RESEARCH PAPER

Pre-service Teachers' Re-constructed Geometry Disposition Scale: A Validity and Reliability Study in the Ghanaian Context

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This study reports on the development, validation, and reliability of a geometry disposition scale (GDS) to measure pre-service teachers' (PSTs') attitudes to geometry learning. PSTs from two Colleges of Education (CoEs) in Ghana volunteered to participate in the study (*N* = 153). A principal component analysis (PCA) extracted four factors: deep affect (positivity expressed towards geometry learning), working privately, collaborative working and technology or calculator use. The final GDS contained 15 items. While validation is still not fully tested, the psychometric properties to-date suggest the GDS has promising benefits in measuring PSTs' attitudes to geometry learning, which may enable the adjustment of the teaching of geometry accordingly.

Background

The current trend of educational systems in most countries around the world shows an overriding objective of investing in Science, Technology, Engineering, and Mathematics (STEM). This is true of Ghana, where it is believed that future technological advancement, development, and innovation is vital to the future of the country (Keaveney et al., 2018). Of particular importance to the context of technological advancement is the contribution of geometry knowledge (Wang, 2016). Geometrical ideas and concepts remain a formidable force in this respect as they are increasingly utilised in pursuits such as architectural design, engineering, building construction and packaging. It is, therefore, not surprising that geometry has been described as the "tool for understanding and interacting with the space in which we live, [and] is perhaps the most intuitive, concrete and reality-linked part of mathematics" (Wang, 2016, p. 1). Thus, Jones (2002, p. 122) said, "geometry [as an appeal] to our aesthetic, visual and intuitive senses." In addition, Kundu (2018, p. 212) described it as a lively and stimulating strand of mathematics, which he argued offers the key needed to understand our world as we experience "geometric figures and [identifying their] relationships." It is "grasping space … that space in which the child lives, breathes, and moves. The space that the child must learn to know, explore, conquer, in order to live, breathe and move better in it" (Freudenthal, 1973, as cited in National Council of Teachers of Mathematics [NCTM], 1989, p. 48). If this sense of geometry as a "grasping space" is to be adopted, a conscious effort must be made to develop children's geometric knowledge and concepts, and to engage them in geometric phenomena. It then becomes important to be deliberate in planning learning activities intended to empower children to build connections and identify relationships and develop spatial sense.

Through the study of geometry, learners are imbued with the requisite mathematical tools and skills that are catalytic to develop the complex reasoning and problem-solving skills used in STEM and its many related skilled trades and professions. It is important, therefore, that school students' capacity to develop the understanding of geometry is enhanced, so that they can participate in a technological world. This requires geometry to be taught well.

A key to this success is an intentional investment of developing such knowledge in our PSTs who will be teaching these school students. The place of geometry in teacher education cannot therefore be overemphasised. It is a crucial strand of mathematics education, and as

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such PSTs are expected to connect geometric concepts to geometric phenomena (Salifu et al., 2018; University of Education Winneba [UEW)], 2018). Notwithstanding this critical importance, multiple studies have identified how PSTs' attitudes to geometry can negatively affect and influence their geometry performance, as discussed next. This study therefore sought to develop, validate, and estimate the reliability of a geometry disposition scale, which can be used to measure the attitude of PSTs to geometry learning and hence inform effective instruction.

Literature

Despite the importance of geometry as suggested, previous research has indicated that the achievement of both PSTs and school students is lower in geometry than in other domains of mathematics. For instance, it was reported that US students showed progress both in national and international organised assessment in other areas of mathematics but failed to sustain that improvement in geometry (Casa et al., 2017). Duatepe (2013) also indicated that students' performance in geometry was adjudged lower than in other areas of the mathematics discipline. This assertion confirmed the reports from earlier studies (e.g., Clements & Battista, 1992) that students were not studying geometry as they should, and is echoed by Dimla (2018).

Research indicates that PSTs have mostly a procedural understanding rather than a relational understanding of geometry. For example, Patkin and Plaksin (2019) conducted a study involving PSTs ($n = 16$), who were taught the geometry of solids during an academic year. The students solved problems based on three dimensional shapes including pyramids. They engaged in other activities to develop their spatial perception and were examined at the end of the year. The findings illustrated that PSTs attained higher in procedural understanding related problems than that of relational understanding, leading the authors to hypothesise that understanding a learned material relationally comes by using special teaching methods. Their limited relational understanding, with high procedural understanding, suggested that the PSTs may have lacked the necessary deep understanding of concepts taught, and this could limit their ability to transfer acquired knowledge fully to their future students.

Research has increasingly identified the under-performance of PSTs in geometry, both internationally (e.g., Aslan-Tutak, 2009), and in Ghana (Salifu et al., 2018). This is worrying, as the trend could hinder progress in STEM related endeavours in the future both globally, and in the context of this study, Ghanaian students, if teacher education does not empower PSTs with sound geometrical ideas and concepts.

Attitude and Its Importance to Learning

The trends in under-performance in geometry have been building for some time. Betiku (2001), for example, observed that students shy away from geometry studies and argued strongly that this behaviour was indicative of negative attitudes when it comes to geometry learning. It was suggested that PSTs' attitudes impair their effective learning of geometry, which contributed to lower geometry performance (Adolphus, 2011). Geometry is not alone in this regard, the learning of mathematics has been associated with many variables, of which attitude towards mathematics learning is one (Mazana et al., 2019).

Affect variables (e.g., attitude) influence the level of personal effort expressed by an individual student to learn mathematics (Fennema & Sherman, 1976). The influence of attitude can either be positive or negative. It can be argued that if students have a positive attitude, they will become active in the knowledge construction process to develop a conceptual understanding of mathematics. In contrast, a negative attitude may cause them to lose interest, and not put in the effort that is needed. It is noted that PSTs' attitudes to teaching methods courses are at times at odds to their knowledge and engagement, but learner-focused teaching relates positively with their course attitudes (Rios, 2017; White et al., 2006). For example, PSTs could be keen about doing mathematics at one time but not have the requisite background to succeed; could be insecure in an aspect of mathematics but feel confident to do mathematics; or show positive attitudes but could not have sufficient mathematical content knowledge. Thus, they suggest support is needed to assist PSTs to become aware of their own attitudes, which can then be made clear and observable.

Extending White et al.'s (2006) and Rios' (2017) arguments, it is suggested that, although students should ideally be independently responsible for knowledge acquisition and engage interactively with their peers (Ontario Education, 2005), teachers should mediate between the learners and the knowledge to be acquired (Arpin & Capra, 2004). The reason is simple: "effective teaching goes further: creating an environment that not only makes learning possible now, but also teaches attitudes and behaviours that enhance learning and success in later life" (Goss & Sonnemann, 2017, p. 7); and teachers' attitudes influence students' attitudes (Tsao, 2017). Thus, if a PST learns geometry in an environment where the lecturer shows a negative disposition towards teaching the subject, it is likely to generate PSTs' dislike towards the subject as well.

Multiple research studies have investigated PSTs' attitudes to the learning of mathematics, of which geometry was a part (Tsao, 2017). Enu et al. (2015) completed a study on the factors influencing PST students' mathematics performance in some selected colleges of education [CoEs] in Ghana. Their study found that 66% disagreed that "they are always under a terrible strain in the mathematics class" (p. 71), and the PST students' mean responses to the survey that explored their attitude towards mathematics indicated a positive attitude towards mathematics. However, the other 34% reported to be under a "terrible strain" when learning mathematics. This was consistent with other research evidence, which suggested a substantial proportion of PSTs held negative attitudes towards mathematics (Burton, 2012). However, attitudes of PSTs towards the learning of geometry in the context of Ghana is an area that has been less explored.

It is argued that if learners are to be encouraged to develop positive attitudes and behaviours to a discipline, it is important that their initial attitudes are measured (Esikci et al., 2017; Tavşancıl, 2006). This was the motivation for the development of the Geometry Disposition Scale (GDS) scale used in this study, and the objectives reported here, namely, to test the factor-structure of the GDS instrument using responses of PSTs sampled from the colleges of education in Ghana, and to interrogate the reliability and the validity of the GDS in the Ghanaian context.

Earlier Geometry Attitude Scales

A search of the literature indicated that there were fewer geometry attitude scales than that for mathematics overall, particularly for studies involving PSTs. Most existing geometry attitudes scales measured only two to three components of attitudes (Avcu & Avcu, 2015); for example *motivation and self-confidence* (Duatepe & Ubuz, 2007); *enjoyment, value, and motivation* (Mogari, 2004); and *usefulness, confidence, and enjoyment* (Utley, 2007). In addition to measuring almost the same dimensions, scales thus far have mostly dealt with senior high school students. This limited attention to attitude dimensions may overlook other dimensions of geometry attitudes that may equally impact students' geometry learning. A Turkish adaptation of Utley's scale to assess undergraduate attitudes to geometry introduced two new dimensions: *future use* and e*veryday use* (see Avcu & Avcu, 2015). This extension of dimensions agreed with earlier authors (Fennema & Sherman, 1976; Utley, 2007) that there were more dimensions of attitudes that could be explored. Further, it has been suggested that the geometry attitude construct may be seen as analogous to that of mathematics attitudes dimensions (Avcu & Avcu, 2015, p. 16). Thus, an adaptation of Brookstein et al.'s (2011) mathematics Students Attitude Survey (SAS) seems appropriate for use in the development of a geometry disposition scale (GDS), as an instrument to explore and measure other unexplored dimensions of PSTs geometry attitude constructs.

This paper therefore reports on one component of a wider ongoing study into the teaching of geometry in teacher education courses, namely the creation and validation of a geometry-specific instrument (GDS) to measure PSTs' attitude to geometry learning.

Methodology

Participants

The participants were first year PSTs in three Ghanaian Colleges of Education. Ethics approval was gained from the Tasmania Social Science Human Research Ethics Committee and subsequently from the president of the Principal Conference of Colleges of Education in Ghana. The PSTs were invited to participate by three geometry educators, who agreed to inform the participants through their various WhatsApp platforms. The questionnaire was completed online, hosted on an online survey platform. Respondents' login to complete the questionnaire indicated explicit consent for participation in the study. In all, 153 PSTs (from 302 invitations) volunteered to participate in the study.

The Instrument

The GDS is a survey questionnaire for the PSTs designed to explore their attitudes towards geometry learning. As introduced in the literature review, the GDS was primarily adapted from the existing mathematics attitude scale developed and validated by Brookstein et al. (2011). In general, the adaptation was to change mathematics terms and references to more specific ones to reflect the context and objectives of the study, which focusses on geometry. For instance, "I think mathematics is important in life" was changed to "I think geometry is important in life."

Ultimately, the GDS contained 15 Likert-type items (as shown in Table 1), with five possible alternatives (from strongly disagree to strongly agree) to collect data directly from the participating PSTs. During the analysis, four factors were identified suggesting four subscales, which are described under results and discussion.

Analysis

An exploratory factor analysis (EFA) with Principal Component Analysis (PCA) technique (IBM SPSS Version 27) was performed to investigate the factor structure of the data and to validate the measuring tool. The strength among the variables was checked by generating and inspecting the correlation matrix, which revealed several coefficient values greater than 0.3 (Tabachnick & Fidell, 2013), signifying healthy strength of the intercorrelation among the variables. Cronbach's alpha tests were employed to check on the internal consistency of the subscales that were created. As a result of this process, 15 items were rejected from an initial bank of 30 items, as described next.

Results and Discussion

Factor Analysis (FA)

During the analysis, each negative item was reverse-scored. Each of the items numbered 12 (My geometry tutor was not friendly and patient with us); 16 (The presence of the geometry tutor in the class puts me off); 27 (Our geometry tutor does not review our assignment/homework); and 30 (My geometry tutor encourages us in class) had low coefficients (less than 0.3) with some other items. This implied they may not factor well and so they were subsequently deleted.

To assess the factorability of the data set, two precautions were observed as we employed factor analysis. The first was to ensure we used an appropriate sampling size. The other was to ensure the sampled data were not an identity matrix. Therefore, Kaiser-Meyer-Olkin (KMO) and the Bartlett's Test of Sphericity were conducted. The KMO measure of sample adequacy was 0.883, which exceeds the recommended 0.6 value (Kaiser, 1974; Tabachnick & Fidell, 2013). A KMO measure close to 1.00 identifies that the sum of partial correlations is large relative to the sum of correlations, which suggests the pattern of correlations is compact and hence factor analysis would result in distinct and reliable factor extraction (Field, 2005). Thus, the KMO statistic here of 0.883 is an endorsement of effective sample size. The Bartlett's Test of Sphericity was found to be significant [(x^2 (325) = 2014.088, $p < 0.000$)], testifying that the sample was not an identity matrix. These statistics show that the data set was appropriate for factor analysis (Field, 2005).

Principal component analysis, with Oblimin rotation, extracted six components with the components having Eigen values of 1 or more. A communality cut-off point of 0.40 was used as recommended by Pituch and Stevens (2016). Thus, Item 7 (In secondary school, I learned geometry more from talking to my friends than from listening to my mathematics teacher) was discarded as its communality (0.386) was under the cut-off point. The process was then re-run with no further changes.

The six component-solution accounted for a total of 67.020% of the variance. Because of the insufficient number of items that loaded into the fifth component (i.e., Item 25 *loaded: 0.768* and Item 6, *loaded: 0.745*) and the sixth component (i.e., Item 11 *loading 0.518*), they were removed and, thus, four components were retained (accounting for 55.063 % of the variance). Subsequently, Items: 25 (I sometimes feel nervous talking out loud in front of my classmates in geometry class); 6 (I get anxious in geometry class); and 11(I enjoy being part of groups learning geometry outside school) were removed from the instrument.

Retained Components (Factors) and Associated Items

The internal consistency using the Cronbach's alpha was determined for each component. The first component explained 36.872 % of the total variance and had the maximum loadings of eight variables: 19, 15, 24, 22, 17, 3, 1, and 8. However, Item 3 (I am able to learn more about geometry when working on my own), as well as Item 8 (Technology/calculator can make geometry easier to understand) were eliminated. This was done to improve factor reliability and to enhance factor meaningfulness, the first component was named *Deep affect* (D) ($\alpha = 0.908$). The items in this factor reflect the positivity that was expressed towards the learning of geometry such as receiving good grades on a geometry test, liking geometry, and geometry being interesting. This factor, similarly, may be seen to reflect one's feeling of confidence in their ability to solve geometry problems, and thinking of geometry being important in life. Thus, "affect is a significant factor in the learning process" (Chamberlin, 2010, p. 175).

The second component, *Working privately* **(**Wp**)** ($\alpha = 0.676$) had five loadings (Items 4, 5, 14, 21 & 29) and accounted for 8.520 % of the variance. The removal of Item 21 (I enjoy working in groups better than alone in geometry class/lecture) improved the alpha coefficient (0.789), but factor interpretation was still difficult. Thus Item 29 (my geometry tutor encourages us in class) was also eliminated, gaining a moderate alpha coefficient ($\alpha = 0.676$)) which was believed appropriate enough, as it ensured factor meaningfulness consistent with the literature (Brookstein et al., 2011). The items in this component reflect working on geometry privately such as preferring to work alone instead of being in group to do geometry, not liking to speak in class or group discussion and disliking geometry lecture attendance.

The third component, *Working collaboratively* **(**Wc**)** ($\alpha = 0.536$)**,** was loaded with three items (13, 18, & 20), and explained 5.190% of the total variance. Wc measures the extent to which PSTs support each other in learning geometry, either in class or outside the classroom.

For instance, whether they enjoy geometry class, participate in geometry discussions, and participate in group activities involving geometry. Although the Cronbach alpha seemed a little low, the variables loaded highly, and the value of learners working co-operatively is upheld in studies that show it fosters learners' learning (Seidouvy & Schindler, 2020); leads to improved attainment (Oner, 2016); and promotes desirable attitudes (Edwards & Jones, 2003). It was, thus, adjudged appropriate for inclusion in the instrument.

Finally, the fourth component, *Technology or calculator use* (Tc) $(\alpha = 0.785)$, accounted for 4.481% of the variation. Two items, Item 2 (In secondary school, my mathematics teachers listened carefully to what I had to say) and Item 10 (I like my own space outside school the majority of the time) made factor meaningfulness difficult. Suggestions to improve factor meaningfulness by Pituch and Stevens (2016) were accepted; and thus these two items were removed. This component shows that PSTs feel good any time they must use technology/calculators to learn geometry, enjoy using computers and/or calculators to learn geometry, and that cell phones are important part of their learning engagement.

Table 1
Summary of the Factor Loadings and Communalities

		Component				
ID	Item	D	Wp	Wc	Tc	Com.
19	I receive good grades on geometry tests and quizzes	.853				.677
15	I like geometry.	.811				.829
24	Geometry interests me.	.761				.745
22	I like to go to the board or share my answers with peers in geometry class/lecture.	.751				.663
17	I feel confident in my abilities to solve geometry problems.	.732				.719
1	I think geometry is important in life.	.491				.793
5	I prefer working alone rather than in groups when doing geometry.		.751			.663
4	I do not like to speak in geometry class or group discussion.		.709			.643
14	I do not like attending geometry lectures.		.603			.761
18	In the past, I have not enjoyed geometry class.			.763		.640
20	I am not eager to participate in discussions that involve geometry.			.691		.740
13	I do not participate in many geometry group activities outside school.			.452		.523
28	When using technology/calculator for learning geometry, I feel like I am in my own private world.				-.836	.586
9	Cell phones are an important technology in my life.				-.703	.632
26	I enjoy using a calculator/computer when learning geometry.				-.434	.745

Summary

This paper reports on a preliminary component of a wider study to create and validate geometry specific instrument to measure PSTs' attitude towards geometry learning. The potential value of such an instrument arose from the literature review which identified two gaps:

a) The few existing geometry instruments mostly measure attitudes of secondary school students towards geometry and tended to assess limited dimensions of attitude such as motivation, liking, enjoyment, and usefulness of geometry.
b) The research literature in mathematics education (e.g., Brookstein et al., 2011; Fennema & Sherman, 1976; Utley, 2007) identified and supported the need for exploration of more attitude dimensions.

Given these gaps, the work of Brookstein et al. (2011) was therefore instrumental in devising the GDS scale, with most of their items adapted for this geometry version.

The large sample size of 153 PSTs who volunteered to participate in this study has provided effective support for the development of the scale. An exploratory factor analysis with PCA technique retained four factors that accounted for a total variance of 55.063% with the first explaining 36.872%. After testing of the value of each item, 15 items were subsequently removed from the initial scale, with the GDS ultimately retaining 15 items that indicated strong correlations and construct validity. These items were further composed of four sub-scales:

Deep affect—positivity expressed towards geometry learning ($\alpha = 0.908$)
Working privately (α = 0.676)
Collaborative working ($\alpha = 0.536$)
Technology or calculator use ($\alpha = 0.785$)

Based on the psychometric properties of this instrument, the GDS was adjudged to be an effective tool, which should prove useful in measuring PSTs' attitudes to geometry learning and help inform instructors in the design of the geometry programs for our PSTs. We thus recommend the GDS for other researchers interested in examining the attitudinal profile of PSTs in learning geometry, which in turn may contribute further to the value of the instrument.

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