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An exploration of Ghanaian students' valuing in mathematics: How does it evolve across school levels?

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Abstract

A total of 1,256 students selected through stratified random sampling from 18 primary and public secondary schools as a fair sample across urban and rural settings in the Cape Coast Metropolis of Ghana responded to the 'what I find important (in my mathematics learning)' questionnaire. Section A contained 64 Likert type questions, and section B contained 10 continua dimension questions in which respondents provided weighted responses on their valuing in relation to learning mathematics, using a slider scale. In this paper, section B was visually analyzed in MS Excel, using the radar chart function to explore the evolution of values in mathematics across school levels. Findings suggested that the students' values in mathematics evolve as they progress through school, shifting from learning content to learning environment to learning approaches.

Keywords: values, value evolution, mathematics, grade level, Ghana, visual analysis

INTRODUCTION

The study of values in mathematics education in Ghana has attracted increased attention since the nation took part in a large international study of valuing in mathematics education known as "the third wave" (Third Wave Lab, 2023). According to TIMSS (2011), project grade eight students from Ghana performed at the lowest level when compared to their peers from 45 participating nations and 14 benchmarking entities (Davis et al., 2019). Elsewhere, earlier research has found that students' mathematics values are more accurate than their expectancy of success in terms of anticipating students' levels of effort (Penk & Schipolowski, 2015). These researchers asserted that value and effort together explain over one quarter of the variance in mathematics scores. Accordingly, a deeper understanding of students' values in mathematics in Ghana is arguably to better understand mathematics teaching and learning in the country. Our aim is step towards understanding why students' performance was not as good as expected and providing suggestions that could help improve student learning outcomes. Initial Ghanaian data collection was conducted in 2016, using "what I find important (in mathematics learning) (WIFI)" paper-based questionnaire (Third Wave Lab, 2023).

Values in Mathematics Education

Drawing from the broader literature, values may be seen as a reflection of what we think is important to us, and are conceptually different to beliefs, which may be seen as a reflection of what we think is correct (Seah et al., 2017). More specifically, valuing is defined as "an individual's embracing of convictions in mathematics pedagogy, which are of importance and worth personally. It shapes the individual's willpower to embody the convictions in the choice of actions, contributing to the individual's thrive ability in ethical mathematics pedagogy. In the process, the conative variable also regulates the individual's activation of cognitive skills and affective dispositions in complementary ways" (Seah, 2019, p. 107).

Historically, mathematics has been seen as value free. A growing body of research in mathematics education has shown that this view of mathematics is not tenable. Indeed there are values in mathematics and its pedagogy (Bishop, 1988, 2008; Clarkson et al., 2019, Dede, 2006). Bishop (1988) identified three pairs of mathematical values that relate to the nature of mathematics: "*rationalism-objectism*, *control-progress*, and *mystery-openness*". Drawing on the work of Bishop (1988), Dede (2006) also identified five pairs of mathematics

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Contribution to the literature

- This paper is possibly the first English language studies into the evolution of student values across grade levels. The paper makes several important contributions to the field. The study was conducted in Ghana, where performance by global standards has been low and, thus, facilitates initial understanding of changes in students' valuing in their mathematics education as they move through school grade levels.
- The findings are of significance to other countries seeking to improve students' performance in mathematics.
- Further, the study advocates the use of radar charts in visual analysis as a widely accessible and valid method for the broader WIFI research member nations.

educational values namely, "*formalistic view-activist view*, *instrumental understanding/learning-relational understanding/learning*, *relevance-theoretical knowledge*, *accessibility-special* and *evaluating-reasoning*" (p. 87). The literature suggests that while no study has added to Bishop's (1988) pairs of values relating to the nature of mathematics, studies have added to the mathematics educational values (Clarkson et al., 2019). These values, and value-pairs, have framed many studies in the area including the present one.

Many studies have been carried out to investigate what students at the pre-tertiary level of education value in their mathematics learning (Davis et al., 2019; Hill et al., 2019; Seah et al., 2017). Others have compared what students from different countries value in their mathematics learning (Dede, 2015; Seah et al., 2017). Studies in students' valuing in mathematics have also explored the relationship between social and personal values and their influence on students' mathematical values. Nakawa (2019), for example, observed that social and personal values formed a vehicle through which mathematical values are formed.

Suherman and Vidakovich (2022) highlighted the need to extend research to non-Western societies and developed the attitudes towards mathematics in secondary education (ATMSE) instrument that examined student's self-perception of mathematics, enjoyment of mathematics, value of mathematics, and perceived mathematics achievement. Using confirmatory factor analysis with a sample of 502 Indonesian secondary students, it was reported that ATMSE is a viable instrument for assessing students' attitudes toward mathematics in Indonesia (Suherman & Vidakovich, 2022).

Other studies have also explored valuing among teachers (Aktas et al., 2019; Kalogeropoulos & Clarkson, 2019). Aktas et al. (2019), for example, explored values that influence teachers' classroom decisions in mathematics at elementary school level and found a relationship between teachers' value and teacher noticing (as in how teachers respond to situations in their classroom). Others have also explored value alignment between teachers and students (Kalogeropoulos & Clarkson, 2019). Kalogeropoulos and Clarkson (2019) explored value alignment strategies that teachers use to engage students in dynamic and flexible classroom interaction. The four value alignment strategies found were *scaffolding*, *balancing*, *intervention*, and *refuge*.

While many studies have explored valuing among students, teachers and value alignment among teachers and students, there is a paucity of research that has explored how students' valuing in mathematics may evolve throughout their years at school. Initial research suggests that what students' value in mathematics learning can and do change during schooling years (Zhang, 2019; Zhang et al., 2016). Zhang (2019) observed from a study involving mainland Chinese students that their valuing changes as they progress through years of schooling. The literature suggests that while certain values may be common across groups of students, others could be unique to certain groups of students (Dede, 2019; Hill et al., 2019). Dede (2019), for example, observed that while rationalism and relevance were valued by all the different groups of students in his study, fun was unique to certain groups and argued that the personal experience of students could influence their valuing in mathematics learning. Again, Hill et al. (2019) observed that values such as peer collaboration/group work and family/familial support were specific to their student- participants. They argued that classroom culture and pedagogy be developed to align with the mathematics educational values of minority students. These observations and argument support earlier observations on the effect of context on students' valuing in mathematics (Bishop, 2008; Dede, 2015). This current study was developed to contribute to international discourse on changes that occur in students valuing during their school years as they progress from one grade level to another, using the situation in Ghana. Furthermore, this study presents the first findings on the evolution of students' values in their mathematics education that emanates from the African continent.

Mathematics Education in Ghana–A Values-Based Perspective

The pre-tertiary mathematics curriculum in Ghana has been reformed and changed from its original objective-based curriculum regime to standards-based, with the aim of developing students who will be confident and capable of fully participating in Ghanaian society and as global citizens (Republic of Ghana Ministry of Education, 2019). At primary level, the mathematics curriculum is focused on developing core competencies in critical thinking and problem solving, creativity and innovation, communication and collaboration, cultural identity and global citizenship, personal development and leadership, and digital literacy. At the high school education level, the common core program (CCP) emphasizes a set of high, internationally-benchmarked career and tertiary education ready standards that will prepare students for post-secondary education, the workplace or both (Republic of Ghana Ministry of Education, 2019).

This reform in curriculum has also come with the introduction of other interventions to improve teaching and supervision in schools such as the continuous professional points system for teachers by the National Teaching Council of Ghana (NTC) to ensure that teachers continually engage in professional learning to update their knowledge to support the demands of the reform, and the review of school inspection handbook by the National School Inspectorate Authority (NaSIA) to ensure effective monitoring and evaluation of teaching and learning in schools. All these interventions aim to generally improve students learning outcomes in all subjects including mathematics. Although the new curriculum highlights the need for mathematics education to promote the development of values such as respect, diversity, equity, and truth and integrity (National Council for Curriculum and Assessment of Ministry of Education, 2019, p. viii), it is evident that these values are not specific to mathematics and its teaching (Bishop, 1988). Meanwhile valuing in mathematics education is positioned in the literature as being driver of mathematics teaching and learning (Seah & Anderson, 2015). The study of values in mathematics and mathematics education in Ghana began with the participation of the country in WIFI study in 2015. Section A of the WIFI questionnaire (Third Wave Lab, 2023) was previously analyzed, using the principal component analysis (PCA) function in SPSS, using the data sourced from 1,256 participants from primary, junior high school (JHS) and senior high school (SHS) levels in the Cape Coast Metropolis of Ghana (Davis et al., 2019; Seah et al., 2017).

Participants were recruited, using a stratified random sampling procedure to fairly represent achievement levels across rural and urban environments. PCA analysis yielded 15 components of the students' set of values that accounted for 52.73% of the total variance and were, thus, considered significant: *achievement, relevance, fluency, authority, ICT, versatility, learning environment, strategies, feedback, communication, fun, connections, engagement, applications,* and *accuracy*. Further analysis by grade level revealed that there were statistically significant differences between primary, JHS, and SHS students for seven components: *achievement, relevance, fluency, authority, ICT, versatility, and strategies* (Davis et al., 2019). Davis et al. (2019) reported that SHS valued *achievement, ICT,* and *strategies* more than JHS who in turn valued these components more than primary students. Davis et al. (2019) hypothesized that values within individual students may evolve as they progress through school levels, and possibly beyond.

In light of the separate inquiry technique adopted by each section of WIFI, recent educational research was reviewed to identify an appropriate analytical technique for the section B data. In research of blended teaching in mathematics education, Kaczynski et al. (2008) have argued the merit of radar charts. Radar charts are graphs with multiple scales that have been used to report self-assessed knowledge and competencies that provide a visual measurement. Further, such visual representations have utility in comparison across time and settings. Accordingly, as one of the first jurisdictions to conduct analysis on the WIFI section B data, we argue that radar charts are of great value to the broader WIFI study and are accessible to all participants, given that no special analytical software is required. For this study, visual analysis via radar charts was adopted to examine the section B data in an attempt to identify similarities and differences between the findings of section A. The research question "does student valuing evolve as they progress through school levels?" was addressed.

METHODOLOGY

Research Design

Since this study sought to explore valuing in mathematics amongst large number of students at the various grade levels at the pre-tertiary level in Ghana to arrive at specific logical conclusions, the positivist research paradigm was employed. A quantitative research design, involving descriptive survey was used to explore what students valued in their mathematics learning. This approach has been recommended in literature for studies that involve data collection from a large number of participants on a given phenomenon within a short time (Creswell, 2012).

Participants

Research participants were selected from Government-funded primary, JHS, and SHS levels in the Cape Coast Metropolis of Ghana. Stratified random sampling was used to obtain a fair representation of schools on the basis of achievement level, and of rural or urban environments. A data set of 1,256 students, drawn from 18 of 76 government-funded schools (with an enrolment of 42,257 students at time of sampling), was developed. 414 students were drawn from upper primary level (primary four, five, and six), 426 and 416 students were drawn from JHS and SHS, respectively.

The list of government-funded schools by location (urban and rural) and achievement level (i.e., above-average, average, and below average-achieving) was obtained from the Cape Coast Metropolitan Education Office. Location of schools and achievement levels formed strata from which schools were selected at each of the levels (i.e., primary, JHS, and SHS). In each of the selected school levels, the research project was shared with both teachers and students before the students were invited to participate in the survey. The research instruments were then administered to the students who consented to participate in the study. The administration of the instrument was done by the third author with the support of some trained research assistants in the schools and were retrieved in the same day.

Instrument

The WIFI questionnaire included 64 five-point Likert-type questions (absolutely important, important, neither important nor unimportant, unimportant, absolutely unimportant) in section A (for example, Q19: Explaining my solutions to the class). 10 slider-scale questions were included in section B (for example, Q69: Applying mathematics concepts to solve a problem ___ ___ ___ ___ ___. Using a rule/formula to find the answer). Four open-ended questions, using sentence starter prompts were included in section C (imagine that we are going to produce a magic pill. Anyone who takes this magic pill will become very good at mathematics. Q77: Most is the important ingredient?) with each section used a separate inquiry technique to develop an understanding of student valuing in their mathematics education. Section B of the validated WIFI questionnaire required the student to weight their response to a bipolar statement regarding a dimension of student valuing in mathematics. The questionnaire may be accessed online at: https://blogs.unimelb.edu.au/thirdwavelab/study-4-what-i-find-important-in-my-maths-learning-wifi/

Data Analysis

To answer the question "does student valuing evolve as they progress through school levels?", a visual analysis was conducted. The radar chart function in MS Excel was used to examine students' values weightings identified within the 10 questions of the section B data: For each question, the students value weighting was coded numerically from one to five, and the average of the students responses was calculated for primary, JHS, and SHS student groups. The statistical mode is useful for reporting the most frequently occurring response. This measure is particularly meaningful for the present study and was adopted as it provides a method to reduce smoothing effects and is therefore arguably a more representative metric.

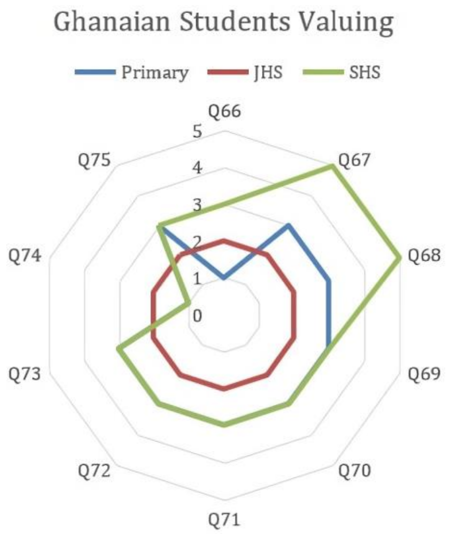

Figure 1. Ghanaian students valuing (Source: Authors' own elaboration)

Table 1. Ghanaian students' valuing changes

Question	Primary	JHS	SHS
Q66	Process	Process	-
Q67	-	Pleasure	Effort
Q68	-	Fixed mindset	Growth mindset
Q69	-	Application	-
Q70	-	Facts/truths	-
Q71	-	Exposition	-
Q72	-	Recalling	-
Q73	-	Rationalism	-
Q74	Openness	Openness	Openness
Q75	-	Control	-

RESULTS

The data was grouped by primary, JHS, and SHS school levels, and each of the ten questions was represented as an axis in the radar chart. The modal score of each question was plotted for each school level as an individual series line, as illustrated in **Figure 1**.

To explore how values evolve across grade levels, an analysis of value changes was carried out across primary, JHS, and SHS levels. This is summarized in **Table 1** in which value change was identified by looking at the different values horizontally across **Table 1** and looking for changes between any two neighboring columns. The results in **Table 1** show that while there was no value change among the JHS students, as could also be seen in **Figure 1**, *process* and *openness* constituted the two for primary school level and *effort*, *growth mindset*, and *openness* constituted value changes for the SHS level. Though processes formed the value change at both primary and SHS levels, at each of the levels, where value changes occurred different attributes were valued by students. *Growth mindset*, which is key for lifelong learning in mathematics, for example, formed one of the value changes in SHS only. The results show in broad terms that value changes in students' mathematics learning may evolve from attributes such as process at primary level to *growth mindset* at SHS level.

DISCUSSION

For the majority of the 10 questions in section B, primary students indicated a mid-point weighting in values between the two polar statements, with notable exceptions in Q66, and Q74. In Q66 the modal score of 1 suggests that students prioritized 'how the answer to a problem is obtained' over 'what the answer to a problem is'. This suggests that the primary students valued process very much. In Q74 the modal score of one suggests that students prioritized 'demonstrating and explaining mathematics concepts to others (e.g., proofs)' over 'keeping mathematics *magical/mystical*'. In this instance, the students' valuing of openness is being emphasized. Taken together, it is apparent that primary students place utmost priority on developing a solid understanding of the concepts required to answer a problem.

JHS students reported a modal score of two for each of the 10 questions. In Q66, the modal score of two suggests that students prioritized 'how the answer to a problem is obtained' over 'what the answer to a problem is'. In this instance, the value of process is important to the students. In Q 67 the modal score of two suggests that 'feeling *relaxed* or having *fun* when doing mathematics' was prioritized over 'needing *hard work* when doing mathematics'. Hence, the value of pleasure is important to the students. In Q68 the modal score of two suggests that 'leaving it to *ability* when doing mathematics' is more important than 'putting in *effort* when doing mathematics'. In this instance the value of *fixed mindset* is important to the students. In Q69 the modal score of two suggests that 'applying mathematics *concepts* to solve a problem' is more important than 'using a *rule/formula* to find the answer'. Hence, the value of application is important to the students. In Q70 the modal score of five suggests that '*mathematical ideas* and *practices* we normally use in life' were prioritized over 'the discovery of *truths* and *facts*'. In Q71 the modal score of one suggests that students prioritized 'someone *teaching* and *explaining* mathematics to them' over '*exploring* mathematics themselves or with peers/ friends/parents'. In Q 72 the modal score of two suggests that '*remembering* mathematics ideas, concepts, or rules' is more important than '*creating* mathematics ideas, concepts, rules, or formulae'. Accordingly, the value of recalling is important to the students. In Q73 the modal score of one suggests that students prioritized 'letting me see concrete examples of triangles first, so that I understand the properties of triangles' over '*telling* me what a triangle is'. In Q74 the modal score of one suggests that students prioritized '*demonstrating* and *explaining* mathematics concepts to others (e.g., proofs)' over 'keeping mathematics *magical/mystical*'. In Q75 the modal score of five suggests that 'using mathematics for *development/progress*' was prioritized over 'using mathematics to *predict/explain* events'; that is, reflecting the valuing of control.

For the majority of 10 questions in section B, SHS students indicated a mid-point weighting in values between the two polar statements. Students reported extreme points on Q67, Q68, and Q74. In Q67 the modal score of five suggests that 'students prioritized *hard work*' over 'feeling *relaxed* or having *fun* when doing mathematics'. In Q68 the modal score of five suggested that students prioritized 'putting in *effort* when doing mathematics' over 'leaving it to *ability*'. Finally, in Q74 the modal score of one suggests that students prioritized '*demonstrating* and *explaining* mathematics concepts to others (e.g., proofs)' over 'keeping mathematics *magical/mystical*'.

In Q66, primary and JHS students valued *process*, yet their senior counterparts in SHS reported a mid-point weighting in this domain. Notable differences were evident in Q67 in which primary students reported a mid-point score and subsequent neutral valuing. At JHS level, students reported to value *pleasure* and, in contrast at the SHS level, the students reportedly valued *effort*. Notable differences were also evident in Q68 in which primary students reported a mid-point score and subsequent neutral valuing. At JHS level, students reportedly valued a *fixed mindset*, and in contrast at the SHS level the students reportedly valued a *growth mindset*. A uniform response was reported in Q74 in which primary, JHS, and SHS students all reportedly valued *openness*. These findings are also in line with those of Davis et al. (2019), who also observed the evolution of values at the various school levels, using section A items of the same questionnaire.

Limitations

This data was collected from 1,256 students from 18 state schools located in the Cape Coast Metropolis of Ghana, using stratified random sampling. While this was an attempt to work with a set of representative data, the findings may still not reflect the national picture.

CONCLUSIONS

This study has shown differences/changes in valuing as students move from primary to JHS and on to SHS. Primary students valued *process* and *openness*, implying they valued both procedural and conceptual knowledge (Groth, 2013). However, they remained indifferent on valuing of the classroom atmosphere or what it takes to learn mathematics. At JHS level, students' valuing began to include prioritization of 'feeling *relaxed* or having *fun* when doing mathematics' over 'needing *hard work* when doing mathematics'. Thus, at JHS level students' valuing evolved to include the valuing of the learning environment. However, at SHS level valuing learning environment gave way to valuing of *hard work*. Again, while primary students appeared to be indifferent as to whether ability or effort is needed to learn mathematics, students in JHS value a *fixed mindset* and their SHS counterparts conversely value a *growth mindset*. There thus appears to be a shift in valuing across the primary and high school years from learning content to learning environment to learning approaches.

Ghanaian students encounter their major high-stake examinations that determines the type of tertiary institution they would continue their education at (i.e., normal university, technical university, polytechnic, colleges of education, nursing colleges, and others). A pass in mathematics at this level is a major determinant of the opportunity for students to access their dream institution and program. The pressure on students to cover the examination syllabus at SHS level just to ensure that they obtain the grade they need in mathematics to progress could explain the shift in valuing at this level. The other factor that could explain the shift in value could be the spiral nature of the Ghanaian mathematics curriculum, where topics are revisited at deeper levels as one moves up the grade levels (Bruner, 1960). Students at higher levels at the pre-tertiary level, that is, SHS level are more likely to value effort, for example, because they need more effort to comprehend a deeper mathematical concepts they encounter at that level. This sets the scene for future research, which might be directed at investigating the relationship between valuing and learning outcomes to help understand why students may perform poorly in mathematics but value important attributes such as understanding in their mathematics learning.

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Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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