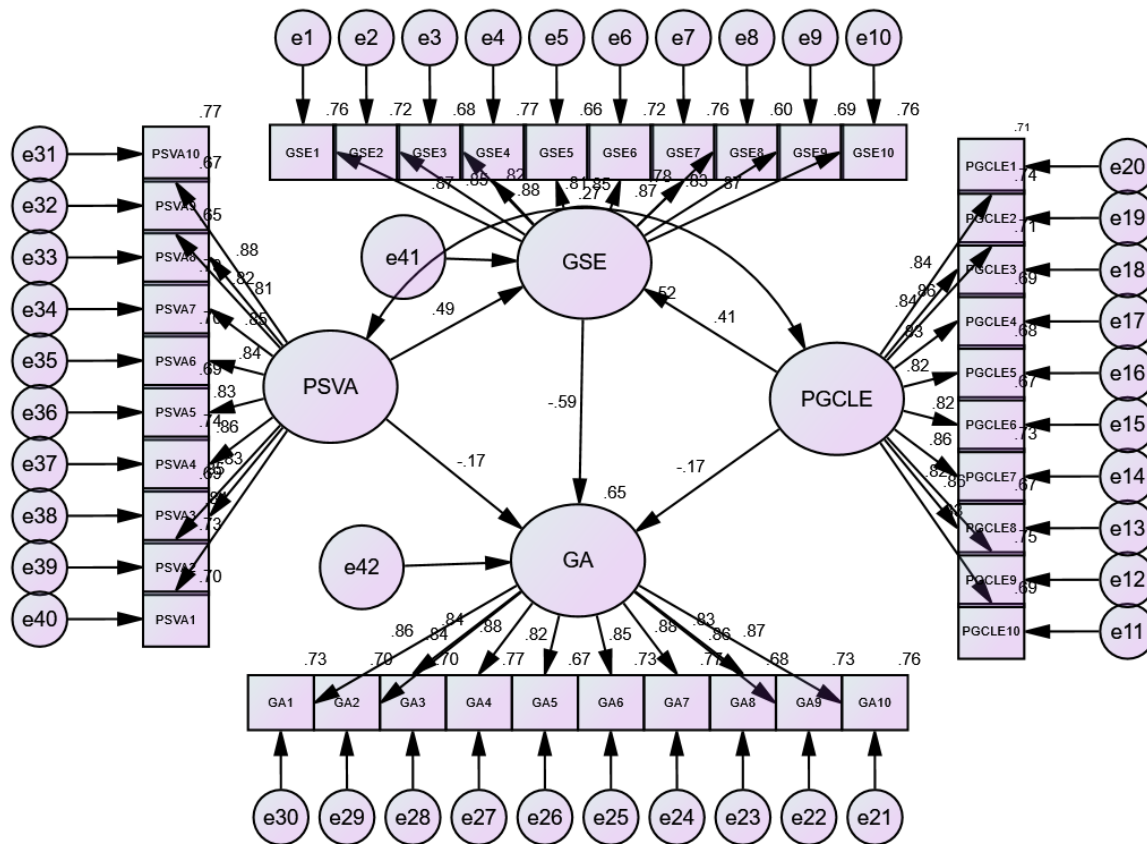


Figure 3. Structural model with standardized estimates.

Note. PSVA = perceived spatial visualization ability; GSE = geometry self-efficacy; PGCLE = perceived geometry classroom learning environment; GA = geometry anxiety. R^2 values are shown for the endogenous latent variables.

Indirect Effects through Geometry Self-Efficacy

The bootstrapped indirect effects supported H6 and H7. PSVA had a negative indirect association with GA through GSE ($B = -.290$, $\beta = -.289$, 95% bias-corrected CI for β [-.346, -.237]), and PGCLE had a negative indirect association with GA through GSE ($B = -.259$, $\beta = -.240$, 95% bias-corrected CI [-.294, -.193]). The corresponding direct effects from PSVA and PGCLE to GA

remained significant, so the pattern was consistent with partial statistical mediation. The cross-sectional design does not establish temporal or causal mediation.

Table 5. Bootstrapped indirect effects through geometry self-efficacy

Hyp.	Indirect path	B	β	95% BC CI for β	Result
H6	PSVA $\rightarrow$ GSE $\rightarrow$ GA	-.290	-.289	[-.346, -.237]	Supported
H7	PGCLE $\rightarrow$ GSE $\rightarrow$ GA	-.259	-.240	[-.294, -.193]	Supported

217

218 Discussion

219 The study examined an integrated geometry-anxiety model in which perceived spatial capability and
 220 classroom experience were linked to anxiety both directly and through geometry self-efficacy. All
 221 hypothesized direct and indirect associations were supported. The overall pattern is consistent with
 222 Control-Value Theory, which locates achievement anxiety within students' control-related appraisals
 223 and learning contexts (Pekrun, 2006, 2024), and with self-efficacy theory, which emphasizes
 224 judgments of capability in task engagement (Bandura, 1997).

225 PSVA was positively associated with GSE ($\beta = .495$). Students who viewed themselves as more
 226 capable of mentally representing and manipulating spatial information also tended to express stronger
 227 confidence in performing geometry tasks. This finding is consistent with geometry research
 228 connecting spatial visualization with geometry self-efficacy (Dursun, 2010; Ünlü & Ertekin, 2017)
 229 and with broader evidence that spatial performance and spatially focused affective perceptions are
 230 related to mathematics experiences (Ferguson et al., 2015; Sokolowski et al., 2019). The
 231 measurement results nevertheless support treating PSVA and GSE as distinct: PSVA concerns a
 232 specific perceived spatial capability, whereas GSE concerns broader confidence across geometry
 233 tasks.

234 PSVA was also negatively associated with GA directly ($\beta = -.174$) and indirectly through GSE ($\beta =$
 235 $-.289$). Students who perceived greater spatial-visualization capability tended to report less geometry
 236 anxiety, and part of this association was statistically linked to stronger geometry self-efficacy. This is
 237 compatible with evidence connecting spatial anxiety and spatial skills with mathematics anxiety
 238 (Ferguson et al., 2015; Sokolowski et al., 2019). The interpretation must remain specific to perceived
 239 capability: the present study did not administer an objective spatial test and therefore does not show
 240 that objectively higher spatial ability reduces geometry anxiety.

241 PGCLE was positively associated with GSE ($\beta = .410$) and negatively associated with GA ($\beta =$
 242 $-.168$). Students who perceived greater teacher support, participation, cooperation, task focus, and
 243 fairness tended to report stronger geometry self-efficacy and lower anxiety. This pattern aligns with
 244 research treating classroom environment as a meaningful psychosocial context (Dorman, 2008;
 245 Kuzle, 2023) and with evidence that teacher behaviours and classroom conditions are related to
 246 mathematics anxiety and control appraisals (Klee et al., 2022; Liu et al., 2024). The finding is also
 247 relevant to Ghanaian evidence: Wilmot et al. (2018) documented students' perceptions of

mathematics classroom environments, while Azuuga et al. (2026) linked classroom management and pedagogical practices with mathematics anxiety among Ghanaian Senior High School students. The present study extends that contextual evidence to geometry-specific anxiety.

GSE showed the strongest direct association with GA ($\beta = -.585$). Students who were more confident in their ability to perform geometry tasks tended to report substantially less geometry anxiety. This accords with geometry research emphasizing self-efficacy as an important affective correlate of geometry learning (Erkek & Işıksal-Bostan, 2015; Ünlü & Ertekin, 2017) and with broader mathematics evidence showing negative associations between anxiety and self-efficacy or competence beliefs (Du et al., 2021; Li et al., 2021; Živković et al., 2023). From a control-value perspective, stronger competence beliefs may correspond to greater perceived control in achievement situations, whereas lower perceived control is closely associated with anxiety (Pekrun, 2006, 2024).

The indirect effects add an important integrative result. GSE statistically accounted for part of the negative associations of both PSVA and PGCLE with GA. Thus, students' perceptions of spatial capability and classroom conditions were related to geometry anxiety partly through their broader confidence in performing geometry tasks. This pattern is theoretically compatible with the proposition that contextual conditions and competence-related appraisals are jointly associated with achievement emotions (Pekrun, 2024; Putwain & Wood, 2023). Because the direct effects of PSVA and PGCLE remained significant, GSE did not account for the entirety of either relationship.

These indirect paths should not be interpreted causally. All constructs were measured at the same time, so the data cannot establish that PSVA or PGCLE precedes GSE or that GSE subsequently changes anxiety. Longitudinal mathematics research indicates that anxiety and control-related beliefs can be reciprocal over time (Putwain & Wood, 2023). Accordingly, the present results support theory-consistent direct and indirect statistical associations, not a demonstrated temporal mechanism.

Recommendations

The findings suggest several evidence-informed directions for practice. Geometry teachers should provide structured opportunities for students to engage with diagrams, mental rotation, transformation, multiple representations, and other spatially demanding activities while offering attainable challenges and constructive feedback. Such practices may support students' perceived spatial capability and geometry self-efficacy, although intervention effects were not tested in this study.

Teachers and schools should also cultivate supportive geometry classrooms in which students can ask questions, explain solutions, cooperate with peers, learn from errors, and participate without unnecessary embarrassment. Particular attention may be given to students who show persistent worry or avoidance in geometry, with support addressing not only content knowledge but also confidence and classroom experience. These recommendations are consistent with control-value approaches to reducing mathematics anxiety that emphasize perceived control, self-efficacy, and supportive instructional conditions (Klee et al., 2022).

Limitations and Directions for Future Research

The findings should be interpreted within several limitations. First, the cross-sectional design does not establish temporal or causal relationships; longitudinal and experimental studies are needed to test

directionality. Second, all four constructs were self-reported. In particular, PSVA reflects perceived rather than objectively demonstrated spatial visualization ability. Future studies should combine self-report PSVA with performance-based spatial measures. Third, data came from one public Senior High/Technical School, so the results should not be generalized automatically to all Ghanaian Senior High School students. Replication across schools, districts, regions, and school types is needed.

Fourth, the five-category indicators were estimated using standard ML in Amos. Although continuous-variable estimation can perform adequately under some five-category conditions, ordinal estimators may be preferable in other conditions (Li, 2016; Rhemtulla et al., 2012); future studies should test robustness using an ordinal estimator such as WLSMV. Finally, the very high internal-consistency coefficients may indicate some item redundancy. Future instrument work should examine whether a shorter set of items can preserve adequate content coverage and measurement quality.

Conclusion

This study provides an integrated account of geometry anxiety involving perceived spatial visualization ability, geometry self-efficacy, and perceived geometry classroom learning environment. PSVA and PGCLE were positively associated with GSE, while PSVA, PGCLE, and especially GSE were negatively associated with geometry anxiety. GSE also showed significant indirect statistical relationships linking both PSVA and PGCLE with anxiety. Within the limits of a cross-sectional single-school design, the findings highlight geometry self-efficacy as an important component of the network of capability perceptions, classroom experiences, and emotions associated with geometry learning.

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References

- Azuuga, C., Agmabire Akendita, P., & Abunkrug, F. (2026). Classroom environment and pedagogical practices as determinants of mathematics anxiety in Senior High School: Evidence from Ghana. *International Journal of Mathematics and Mathematics Education*, 4(2), 85–101. <https://doi.org/10.56855/ijmme.v4i1.1840>
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman.
- Cantürk-Günhan, B., & Başer, N. (2007). Geometriye yönelik öz-yeterlik ölçeğinin geliştirilmesi [The development of self-efficacy scale toward geometry]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 33, 68–76.
- Dorman, J. P. (2008). Use of multitrait-multimethod modelling to validate actual and preferred forms of the What Is Happening In this Class? (WIHIC) questionnaire. *Learning Environments Research*, 11(3), 179–193. <https://doi.org/10.1007/s10984-008-9043-6>
- Du, C., Qin, K., Wang, Y., & Xin, T. (2021). Mathematics interest, anxiety, self-efficacy and achievement: Examining reciprocal relations. *Learning and Individual Differences*, 91, 102060. <https://doi.org/10.1016/j.lindif.2021.102060>
- Dursun, Ö. (2010). The relationships among the preservice teachers' spatial visualization ability, geometry self-efficacy, and spatial anxiety [Master's thesis, Middle East Technical University]. METU Open. <https://hdl.handle.net/11511/19833>
- Erkek, Ö., & Işıksal-Bostan, M. (2015). The role of spatial anxiety, geometry self-efficacy and gender in predicting geometry achievement. *Elementary Education Online*, 14(1), 164–180. <https://doi.org/10.17051/eeo.2015.18256>
- Ferguson, A. M., Maloney, E. A., Fugelsang, J., & Risko, E. F. (2015). On the relation between math and spatial ability: The case of math anxiety. *Learning and Individual Differences*, 39, 1–12. <https://doi.org/10.1016/j.lindif.2015.02.007>
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39–50. <https://doi.org/10.1177/002224378101800104>
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115–135. <https://doi.org/10.1007/s11747-014-0403-8>
- Klee, H. L., Buehl, M. M., & Miller, A. D. (2022). Strategies for alleviating students' math anxiety: Control-value theory in practice. *Theory Into Practice*, 61(1), 49–61. <https://doi.org/10.1080/00405841.2021.1932157>
- Kline, R. B. (2023). *Principles and practice of structural equation modeling* (5th ed.). Guilford Press.

- 361 Kuzle, A. (2023). Elementary school children's perceptions of geometry classroom as a psychosocial
362 learning environment: An analysis of participant-produced drawings. *Learning Environments*
363 *Research*, 26, 379–399. <https://doi.org/10.1007/s10984-022-09430-0>
- 364 Li, C.-H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum
365 likelihood and diagonally weighted least squares. *Behavior Research Methods*, 48, 936–949.
366 <https://doi.org/10.3758/s13428-015-0619-7>
- 367 Li, Q., Cho, H., Cosso, J., & Maeda, Y. (2021). Relations between students' mathematics anxiety and
368 motivation to learn mathematics: A meta-analysis. *Educational Psychology Review*, 33(3),
369 1017–1049. <https://doi.org/10.1007/s10648-020-09589-z>
- 370 Liu, S., Leung, F. K. S., & Jiang, Z. (2024). The appraisal antecedents of Shanghai students'
371 mathematics anxiety and the moderating effects of teacher behaviours: From the perspective
372 of the control-value theory. *Asia Pacific Journal of Education*, 44(2), 251–264.
373 <https://doi.org/10.1080/02188791.2022.2049699>
- 374 Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and
375 implications for educational research and practice. *Educational Psychology Review*, 18(4),
376 315–341. <https://doi.org/10.1007/s10648-006-9029-9>
- 377 Pekrun, R. (2024). Control-value theory: From achievement emotion to a general theory of human
378 emotions. *Educational Psychology Review*, 36, Article 83. [https://doi.org/10.1007/s10648-](https://doi.org/10.1007/s10648-024-09909-7)
379 [024-09909-7](https://doi.org/10.1007/s10648-024-09909-7)
- 380 Putwain, D. W., & Wood, P. (2023). Anxiety in the mathematics classroom: Reciprocal relations with
381 control and value, and relations with subsequent achievement. *ZDM–Mathematics Education*,
382 55, 285–298. <https://doi.org/10.1007/s11858-022-01390-2>
- 383 Rhemtulla, M., Brosseau-Liard, P. É., & Savalei, V. (2012). When can categorical variables be
384 treated as continuous? A comparison of robust continuous and categorical SEM estimation
385 methods under suboptimal conditions. *Psychological Methods*, 17(3), 354–373.
386 <https://doi.org/10.1037/a0029315>
- 387 Sağlam, Y., Türker, B., & Umay, A. (2011). Geometry anxiety scale for secondary school students.
388 *Procedia - Social and Behavioral Sciences*, 15, 966–970.
389 <https://doi.org/10.1016/j.sbspro.2011.03.222>
- 390 Sokolowski, H. M., Hawes, Z., & Lyons, I. M. (2019). What explains sex differences in math
391 anxiety? A closer look at the role of spatial processing. *Cognition*, 182, 193–212.
392 <https://doi.org/10.1016/j.cognition.2018.10.005>
- 393 Turgut, M. (2015). Development of the spatial ability self-report scale (SASRS): Reliability and
394 validity studies. *Quality & Quantity*, 49(5), 1997–2014. [https://doi.org/10.1007/s11135-014-](https://doi.org/10.1007/s11135-014-0086-8)
395 [0086-8](https://doi.org/10.1007/s11135-014-0086-8)
- 396 Wilmot, E. M., Asomah, K. R., & Ntow, F. D. (2018). What is happening in Ghanaian Junior High
397 School mathematics classrooms? A look at students' perception. *The Oguuaa Educator*, 12, 68–
398 86.

- 399 Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for
400 structural equation models: An evaluation of power, bias, and solution propriety. *Educational*
401 *and Psychological Measurement*, 73(6), 913–934. <https://doi.org/10.1177/0013164413495237>
- 402 Ünlü, M., & Ertekin, E. (2017). A structural equation model for factors affecting eighth graders'
403 geometry achievement. *Educational Sciences: Theory & Practice*, 17(5), 1815–1846.
404 <https://doi.org/10.12738/estp.2017.5.0545>
- 405 Živković, M., Pellizzoni, S., Doz, E., Cuder, A., Mammarella, I., & Passolunghi, M. C. (2023). Math
406 self-efficacy or anxiety? The role of emotional and motivational contribution in math
407 performance. *Social Psychology of Education*, 26(3), 579–601.
408 <https://doi.org/10.1007/s11218-023-09760-8>