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# The Attributes of Mathematics Learning Which Ghanaian Senior High School Students Value

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**Abstract**

Valuing constitutes an important aspect of mathematics pedagogy and hence student learning outcomes. This study surveyed 416 students from Cape Coast, Ghana to explore what senior high school students in this country in West Africa valued in their study of mathematics. The data collected were analyzed using principal component analysis. The results suggest that Ghanaian senior high school students found *connections, understanding, fluency, learning technologies, feedback, instructional materials, open-endedness* and *problem-solving* important in their mathematics learning. Implications of the findings for curriculum delivery in mathematics and future research opportunities are also discussed.

**Keywords**: connections, explicit values, implicit values, pedagogical values, understanding

## Introduction

The need for pedagogical reform in Ghanaian mathematics education is well-established (Frimpong, 2017; Mullis et al., 2012). Although there have been several attempts to address the difficulties students have with mathematics learning, such as the commissioning of a secondary education improvement project in 2014 (World Bank, 2018), little improvement in students' performance in mathematics has been achieved (Frimpong, 2017; Ghana News Agency, 2015; Ghana Star News, 2016).

Rather similar phenomena have been observed elsewhere in the world, in which decades of mathematics education research interventions and initiatives have failed to bring about significant improvements to students' learning of mathematics. Perhaps, as Seah (2019) proposed, we have not paid enough attention to the role of conation in facilitating learning and teaching, and in particular, to the variable of values. That is, students' learning outcomes are not only linked to cognitive and affective processes, but also to how these processes have been considered important–and thus, valued–by students and other stakeholders. In this context, valuing refers to:

> 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 thriveability 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)

## Literature Review

What students deem important, or what they value, in their mathematics education affects their choice of mental strategies, reasoning, and decisions while learning (Seah et al., 2017a). A student's valuing in mathematics education is socio-culturally driven, and therefore, context specific (Bishop, 2008). Students from different schools may value things differently, as the socio-cultural context of a school influences what the students and their teachers consider important in facilitating the development of mathematical thinking (Bishop, 2008).

Bishop (1996) conceptualized three categories of values in mathematics pedagogy, namely, mathematical, general educational, and mathematics educational. Bishop (2008) posits mathematical values as those "which have been developed as the knowledge of mathematics has developed within 'Westernised' cultures" (p. 83) and holds the view that there are three pairs of mathematical values: *rationalism-objectism*, *control-progress* and *mystery-openness* (Bishop, 1988). These pairs of complementary mathematical values correspond to White's (1959) three components of culture, that is, ideological, sociological, and sentimental respectively (Bishop, 1988). Rationalism and objectism reflect the ideologies of mathematics which drive the development of mathematical knowledge. On the other hand, the values which correspond to the sentimental component of culture, control and progress, reflect the attitudinal dimension of the development of mathematical knowledge. The values of mystery and openness relate to societal perceptions such as the ownership of mathematical knowledge and the relationship between the originators of mathematical knowledge and others within the society that drive the development of mathematical knowledge (Bishop, 1988).

According to Bishop (1988, 2008), the valuing of *rationalism* reflects placing importance to mathematical argument, reasoning, logical analysis and explanation; while objectism refers to objectifying, concretizing, and symbolizing mathematical ideas. If one values control, then one would want to master rules, facts, procedure, and established criteria; whereas if one values progress, then one is valuing alternative methods, development of new ideas and questioning of existing ones. For the third pair of mathematical values, openness is about emphasizing proofs and individual explanations, while the valuing of mystery signifies the importance of wonder, fascination and the mystique associated with mathematical ideas (Bishop, 2008). In Bishop's (1988) mind, these pairs of values are complementary, an indication that mathematics education has to promote the development of each of these pairs of values through effective pedagogy. For instance, the development of control in a child without development of progress might create a situation where the child's world view of mathematics would be restricted to the study of rules and formulae. As such the child would find the study of rules and formulae very important to their learning of mathematics, but not to the exploration of alternative approaches to solving problems.

Bishop (2008) posits that general educational values constitute "values associated with the norms of the particular society, and of the particular educational institution" (p. 83). These may include norms such as punctuality, forthrightness, neatness, and respect for alternative views. These values are not specific to mathematics education, but have the tendency nevertheless to influence what students find important as they engage with mathematical concepts and skills (Bishop, 1988).

Mathematics educational values are those which are embedded in curricula, textbooks as well as teachers' professional practices (Bishop, 2008). These are attributes of mathematics learning or teaching which students or teachers would emphasize, and which they think are important to success in mathematics education. Examples would include *practice, discussions, Information and Communication Technology (ICT), effort,* and *ability*.

Values in the mathematics classroom have been classified differently by other scholars. For example, Dede (2011) identified two types of values–explicit and implicit–which exist in the planned curriculum. Mathematical values such as rationalism, progress, and mystery would be considered as explicit values in the mathematics curriculum, while values such as *flexibility, open mindedness, efficiency, systematic procedures, effective organization, creativity, enjoyment* and *persistence* are implicit in the mathematics curriculum. This classification of explicit valuing largely reflects Bishop's classification of values inherent in Western mathematics, while the classification of implicit values in the planned curriculum reflects Bishop's (1996) classification of mathematics educational and general educational values. For example, organization, flexibility, and persistence in Dede's (2011) implicit values are not specific to mathematics and could therefore be classified under general educational values in Bishop's (1996) classification. The valuing of mathematical values could therefore be viewed as explicit valuing, whereas valuing of mathematical educational and general education values could be viewed as implicit valuing based on Dede's (2015) classification.

### *Prior Studies on Values and Valuing*

Prior studies have explored what students and teachers value in primary and secondary mathematics pedagogy (Dede, 2015; Seah et al., 2017a; Seah et al., 2017b). Seah et al., (2017b) reported a survey of 3,818 primary and secondary school students in Japan which revealed the valuing of a range of nine attributes in mathematics learning, which were *creativity, discussion, ICT, know-how, mystery, others' involvement, reality, results and wonder.* A similar study involving Hong Kong primary and secondary students showed that they valued alternative approaches, applications, effort, exposition, explorations, feedback, ICT, (mathematics) identity, and recall. In Mainland China, Zhang (2019) investigated valuing in mathematics among primary and secondary school students, and found that students generally valued student-centered approaches that were teacher-led.

While understanding what primary and secondary school students value in mathematics and in their mathematics education is important, it does not determine the extent to which these values predict mathematics performance, perhaps leading to tertiary studies of mathematics. Furthermore, in each of the studies reported, data from both primary and secondary school students were combined in the analysis. However, further analysis of the data from the countries studied have shown that significant differences exist in what primary and secondary school students value in their mathematics learning (Davis et al., 2019; Seah et al., 2017a). For example, Seah et al.'s (2017a) study revealed that the nine attributes which Japanese students valued were different in statistically significant ways depending on whether they were primary or secondary school students. Similarly, Davis et al. (2019) found statistically significant differences amongst students in Ghanaian primary, junior high, and senior high schools for seven of the attributes valued most in their mathematics learning: achievement, relevance, fluency, authority, ICT, versatility, and strategies. Zhang (2019) also found both grade level and gender differences in valuing among Mainland Chinese students. The study reported that primary school students valued *ability, effort, diligence, use of formulas* and *memory* more, while secondary school students placed greater value on *knowledge* and *thinking*. Seah and his colleagues (2017b) proposed that the value designations of students may differ depending on the wealth of the nation that they originate from as well as their country's performance in international comparative assessments. Most specifically, Seah and his colleagues (2017b) contended that Ghanaian students' valuing with regards to mathematics learning might be more extrinsic in nature. In other words, the attributes of mathematics and of the learning of mathematics that were embraced by students in Ghana appeared to relate more with what could be done with the mathematical knowledge rather than with the nature of mathematics itself. This is reflected, for example, in the valuing of *relevance* and *applications* of the discipline, and how mathematics performance is accompanied by a sense of *achievement*.

Based on the findings of previous studies such as those outlined above, there is a need to investigate how valuing at the various grade levels in Ghana reflect the global picture presented by Seah and his colleagues (2017b). This current study should contribute to the existing literature by further expanding upon what we collectively know about values and valuing; specifically focusing on what senior high school students value in the learning of mathematics. This study will further explore how valuing among senior high school students compares to valuing by Ghanaian students across the various grade levels (grades 1-12). Senior high school students' valuing formed the focus of this study because students at this grade level in Ghana constitute the group of junior high school students who were able to pass the national entrance examinations in all subjects, including mathematics. The main research question that guided this study is: *What do public senior high school students in Ghana find important when learning mathematics?*

## Methods

This study sought to elicit the views of a large number of research participants; therefore, a survey questionnaire method was utilized to collect the data (Creswell, 2012). In this context, the previously validated *What I Find Important (in my mathematics learning)* (WIFI) questionnaire was adopted for this study. The questionnaire was originally developed in English and has subsequently been translated to other languages such as Chinese, Japanese and Turkish. Given that the senior high school curriculum in Ghana is delivered in English, the original, English version of the questionnaire was administered in this study. The questionnaire is comprised of four sections. Section A is made up of 64 five-point Likert-type items, each of which allows respondents to indicate how important mathematics pedagogical activities such as small-group discussions (item 3) and homework (item 57) are to them. The five-point scoring system ranges from 1 point (for absolutely important) to 5 points (for absolutely unimportant). Section B is made up of 10 continua dimensions, each related to a pair of bipolar statements. Respondents indicate along the continuum how much their valuing is aligned to these statements. Section C is made up of four contextualized items which seek to stimulate values-based responses. The items in Section D survey the respondents' biographic data.

As this study is interested in what students value in their study of mathematics, only the 64 Likert-type items (i.e. Section A) of the WIFI questionnaire were used to obtain the data for this research. Shortening an established questionnaire by sampling items without sacrificing the overall scope of data collection that is intended in the questionnaire is a common and practical methodological approach. This strategy is commonly used in values research, where "measures are all lengthy and require relatively long time to complete" (Roccas et al., 2017, p. 27).

As part of the validation process for this questionnaire, a pilot test was conducted. The survey was administered in a district which shared similar characteristics to Cape Coast. This was done by administering the questionnaire to students, after which they were interviewed to ascertain whether their interpretation of the items reflected what information the items sought to elicit. Through this process, a few of the items that were not clear to the students were slightly modified to make them clearer. The modified WIFI questionnaire was then reviewed by several fellow researchers in mathematics education to ensure that the questions would elicit a valid response. This development of the modified questionnaire thus reflects a form of the Delphi technique (see Isaac & Michael, 1997).

The student participants for this study were drawn from public senior high schools in Ghana's Cape Coast Metropolis, Cape Coast being the capital of the Central Region of Ghana with numerous educational institutions, including many of the country's most regarded senior high schools. Ghana's premier teacher education university is also located in this Metropolis. The list of senior high schools was obtained from the Metropolitan Education Office. Pre-tertiary schools in Ghana are usually categorized based on their achievement in the national examinations as above-average, average, and below-average achieving schools, and the list obtained reflected this distinction. Treating each of the achievement levels and school context (urban/rural) as strata, stratified random sampling (Ackoff, 1953) was employed to select 6 out of every 10 senior high schools in the Municipality. This approach to sampling allowed us to randomly select schools from within each subgroup (stratum) of the population, such that each stratum is adequately represented. In each of the schools, the $10^{th}$, $11^{th}$, and $12^{th}$ grade levels also formed strata from which participants were selected. To solicit participation, a short presentation was made to the students about the research project, after which students were offered the opportunity to participate in the study. In all, 416 senior high school students took part in the study; comprising of 92 students from $10^{th}$ grade, 160 students from $11^{th}$ grade, and 164 students from $12^{th}$ grade. In addressing the research question, a principal component analysis, which is "the default method of factor extraction used by SPSS" (George & Mallery, 2003, p. 256), was executed using the SPSS software to analyze the data. Through this analysis process, the value labels corresponding to the attributes valued by students in their mathematics education were derived.

## Results

The data gathered from the modified WIFI questionnaire were screened prior to analysis. The Kaiser-Meyer-Olkin measure (Kaiser, 1970) of sampling adequacy was .884 and Bartlett's (1950) test of sphericity was significant at the .000 level. As such, factorability of the correlation matrix was assumed. This means that the identity matrix of the questionnaire was reliable and confirmed the usefulness of the principal component analysis

### *Principal Component Analysis*

A principal component analysis with a varimax rotation and Kaiser normalization were used to analyze the responses from the items in the questionnaire. This process is used to show how the questionnaire items loaded onto different components. The significance level was set at .05 and a cut-off criterion of .30 was used for component loadings. This cut-off value (i.e. .30) is appropriate for the type of analysis conducted in this study (see Field, 2013; Samuels, 2016).

We settled on eight components of the students' set of values for mathematics learning: *connections, understanding, fluency, learning technologies, problem-solving, feedback, instructional aid, and open-endedness*. This decision was based on a number of considerations. The literature suggests the retention of all factors with eigenvalues greater than 1 (Samuels, 2016). Based on this rule, 17 components had eigenvalues greater than 1, which accounted for approximately 61% of the total variance, and were retained. The scree plot suggested an elbow at the 3$^{rd}$ or 4$^{th}$ component. However, the result of the parallel analysis suggested that retaining six factors would be sufficient. The confirmatory factor analysis test, which tests the hypothesis that *n* factors are sufficient, was carried out. Data from this analysis can be found in Appendix A. Although the parallel analysis suggested that six factors be retained, this number of factors was not sufficient from the confirmatory test. According to Streiner (1994), at least 50% of the total variance should be explained by the retained factors. Retaining 17 factors which explained 61% of the variation meets this requirement, however, this number was also too large and affected interpretability. We therefore identified eight components which explained about 44.5% of variation. This data table can be found in Appendix B.

Although a quantitative approach was used to arrive at the components using SPSS software, the naming of the components was achieved using a qualitative approach. Each component was named based on the authors' negotiated interpretation of the value represented by most of the items that loaded on that component projected. In other words, all the items grouped under each of the eight components by the SPSS software were considered by the authors and labelled according to what most of them collectively represented.

Take Component 1 (C1) for example. It was given the value label *connections*. Yet, item 62 *Completing mathematics work* which loaded onto this component seems not to be reflective of connections. However, the majority of the items that loaded on C1 such as *Looking out for mathematics in real life* (item 39), *Stories about mathematics* (item 17) and *Outdoor mathematics activities* (item 34) showed connections between mathematics and students' daily realities. These represent connections between mathematics and those who originate mathematical ideas, and work with the ideas and connections between mathematics and recreational activities. Connections is also evident through *Relationships between mathematics concepts* (item 26) and *Looking out for* *mathematics in real life* (item 39). As such, this first component C1 which consisted of 19 items and which accounted for 20.44% of the total variance was given the label connections.

The second component (C2) was comprised of 11 items which together accounted for 7.03% of the total variance. These items include *Examples to help me understand* (item 49), *Understanding why my solution is incorrect or correct* (item 63), *Understanding concepts/processes* (item 54), and *Learning through mistakes* (item 51). Accordingly, C2 was labeled *understanding*.

The third component (C3) comprised 12 items which together explained 4.11% of the total variance. These include *Doing a lot of mathematics work* (item 37), *Practicing with lots of questions* (item 36), *Practicing how to use mathematics formula* (item 13), *Memorizing fact* (item 14) and *Alternative solutions* (item 30). C3 was labeled *fluency*.

The fourth component (C4) comprised six items which explained 2.96% of the total variance. Some of the items were *Using the calculator to check the answer* (item 22), *Learning mathematics with internet* (item 24), *Learning maths with computer* (item 23) and *Mathematics games* (item 25). C4 was named as *learning technologies*.

The four items in the fifth component (C5) together accounted for 2.66% of the total variance. Some of the items were *Problem-solving* (item 2) and *Investigation* (item 1). C5 was named as *problem-solving*.

The sixth component (C6) has three items, which explained 2.61% of the total variance. The items were *Feedback from my teacher* (item 44) and *Feedback from my friends* (item 45). C6 was named as *feedback*.

The seventh component (C7) with its two items explained 2.39% of the total variance, the items being *Using diagrams to understand mathematics* (item 47) and *Using concrete materials to understand mathematics* (item 48). C7 was named *instructional aid*.

The eighth component (C8) comprised four items which explained 2.24% of the total variance. The items were *Being lucky at getting the correct answer* (item 27) and *Looking for different possible answers* (item 16). C8 was named as *open-mindedness*

### *Comparison With Previous Studies*

Using data from other related studies conducted in Hong Kong and Japan, we focused our comparison on the top five components and their selected associated items from this study. These two countries were chosen for comparison because they are among the top performing countries in the *Trends in International Mathematics and Science Study* (Mullis et al., 2012). In this study, eight attributes were identified: connections, understanding, fluency, learning technologies, feedback, instructional aid, open-endedness, and problem-solving. The literature suggests that Hong Kong students who were administered a similar survey were found to value nine attributes in their mathematics namely, *alternative approaches, applications, effort, exposition, explorations, feedback, ICT, (mathematics) identity,* and *recall.* On the other hand, the Japanese students also valued nine attributes, which are *creativity*, *discussion, ICT, know-how, mystery, others' involvement, reality, results* and *wonder*. (Seah et al., 2017a).

Table 1 presents a summary of comparison of the top five attributes and the selected examples of associated items valued by Ghanaian Senior High School Students and Hong Kong and Japanese students. Results from Table 1 show that although the attributes valued by students are labelled differently by the researchers from the three countries, the associated items are generally similar. For example, items loaded on component label 1 from the Ghanaian results (*connections*) are like items that loaded on component label 1 from the Japanese results (*wonder*) and two from the Hong Kong results (*alternative approaches*). The subjective nature, informed by insiders' cultural knowledge, of the component names might have accounted for the difference in component labels across the three contexts. Another possible explanation is the differences of the local languages used in Ghana, Hong Kong, and Japan.

**Table 1**. Comparison of the Top Five Attributes and Selected Examples of Associated Items Valued by Ghanaian Senior High School Students, Hong Kong and Japanese Students

| Components | Ghana (Senior High School Students only) | Hong Kong | Japan |
|---|---|---|---|
| 1 | **Connections**:<br>• Stories about mathematicians<br>• Stories about recent development in mathematics<br>• Stories about mathematics | **Exploration**:<br>• Knowing the steps of the solution<br>• Understanding concepts process<br>• Understanding why my solution is incorrect or correct | **Wonder**:<br>• Stories about mathematicians<br>• Stories about mathematics<br>• Stories about recent developments in mathematics |
| 2 | **Understanding**:<br>• Examples to help me understand<br>• Understanding why my solution is incorrect or correct<br>• Knowing which formula to use | **Alternative Approaches:**<br>• Stories about mathematics<br>• Stories about mathematicians<br>• Outdoor mathematics | **Creativity**<br>• Alternative solutions<br>• Looking for different ways to find the answer<br>• Looking for different possible answers |
| 3 | **Fluency**:<br>• Doing a lot of mathematics work<br>• Practicing with lots of questions<br>• Practicing how to use mathematics formula<br>• Memorizing facts | **Effort**:<br>• Doing a lot of mathematics work<br>• Practicing with a lot of questions<br>• Completing mathematics work | **Results:**<br>• Memorizing facts (e.g., Area of a rectangle ¼ length X breadth)<br>• Practicing how to use math formulae<br>• Problem-solving |
| 4 | **Learning Technologies**:<br>• Learning Technologies:<br>• Learning mathematics with the computer<br>• Learning mathematics with the internet<br>• Using calculator to calculate | **(Mathematics) Identity:**<br>• Alternative solutions<br>• Students posing maths problems<br>• Verifying theorems hypotheses | **Others' Involvement:**<br>• Feedback from my teacher<br>• Teacher helping me individually<br>• Feedback from my friends<br>• Me asking questions |
| 5 | **Problem-Solving**:<br>• Problem-solving<br>• Investigation<br>• Learning the proofs | **Recall**:<br>• Knowing the times tables<br>• Memorizing facts<br>• Given a formula to use | **Know-how:**<br>• Shortcuts to solving a problem<br>• Knowing the steps of the solution<br>• Remembering the work we have done<br>• Understanding concepts/ processes |

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## Discussion

In this study, 416 senior high school students studying in Cape Coast, Ghana were surveyed with the WIFI questionnaire to find out what they valued in their mathematics learning experiences. The principal component analysis identified eight attributes which these students valued most in their mathematics learning, explaining 44.5% of the total variance. These attributes, in order of proportion of variance explained from the largest to the smallest, are: connections, understanding, fluency, learning technologies, problem-solving, feedback, instructional aid, and open-endedness.

Among these eight attributes, perhaps the one which emerged unexpectedly was the Ghanaian students' valuing of instructional aid at the senior high school level. One would expect that teenagers in the last three years of secondary schooling would view mathematics as an abstract discipline and would not desire manipulatives and other learning aids. Perhaps these students have realized that instructional aid such as manipulatives do not lose their effectiveness even when they are at the highest secondary grade levels exploring advanced topics.

Our results suggest that what Ghanaian students in senior high schools value in their mathematics learning experiences differ from what their peers in general, irrespective of school year levels, valued in their mathematics learning (Seah et al., 2017a). What the senior high school students in this study valued is likely associated with facilitating entrance into tertiary institutions. For example, these students' valuing of connections and understanding could be because embracing these attributes improves their capacity to negotiate with contextualized mathematics problems that are encountered at the senior high school levels. The comparatively simple, computational type of mathematics questions which students commonly encounter at primary school or junior high school levels would not require students to value these attributes.

The mathematics pedagogical activities represented by the individual questionnaire items that Ghanaian students found important in their learning were similar to what students from high-performing countries in East Asia valued in their mathematics education. For example, one of the attributes Hong Kong students valued most was exploration which includes *Understanding why my solution is incorrect or correct* (item 63), *Learning through mistakes* (item 51), *Knowing the steps of the solution* (item 56) (Seah et al., 2017a). Although the component under which these items loaded was not labeled exploration but understanding in our study (Appendix B), it is evident that the Ghanaian senior high school students also regarded *Understanding why my solution is incorrect or correct* (item 63), and *Knowing the steps of the solution* (item 56) very highly in their mathematics learning experiences.

However, the ways which these items loaded onto the components differently in the datasets for the different countries suggests that what Ghanaian students value in mathematics learning is different to their peers in East Asian countries. As shown in Table 1, it appears that while Ghanaian students' valuing was intrinsic to mathematics and mathematics pedagogy, Hong Kong students' valuing was more pragmatic and practical. On the other hand, what students in Japan valued, creativity and wonder, seemed to reflect an education culture that emphasizes the cultivation of a sense of innovation and creativity amongst students.

The results from this study also suggest that researchers should not draw conclusions about the effectiveness of mathematics education systems simply by looking at individual pedagogical features or initiatives. As is evident in Table 1, although the students in Ghana and Hong Kong embraced stories about mathematics, and about mathematicians, it does not imply that they share the same overall value system. Afterall, each pedagogical feature is only one of several that make up the valuing in each education system. At the same time, we cannot deduce from any pedagogical feature what is/are being valued more generally. Perhaps, therefore, it is not advisable to look at successful education systems to adopt some of their pedagogical features or initiatives. Instead, there may be greater value in examining all pedagogical features and initiatives, thereby allowing us to distil and identify the underlying valuing of the students. To put this bluntly, we are suggesting that lesson observations of what students and teachers do in class may not be that useful in helping us understand why mathematics pedagogy is successful (or not) in this class or in the society within which this class is located. Rather, we need to ask ourselves what culturally-based values are being reflected by these observations, and how these values might explain the quality of mathematics education.

Thus, at the level of individual learning activities valued by the student participants, we can still see how each of these might relate to Bishop's (1988) six mathematical values. For instance, *Explaining where the rules/formulae came from* (item 40), *Mathematics debate* (item 9), and *Verifying theorems/hypothesis* (item 31) relate to rationalism, while *Connecting mathematics to real life* (item 12) relates to objectism. At the same time, the activities which make up the students' valuing of fluency relate to the mathematical value of control. For example, *Doing a lot of mathematics work* (item 37) and *Practicing with lots of questions* (item 36). The valuing of *Alternative solutions* (item 30) relates to progress. Considering the third pair of mathematical values, openness is evidently valued as part of the students' valuing of feedback, such as *Feedback from teacher* (item 44), *Feedback from students* (item 45) and *Small-group discussion* (item 7). On the other hand, the senior high school students' valuing of open-endedness largely reflects mystery. Valuing *Being lucky at getting the correct answer* (item 27), *Shortcuts to solving problems* (item 16) and *Looking for different possible answers* (item 55) projects the mystic surrounding mathematics and those who handle the subject.

The Ghanaian senior high school students' valuing, unlike those identified for students across the school years (Seah et al., 2017b), appeared to be intrinsic to mathematics. That is, inherent to mathematics as a discipline. These included the valuing of connections, understanding, feedback, and instructional aid. The differences in valuing might be attributed to the differences in socio-cultural contexts between primary and secondary schooling (Davis, Carr & Ampadu, 2019). Generally, public senior high schools possess more resources compared to the primary and junior high schools. They are afforded better classrooms and library facilities, official vehicles for heads/principals, vehicles (buses, trucks) for the operations of the school, and specialists with deeper content knowledge, among others. On the other hand, primary and junior high schools operate with very limited resources. Many of these schools do not have a library, for example. Some do not even have electricity. We argue that senior high school students can develop more intrinsic values in mathematics due to the socio-cultural context of their education system.

Many of the student values that were embraced at the senior high school levels corresponded to the 21st century skills that are generally agreed globally to be important. Learning technologies notwithstanding, the students' valuing of understanding, fluency as well as problem-solving reflected three of four mathematics proficiencies specified in the Australian Curriculum: Mathematics (Victorian Curriculum and Assessment Authority, 2017). Even though Ghana and

Australia are different in many ways, Ghana senior high school students valued all but one of the Australian mathematics proficiencies. Since the relatively new curriculum "aims to be relevant and applicable to the 21st century …. [and the] proficiencies enable students to respond to familiar and unfamiliar situations by employing mathematical strategies to make informed decisions and solve problems efficiently" (Australian Curriculum Assessment and Reporting Authority, n.d., para 1), it would appear that the senior high school students in Ghanaian schools have been developing important values that will position them well for their respective future careers.

## Conclusions and Implications

Senior high school students in Cape Coast public schools value connections, understanding, fluency, learning technologies, feedback, instructional aid, open-endedness and problem-solving in their mathematics learning experiences. These attributes differ from the valuing reported by Ghanaian students as a group across the whole spectrum of school levels (see Seah et al., 2017b). In particular, what were valued by the senior high school students were made up of many intrinsic values such as understanding and connections. Many of these are also commonly related to 21st Century skills.

Although the Ghanaian students valued similar mathematics pedagogical activities with their peers from East Asian high-performing education systems like Hong Kong and Japan, these activities were grouped differently. As such, they reflected different underlying values. In general, the Ghanaian students valued attributes that were more intrinsic to mathematics. Whereas in comparison, the Hong Kong and Japanese students values appeared to be more practical (*relevance*) and creative (diversified mathematical thinking) respectively.

### *Theoretical Implications*

The different learning activities which students in Ghana valued in mathematics learning could be categorized into eight groups, each of which represents a value. Comparing this set of data with similar data collected in other countries, it is evident that each name identifying an individual value was guided both by what the learning activities (which are the questionnaire items) represented as a group, as well as how these were interpreted locally. In other words, two mathematics education systems may emphasize several mathematics pedagogical activities similarly, but they will represent different meanings to the different cultures, resulting in different value labels. This finding supports Bishop's (2008) assertion that values in mathematics education is socio-culturally driven. It also provides insights into how value labelling is influenced by the socio-cultural background of the research.

### *Practical Implications*

The theoretical implications arising from this study leads to an important practical implication; it is not useful to learn from *successful* mathematics education systems by adopting individual pedagogical features or initiatives. Instead, much can be gained by first developing a full picture of the different pedagogical features or initiatives within an education system, followed by the identification of the underlying values.

This study has also shown that unlike Hong Kong and Japanese students', valuing which were practical and innovative in nature respectively, Ghanaian students' valuing tended to be more intrinsic of mathematics and of mathematics learning. Given that Hong Kong students' valuing in mathematics education has been found to be more pragmatic and practical, it may be worthwhile for mathematics lessons in Ghana to be designed such that students also appreciate attributes which reflect these more extrinsic qualities. This might well enable Ghanaian students to perform better in mathematics assessments.

In any case, having now identified the eight attributes which Ghanaian senior high school students value while learning mathematics, educators should have more confidence leveraging these pedagogies to support students' cognitive and affective growth in the classroom. It also paves the way for teachers to promote students' valuing of various learning attributes which can improve the mathematical learning experiences for the future leaders, workers, and citizens of the nation.

## Limitations and Future Research

This study was conducted in a small geographic area in Ghana, that is, Cape Coast Metropolis. Given that it was not feasible to survey the entire country, the data from the 416 student participants only provides a snapshot of the educational valuing of senior high school students in the country. Thus, this small sample limits the generalizability of the results to broader populations.

Presently, Ghana is the only country in sub-Saharan Africa that has used the WIFI questionnaire. Future research may be extended to include other sub-Saharan countries. This could help ascertain how similar, or different, students' values in learning mathematics are in this sub-region. In addition, future studies could explore how educational value designations might reflect students' performance in international comparative tests, such as the Trends in International Mathematics and Science Study and Programme for International Student Assessment.

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**Appendix A.** Goodness of Fit Test

| Model | % of Variance | Chi-Square | df | Sig. |
|---|---|---|---|---|
| 4 | 34.54 | 3383.30 | 1766 | 1.94e-104 |
| 6 | 39.93 | 2938.96 | 1647 | 6.48e-76 |
| 8 | 44.45 | 2566.06 | 1532 | 2.37e-55 |
| 16 | 59.45 | 1501.96 | 1112 | 3.84e-14 |
| 17 | 61.06 | 1403.03 | 1064 | 1.03e-11 |

**Appendix B.** Rotated Component Matrix

| Variable | Component | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **CONNECTIONS** | | | | | | | | |
| 61. Stories about mathematicians | 0.708 | | | | | | | |
| 18. Stories about recent development in mathematics | 0.689 | | | | | | | |
| 17. Stories about mathematics | 0.679 | | | | | | | |
| 40. Explaining where rules/formulae came from | 0.601 | | | | | | | |
| 34. Outdoor mathematics activities | 0.583 | | | | | | | |
| 60. Mystery of mathematics | 0.573 | | | | | | | |
| 59. Knowing the theoretical aspects of mathematics | 0.542 | | | | | | | |
| 39. Looking out for mathematics in real life | 0.527 | | | | | | | |
| 26. Relationships between mathematics concepts | 0.526 | | | | | | | |
| 9. Mathematics debate | 0.467 | | | | | | | |
| 29. Making up my own mathematics questions | 0.460 | | | | | | | |
| 31. Verifying theorems/hypothesis | 0.458 | | | | | | | |
| 62. Completing mathematics work | 0.457 | | | | | | | |
| 12. Connecting mathematics to real life | 0.432 | | | | | | | |
| 20. Mathematics puzzles | 0.424 | | | | | | | |
| 57. Mathematics homework | 0.418 | | | | | | | |
| 32. Using Mathematical words | 0.410 | | | | | | | |
| 11. Appreciating the beauty of mathematics | 0.392 | | | | | | | |
| 52. Hands-on activities | 0.333 | | | | | | | |
| **UNDERSTANDING** | | | | | | | | |
| 49. Examples to help me understand | | 0.677 | | | | | | |
| 63. Understanding why my solution is incorrect or correct | | 0.672 | | | | | | |
| 58. Knowing which formula to use | | 0.643 | | | | | | |
| 50. Getting the right answer | | 0.636 | | | | | | |
| 56. Knowing the steps of the solution | | 0.609 | | | | | | |
| 51. Learning through mistakes | | 0.592 | | | | | | |
| 54.Understanding concepts/processes | | 0.529 | | | | | | |
| 5. Explaining by the teacher | | 0.475 | | | | | | |
| 6. Working step-by-step | | 0.399 | | | | | | |
| 46. Me asking questions | | 0.387 | | | | | | |
| 42. Working out the mathematics by myself | | 0.368 | | | | | | |
| **FLUENCY** | | | | | | | | |
| 37. Doing a lot of mathematics work | | | 0.649 | | | | | |
| 36. Practicing with lots of questions | | | 0.628 | | | | | |
| 13. Practicing how to use mathematics formula | | | 0.511 | | | | | |
| 14. Memorising facts | | | 0.508 | | | | | |
| 35. Teacher asking questions | | | 0.506 | | | | | |
| 38. Given a formula to use | | | 0.476 | | | | | |
| 53. Teacher use of keywords | | | 0.445 | | | | | |
| 43.Mathematics tests/examinations | | | 0.413 | | | | | |
| 30. Alternative solutions | | | 0.380 | | | | | |
| 33. Writing mathematics activities | | | 0.354 | | | | | |
| 28. Knowing the times table | | | 0.347 | | | | | |
| 15. Looking for different ways to find the answer | | | 0.341 | | | | | |
| **LEARNING TECHNOLOGIES** | | | | | | | | |
| 23. Learning mathematics with the computer | | | | 0.716 | | | | |
| 24. Learning mathematics with the internet | | | | 0.688 | | | | |
| 4. Using calculator to calculate | | | | 0.543 | | | | |
| 22. Using the calculator to check the answer | | | | 0.492 | | | | |
| 25. Mathematics games | | | | 0.473 | | | | |
| 41. Teacher helping me individually | | | | 0.341 | | | | |
| **PROBLEM-SOLVING** | | | | | | | | |
| 2. Problem-solving | | | | | 0.500 | | | |
| 1. Investigation | | | | | 0.470 | | | |
| 8. Learning the proofs | | | | | 0.426 | | | |
| 7. Whole-class discussions | | | | | 0.400 | | | |
| **FEEDBACK** | | | | | | | | |
| 44. Feedback from my teacher | | | | | | 0.539 | | |
| 45. Feedback from my friends | | | | | | 0.536 | | |
| 3. Small-group discussions | | | | | | 0.350 | | |
| **INSTRUCTIONAL MATERIALS** | | | | | | | | |
| 47. Using diagrams to understand mathematics | | | | | | | 0.611 | |
| 48. Using concrete materials to understand | | | | | | | 0.537 | |
| **OPEN-ENDEDNESS** | | | | | | | | |
| 27. Being lucky at getting the correct answer | | | | | | | | 0.529 |
| 16. Looking for different possible answers | | | | | | | | 0.463 |
| 55. Shortcuts to solving problems | | | | | | | | 0.455 |
| 19. Explaining my solutions to the class | | | | | | | | -0.319 |

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