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Cultural Symbols Didactize Concreteness Fading in Basic Multiplication

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Abstract

The purpose of this study is to use cultural Adinkra artifacts to present "Concreteness Fading" in the basic multiplication of one-digit and one-digit numbers. Employing a quantitative approach, the researcher adopted a one-group pretest-posttest quasi-experimental design, and randomly selected 51 participants from 300 student teachers. Data collection involved two sets of tests, analyzed in two stages through task-based transcripts and paired-sample *t*-tests. The first stage analyzed the tasks the student teachers solved using "Concreteness Fading". The results revealed smooth and joyful navigations of the stages of Concreteness Fading using the Adinkra symbols. The second stage analyzed the performance of the student teachers with *t*-test statistics to show significant differences between the control and experimental groups. The results of one sample *t*-test and paired samples *t*-test showed that student teachers solved more problems correctly using Concreteness Fading than the conventional concrete manipulatives. Following the findings, we concluded that heavy use of only concrete objects and examples without abstracting can be detrimental to teaching mathematics. We, therefore, recommended that student teachers should always avoid rushing to symbols and symbolic manipulations of mathematics but rather align their methods, techniques, and strategies in the transition through the three stages of Concreteness Fading.

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INTRODUCTION

Jerome Brunner originally conceived Concreteness Fading in three developmental stages, and named them enactive, iconic, and symbolic (Bruner, 1974; Kim, 2020). The concept was later modified to Concrete, Representational, Abstract (CRA), or Concreteness Fading to refer to a three-step progression from a physical, diagram, and abstract states (Fyfe et al., 2014; Kokkonen & Schalk, 2021; Pearce & Orr, 2018). Through fading, student-teachers can "empty" the learned concepts of its specific sensory and perceptual properties, so they can grasp its formal, abstract properties (Pearce & Orr, 2018).

Research (e.g. Fyfe & Nathan, 2019; Kokkonen et al., 2022; Kokkonen & Schalk, 2021; McNeil & Fyfe, 2012; Pearce & Orr, 2018; Pickering, 2022; Suh et al., 2020) suggests that concrete representations get "faded" to yield more generalizable both during and after instruction. The abstract nature of the indigenous artifacts and their applications to the teaching and learning of mathematics require conscious fading.

Despite the long existence of "Concreteness Fading", it remains much swallowed! Moreover, it has evolved with many variants, making it difficult to know where to fit indigenous artifacts (Suh et al., 2020). Kokkonen et al. (2022) make more encouraging evidence for the effectiveness of concreteness fading. McNeil and Fyfe (2012) contend that no study has experimentally tested the effects of concrete-to-abstract representations. It is even inconceivable to embed artifacts like 'Adinkra' into "Concreteness Fading". Experimentations by Aduko and Armah (2022), and Donovan and Fyfe (2022) revealed significant differences between groups, suggesting potential benefits of concreteness fading. This study proffers local indigenous "Adinkra" artifacts that have always been glossed over. The virtues and values of these indigenous materials in mathematics learning cannot be over-sympathised (Clement Ayarebilla Ali, 2022).

An Overview of Adinkra Artefacts

Figure 1 shows nine of the Adinkra artifacts that were employed in this study. Each of these artifacts belongs to the different categories that the researcher has adapted and employed from Efiabevi (2013). The Akan word 'Adinkra' means "Farewell" (Kuwornu-Adjaottor et al., 2016). 'Adinkra' are traditional symbols that are primarily a usual translation of thought and ideas, expressing and symbolizing the values and beliefs of the people among whom they occur (Clement Ayarebilla Ali, 2021; Clement Ayarebilla Ali & Anderson, 2021). These symbols are embossed on textiles, pottery, stools, umbrella tops, linguist staff, logos, clothes, furniture, sculpture, earthenware pots, and many others (Babbitt et al., 2015; Boddy-Evans, 2020; Kuwornu-Adjaottor et al., 2016).

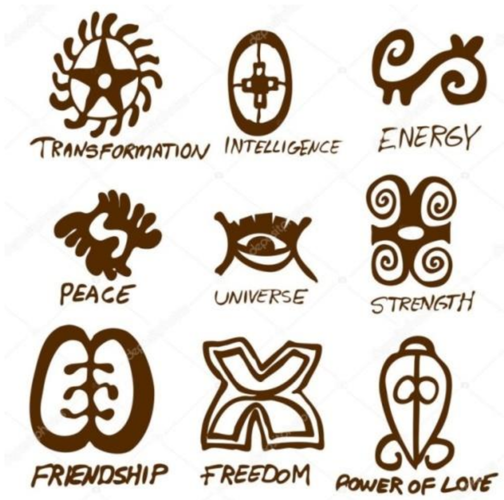


Figure 1. Indigenous Ghanaian "Adinkra" Symbols (Efiabevi, 2013)

Figure 1 shows a sample of nine 'Adinkra' symbols that the student teachers used to preview the concrete representations. They embossed them with interesting and thought-provoking English language interpretations. Some of these meanings are 'friendship', 'power of love', and 'intelligence'. I selected the nine symbols purposely to motivate the student teachers to take up such positive values that can be mathematically interpreted. This encouraged them to actively participate in the experiments.

According to Okyere (2021), the Adinkra symbols were not originally used to teach mathematics. However, they still communicate strong and enviable mathematics ideas, values, and knowledge. The link of "Adinkra" symbols, and its immersed contributions to the teaching and learning of mathematics, in this context, multiplication of 1-digit by 2-digit numbers, was the major motivation. Adinkra symbols have mathematics digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9), operators (+, -, ×, ÷), and relaters (=, >, <, ≥, ≤) (Douglas et al., 2020). This brings to bear the context of mathematics in indigenous settings (Ali, 2021; Ali & Anderson, 2021; Kofi et al., 2021). Instead of the above literature, as a research question (RQ) in this study, how can "Adinkra" symbols help student teachers perform tasks in the three stages of multiplication of 1-digit and 2-digit numbers?

This research is so important for numerous reasons. Concreteness fading has variously been presented in other research works. The uniqueness of this study is the use of cultural artefacts. The new value of this study can be observed in the use of Adinkra symbols. These symbols abound in the environment. However, not many many people and mathematics educators link them to mathematics learning (Ali & Davis, 2016). By extension, the world of mathematics education could be expanded and extended to cultures and their artefacts. The symbols of mathematics are pure cultures of Arabic, Hindu, and European interplay. Mathematics learners, educators, and researchers of African origin may add this knowledge to their literature (Ali, 2021).

RESEARCH METHODS

In this section, the researcher presents the research design, experimentations, population and sample, data analysis instrumentations, and validity of the findings.

The Research Design

The researcher adopted a one-group pretest-posttest quasi-experimental design. In this design, groups of student teachers were classified based on their program of study, namely General Science, Social Studies and Humanities, Literacy and English Language, and Agricultural Science and Home Economics. First, the student teachers were given the "Adinkra" to learn and connect them to concrete materials. The design sought to delve deep into the principles of the model to link to the concept of multiplication of 1-digit by 2-digit numbers through the three stages (Kim, 2020).

The Experimentations

Two stages of experimentation were undertaken with 51 student teachers. These experimentations were based on two methods of teaching. The two methods of teaching were the conventional method as control and the "Concrete Fading" as experimental treatments respectively. In the control (CG), all the student teachers were tested before and after having explained the concept of the conventional method, after which a test was taken. The test before the teaching was called the 'pretest' and the test after the test was called the 'posttest' (Donovan & Fyfe, 2022).

In the experimental (EG), the students were first tested with the control (pretest). Then the student teachers were given a set of tasks in multiplications of 1-digit and 2-digit numbers. In the Concrete stage, real objects were used to teach the multiplications. The researcher did not move away from these concrete examples when explaining the concepts. In the representation stage, objects were drawn or taken snapshots. In the Abstract stage, no concrete examples were used and student teachers were taught using multiplication problems only (Kuepper-Tetzel, 2018).

In the experimental stage, the researcher started with concrete objects, then moved to a paper-based version that increased the abstractness of the representation (Suh et al., 2020), but still used the objects from before, and lastly concluded with numeric representations alone. The multiplication problems used during the first phase were relatively easy (e.g. 3×12) as compared to the ones student-teachers had to solve during the abstract stage (e.g. 32×25) (Kuepper-Tetzel, 2018). After they had completed the tasks, they were given a set of tasks in multiplication of 1-digit by 2-digit numbers called posttest. Then the worksheets were retrieved and analyzed based on the stages of the "Concreteness Fading" principle (Febriana et al., 2019).

Populations and Sample

Nearly 300 student teachers were offering Post Diploma in Basic Education programs at the University of Education, Winneba in Ghana (distance module). However, the researcher used the simple random sampling technique to select 51 student teachers who offered mathematics as their specialization. The 51 student teachers cut across genders, regions of Ghana, and knowledge of Ghanaian languages and culture. They also offered mathematics as their course for a professional teaching career and needed more methodologies and resources for improved learning outcomes. In the selection process, the researcher first took the index numbers of student teachers. Then a table of random numbers was generated to match the last digit of their index numbers. Any number that appeared on the table was selected (Ali, 2021).

Instrumentations

The researcher used two sets of instruments to collect the data. The first set of instruments was pretesting. In the pretesting, the researcher administered items based on the multiplication of one-digit by two-digit numbers via the conventional method of teaching. The second set of instruments was testing. In the testing, the researcher administered items based on "Concreteness Fading", having taken the student teachers through the indigenous 'Adinkra' symbols. The items were similar to those administered in the pretesting (Ali & Davis, 2018).

Data Analysis

The researcher used one sample *t*-test for the analysis to determine whether the sample mean was significantly greater or less than the hypothesized value of 0. The *t*-test was preceded by tasks on the Adinkra symbols. The data satisfied the *t*-test assumptions to determine whether there was statistical evidence between paired observations. The tool assumed that the data were measured in interval and ratio scales, the sample size was large, the data was homogenous, and the distribution was normal (Creswell & Creswell, 2018).

The measurements of the stages were taken at two different times with an intervention administered between the two time points, the measurements were taken under two different conditions and the measurements were taken from two halves or sides of the subject or experimental unit (Creswell & Creswell, 2018). This method helped the researcher to fashion out theories, policies, and practices that can incorporate indigenous artifacts into the Concreteness Fading.

Validity and Reliability

The researcher chose test-retest reliability to assess whether the performance in the conventional method yielded the same results as the performance in the "Concreteness Fading". Indeed, the Cronbach alpha coefficient yielded 0.78 (Bhattacherjee, 2023). In validity, the researcher assessed three main measures of validity, vis-à-vis criterion, construct, and content. This measured all the student teachers' knowledge in "Concreteness Fading".

Threats to Internal Validity

The researcher-controlled history (unrelated events such as fatigue that nearly influenced the performance), maturation (outcomes of the performance in the post-test that were nearly influenced by the pre-test), instrumentation (differences in times of the pre-test and post-test that nearly influenced performance) and testing (pre-test that nearly influenced the post-test). These were accomplished by manipulation, elimination, inclusion, statistical control, and randomization (Bhattacherjee, 2023).

Ethical Considerations

The researcher paid attention to voluntary participation, informed consent, anonymity, confidentiality, potential for harm, and results communication (Ali, 2022). Ethical protection aims to protect the rights of research participants, enhance research validity, and maintain scientific or academic integrity (Ali & Davis, 2018; Bhandari, 2020).

RESEARCH RESULTS

In answering this research question (RQ: How can "Adinkra" symbols help student teachers perform tasks in the three stages of multiplication of 1-digit and 2-digit numbers?), four tasks were used with "Adinkra" symbols. These included "Friendship", "Power of Love", "Strength" and "Intelligence".

Table 1. Descriptive statistics of participant scores

Group	Number	Minimum	Maximum	Mean	SD
CG (Pretest)	51	12	17	14.23	1.224
EG (Pottest)	51	17	20	16.22	1.032

In Table 1, the minimum value for the control and experimental stages was 12, and the maximum was 17. This gave a mean of 14.23(1.224) and 16.22 (1.032). It can be inferred that the mean values of the experimental stage were not only higher than the control but they were also more compact. The little variation was a good indication many participants had near-equal understanding after the interventions.

Table 2. Paired sampled *t*-test scores of participants' scores

Groups		Mean	SD	Confidence interval		*t*	*df*	Sig. (2-tailed)
				Lower	Upper			
Pair	CG vr EG	-3.12	1.65	-4.12	-2.12	-5.64	50	0.000

In Table 2, the significant value of the paired-sample statistics was less than 0.05. This means there was a difference between the control and experimental stages. Compared with Table 1, it can be concluded that the experimental stage produced a higher score resulting in the difference. This could be attributed to the cultural Adinkra artefacts that were used to better illuminate Concreteness Fading in Multiplication.

Task 1: The Results with "Adinkra" Symbol for "Friendship"

The student teachers brainstormed the issues around friendship and related the concept to learning. According to Dicken (2023), one may think a friendship will last forever but it is not uncommon for some friends to fade. Sometimes, a disagreement or falling out creates a gap between friends. Other times, commitments like work, distance, or family result in a friendship slowly fading away without animosity. Student teachers accepted the value of 'friendship' and believed that learning multiplication starts with own friendship. They applied the value during the group discussions in a friendly and cordial atmosphere. Concreteness Fading offered solutions for making these connections as in Figure 2.

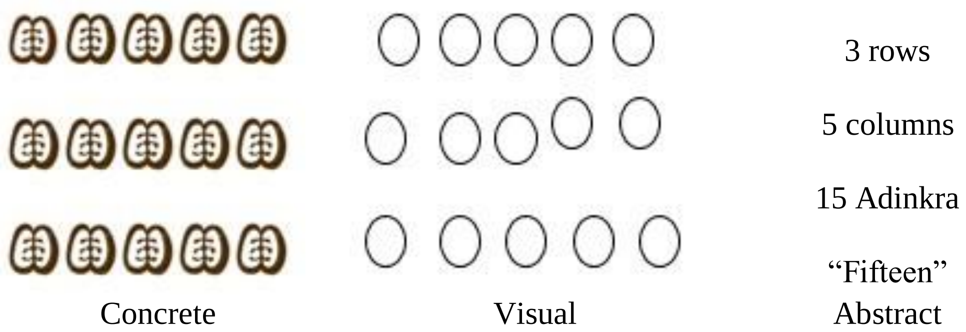
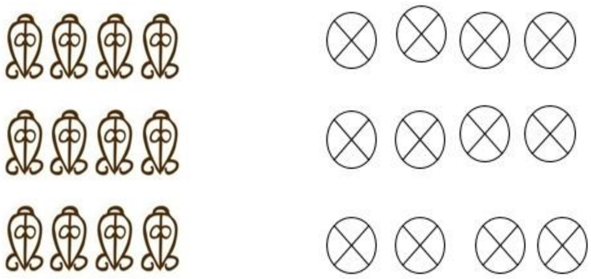


Figure 2. Concreteness fading without numbers (Pearce & Orr, 2018)

In Figure 2, Pearce and Orr (2018) started with these concrete manipulatives, progressed to drawing those representations, and finally, represented the mathematical thinking abstractly through symbolic notations. "Adinkra" are varied symbols and represent various mathematical contexts (Ali, 2019). The "Adinkra" symbols represent concepts or aphorisms and are used extensively in fabrics, pottery, logos, and advertising (Efiabevi, 2013). Even though one cannot directly link them to numbers and operations, they abound in rich affective attitudes (strength, forgiveness, faithfulness, friendship, and peace) and values (e.g. royalty, truth, courage, and understanding) enshrined in the new Ghanaian curricula of pre-tertiary education levels (Kofi et al., 2021; Ministry of Education, 2019).

Task 2: The Results with "Adinkra" Symbol for "Power of Love"

The power of love for mathematics has widely been discussed. For instance, Brown (2019) opines that the four ways to add love for mathematics are to commit to inspiring teaching, preach the value of mistakes, advocate for growth mindsets, and strengthen your mathematics skills. These four ways were adequately exemplified in carrying out the activities with the "Adinkra" symbol in the "Concrete Fading" as shown in Figure 3.



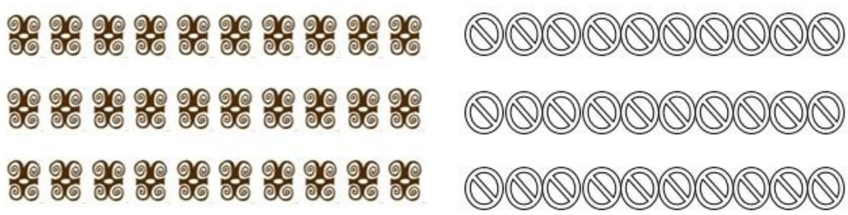
$$\begin{array}{r} 3 \\ \times 4 \\ 12 = (10+2) \end{array}$$

Figure 3. Linear Concreteness Fading without Numbers (Pearce & Orr, 2018)

Figure 3 shows how the conceptual understanding of "Love" continues to deepen through the use of the "Power of Love". At this stage, student teachers continued sharing using visuals and gradually introducing symbolic notations. Different representations of concrete materials were required to consolidate learning. Moreover, since student teachers had a significant amount of time to inquire, investigate, and solve problems using both concrete and visual representations, they readily developed the ability to visualize different representations in their minds. It was more efficient to use symbolic notations and operations in multiplication rather than building concretely or drawing visually (Pearce & Orr, 2018).

Task 3: The Results with the "Adinkra" Symbol for "Strength"

Bowen (2021) has acknowledged a strength-based perspective of learning mathematics and advocated for lessons from a strengths-based perspective. This means focusing on what students already know, uncovering their strengths, and building on those strengths through instruction. This view is an excellent way to start using symbols from student teachers' environment culture and customs and scaffold them to much higher heights (Kofi et al., 2021).



$$\begin{array}{l} 10 \\ \times 3 \\ 30\ (3\ \textit{tens}) \end{array}$$

Figure 4. Concreteness fading with small numbers (Pearce & Orr, 2018)

Figure 4 shows how "Strength" propelled the student teachers to adequately prepare and enter into the abstract stage. As student teachers were shown how easy multiplication can be performed by having a conceptual understanding, they eventually jumped on the opportunity to multiply numbers without using manipulatives and representations. The more students linked their concrete and visual models to more abstract representations, the stronger their conceptual understanding supported any procedural approaches to progressive and effective algorithms in multiplication (Pearce & Orr, 2018).

Task 4: The Results with "Adinkra" Symbol for "Intelligence"

The fourth task was "Intelligence". Logsdon (2022) found that children with increased logical-mathematical intelligence are typically methodological and logical in thinking. Children may be adept at solving mathematics problems in their heads and drawn to logic puzzles and games. Mathematics "intelligence" exhibits children's abstract concepts, categorization, classification, patterns, problem-solving, and visual analysis (Bartolomei-Torres, 2022).

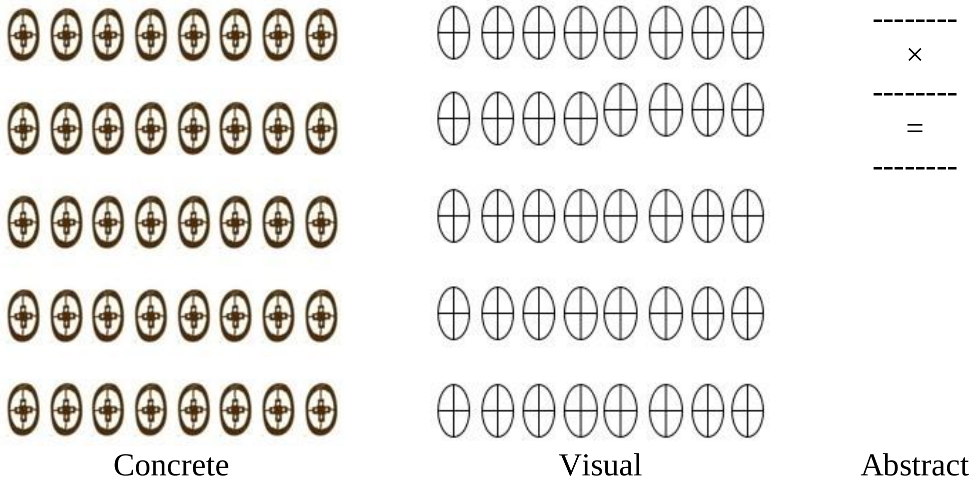


Figure 5. Concreteness fading with scaffolding activity (Pearce & Orr, 2018)

In Figure 5, student teachers have fully applied intelligence to transition and transfer knowledge into the abstract stage. In this stage, they scaffolded the concreteness fading models; they could easily conceptualize the movement without being assisted (Horn-Olivito & Martinovic, 2017; Kofi et al., 2021).

DISCUSSION

As originally conceived, it is a three-step progression that begins with enacting a physical instantiation of a concept, moves to an iconic depiction, and then fades into a more abstract representation of the same concept (Suh et al., 2020). It takes its source from Bruner's iconic, enactive, and symbolic stages (Bruner, 1974). This shows that learning from concrete materials that "fade" to abstract symbols benefits transfer, the progression from concrete to abstract is better than the reverse, learning from concrete materials is similar to learning from abstract symbols, and the benefits of "fading" extend to children with low and high prior knowledge (Fyfe et al., 2015).

Ching and Wu (2019) examined the effectiveness of various instructional strategies that aimed to enhance children's understanding of the inversion concept using 140 kindergarten pupils randomly assigned to each group of concrete-only, abstract-only, concreteness fading, abstract-to-concrete, and control. All the intervention (experimental) groups showed significantly greater progress than the control group in solving the inversion problems in the post-tests. In their findings, it was revealed that concrete representations were more effective than abstract representations. The superior benefits of concreteness fading appeared more prominent in the post-test scores for children with lower prior knowledge. The findings of Ching and Wu (2019) brought to light two key implications: (1) concrete representations should not be avoided in teaching mathematics, and (2) the order of the various representations is key for effective learning.

In particular, Pearce and Orr (2018) made significant and inspirational findings on the “Concreteness Fading” of the multiplication of numbers. Pearce and Orr (2018) discovered that using circular manipulatives like doughnuts was more concrete than drawing doughnuts or using symbols (numbers and operations). It was revealed that using concrete manipulatives was still more abstract than using the actual items in the quantity being measured.

On average, student teachers performed more problems correctly using “Concreteness Fading” as compared to the conventional methods. Kuepper-Tetzel (2018) discovered that heavy use of concrete objects and examples without abstracting from them can be detrimental to solving mathematics problems. “Concreteness Fading” can also always be done in different ways, namely providing concrete examples first, then substituting concrete with more abstract ones, and, finally, moving completely to an understanding of the abstract principles (Kuepper-Tetzel, 2018). This has completely answered and satisfied the domain of the study.

CONCLUSION

The results of Tables 1 and 2, and the transcripts on Figures 2 to 5 have shown that the student teachers used Adinkra Artefacts to solve the problems on Concreteness Fading The findings of the results on Tables 1 and 2 show that student teachers could readily navigate easily from the concrete into the abstract stage in the multiplication of 1-digit by 2-digit numbers. Particularly, it was evident that the student teachers had a lot of fun and play when using the “Adinkra” symbols.

The findings in Table 2 also show that the performance of student teachers improved in the “Concrete Fading” tasks as compared to the tasks involving the usual conventional methods of multiplication. Therefore, starting every mathematics lesson with concrete materials is nonnegotiable. The improvement was much more remarkable in the transition from visual to abstract than from concrete to visual. This big improvement was attributable to the “Concreteness Fading” principle and it is “Adinkra” that added more impetus to the tasks. This is contrary to the expectation that real concrete materials enhance learning than abstract ones. It is rather the value and virtue of the concrete material that matters more!

We, therefore, recommend that student teachers must always avoid rushing to symbols and symbolic manipulations of mathematics. It is not uncommon to observe many student teachers rushing towards using symbols for the multiplication of 1-digit by 2-digit numbers. This tends to veer the classroom into instrumental learning without making any deeper understanding and appreciation of the concepts therein.

We also recommend that student teachers endeavor to help their children develop a firm grasp of their indigenous artifacts like "Adinkra" in every mathematics domain. Even though the curriculum is emphatic on the use of local and indigenous materials that are easily accessible to pupils, it is not uncommon to hear many teachers complain about a lack of teaching and learning resources. Materials are readily available for addition and subtraction. However, resources to use for multiplication activities in school mathematics remain untapped.

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Interest as Predictor of Mathematics Achievement among Senior Secondary School Students in Bida Educational Zone, Niger State, Nigeria

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Abstract

This study investigates whether senior secondary school students' interest could predict their academic achievement in mathematics. A correlation research design was used with two research questions and one null hypothesis to guide the study. The target population encompassed 13866 students (9464 males and 4402 females) in SSSII across 46 senior secondary schools owned by the Niger state government, distributed within Bida educational zone spanning five local government areas. Using a multistage sampling method, a sample of 462 students (30% of the population) was selected. Two research instruments, (Mathematics Interest Scales [MIS] and Mathematics Achievement Test [MAT]) were validated with reliability coefficient (r=0.79 and 0.92). Data analysis was carried out using frequency, percentage, and Pearson Product-Moment Correlation (PPMC). The findings revealed that a significant portion of students had a low interest in mathematics, which was found to predict approximately 44% of the variations in academic achievement scores. Moreover, the study demonstrated a substantial relationship between students' interest in mathematics and their academic performance. These findings led to recommendations. Emphasizing perseverance in mathematics learning, teachers were encouraged to adopt innovative, learner-centric teaching strategies. Additionally, ensuring teacher motivation and support was deemed essential for assisting students in their mathematics education among others.

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INTRODUCTION

In Nigeria, mathematics holds a pivotal role as a mandatory subject in both primary and secondary education. Mathematics, as an academic discipline, delves into the realms of numbers, shapes, patterns, and their intricate relationships. It equips learners with the vital ability to communicate using symbols and logical reasoning, fostering logical thinking, precision, and spatial awareness (Arhin & Yanney, 2020).

Mathematics is regarded as one of the core prime instruments for understanding and exploring the scientific, technological, economic, and social and information world. Science, Technology, Engineering and Mathematics (STEM). Mathematics education is considered as a precious way to make the education system keep up with the developments and to meet the expectations of 21st century skills (Ghazali & Yusuf, 2022; Kazu & Kurtoglu Yalcin, 2021). Mathematics underpins the others science disciplines and it is recognized as the foundation for all other science disciplines (Just & Siller, 2022). Mathematics, therefore, remains a fundamental subject, often necessitating a credit pass in public examinations for admission into science, engineering, and technology programs at tertiary institutions. Nevertheless, despite its paramount importance, students' performance in public examinations has been persistently subpar globally (Mazana et al., 2020). Research findings have attributed this underperformance to multifaceted factors, both related to students and teachers. Teaching of mathematics has been reported to be a strenuous task (Rodríguez-Naveiras et al., 2023), so also, for most learners, learning mathematics is difficult because of its abstractness. This abstractness led many students to lose interest, thus resulting in low achievement (Yeh et al., 2019).

Academic achievement, the yardstick for assessing students' success or failure upon program completion, is typically evaluated as either high or low, corresponding to good or poor performance. This achievement can affect the students' current and future life, as well as portraying students' inherent productivity and ability (Mappadang et al., 2022). The assessment of academic achievement hinges on examinations or continuous assessment, with numerous factors like test anxiety, learning environment, motivation, interest, and emotions influencing the outcome. Academic achievement is deemed high when it surpasses or meets the expected standard and poor when it falls below this standard (Scholastica, 2020). Despite poor results in external examinations (SSCE & NECO), attributable to diverse factors such as students' interest, personal attributes, motivation, and instructional methods, focusing on students' interests becomes a reasonable approach to understanding academic achievement in mathematics.

Interest, a concept widely recognized in both psychology and education, refers to an individual's inclination to engage with specific content, such as mathematics, over time. It encompasses attributes like curiosity, sustained concentration, pleasant feelings, and heightened motivation to learn (Owora & Chika, 2019). Interest exerts a positive influence on attention, goal setting, and learning styles, benefitting individuals of all ages within and beyond the school environment. Interest serves as a potent motivational force that ignites learning and steers academic success (Zambuk, 2021). Interest is said to be a powerful driving factor that triggers and promotes learning and is considered essential for academic success. Interest is characterized by increased effort, attention and affect, experienced in any particular time, as well as an enduring predisposition to reengage in academic task, like mathematics. The presence of interest can ensure active and meaningful engagement in academic activities, which is key to academic success and better learning outcomes (Toli & Kallery, 2021).

Emefa et al. (2020) define interest as a psychological state occurring during the interaction between a person and a specific subject or activity, including the process of willingness, attention, concentration and positive feeling towards that particular subject or activity. In this study, interest is operationalized as the emotional engagement of students in mathematics learning, signifying their enjoyment of mathematical tasks (Wong & Wong, 2019). Being interested in mathematics entails an active involvement in all mathematical activities, and the role of the teacher in fostering this interest is undisputed. Although students bear the primary responsibility for their learning, teachers play a pivotal role in guiding them on their quest for knowledge. Through effective teacher-student interactions, interest in mathematics can be nurtured and sustained, equipping students with the essential skills to become proficient mathematics learners. Therefore, interest emerges as a predictive factor for academic achievement and holds particular relevance when crafting effective instructional strategies for mathematics.

Furthermore, societal beliefs can shape students' attitudes towards mathematics. Some students are led to believe, by parents, peers, or teachers, that mathematical ability is innate or a gift, while others are instilled with the notion that mathematical prowess can be cultivated through diligence (Scholastica, 2020). When students perceive mathematical ability as innate, they are more likely to lose interest when confronted with challenges. Conversely, those who view it as a product of hard work and collaboration tend to maintain their interest despite obstacles (Owora & Chika, 2019).

Psychologists have identified two categories of interest: individual interest and situational interest. Individual interest, akin to personal interest, reflects a relatively stable affection for specific subject areas or objects. It is instrumental in sustaining engagement and long-term learning. For instance, a student with a personal liking for mathematics would willingly solve math problems both in and outside the classroom. Situational interest, on the other hand, is a transient state aroused by specific features of a situation or task, often influenced by the teacher. While situational interest can impact extrinsic motivation, individual interest holds long-term sway over intrinsic motivation (Scholastica, 2020).

To foster effective mathematics learning and academic achievement, students need to develop and nurture individual interest, which gradually molds their long-term engagement with the subject. Situational interest, though fleeting, can enhance extrinsic motivation and create transient engagement during specific learning experiences. Thus, the interplay between individual and situational interest becomes crucial in understanding how students engage with mathematics and its impact on their academic outcomes (Owora & Chika, 2019).

The significance of interest in any task is reflected in the visible display of effort, which manifests as the repetition of activities without experiencing boredom, improved performance, and enhanced creativity in the respective area. Zambuk (2021) highlights that generating interest can be challenging if the underlying potential is absent. While interest can be easily sparked, sustaining it requires concrete factors. Both intrinsic and extrinsic motivating factors play pivotal roles in generating and maintaining interest, particularly within the purview of teachers. Research findings underscore the importance of perseverance in generating and sustaining learners' interest. Here, experienced and determined teachers have a vital role in stimulating and nurturing interest among students. Although interest towards mathematics has been considered an important factor influencing participation and success in mathematic (Oluyemo et al., 2020), studies have shown that negative interest toward the learning of mathematics has been exhibited even by primary school pupils (Okenyi, 2023). However, learner-centred instructional strategies can improve and sustain students' interest in mathematics (Asmira et al., 2021; Fabarebo et al., 2023; Kihwele & Mkomwa, 2023; Ryan et al., 2022).

Previous studies related to this topic have consistently emphasized the significant correlation between interest and academic achievement in mathematics (Arhin & Yanney, 2020; Mappadang et al., 2022; Onah & Anamezie, 2022; Wong & Wong, 2019). Additionally, findings suggest that the degree of motivation significantly impacts academic achievement in mathematics, with achievement motivation emerging as a predictor of academic success among senior secondary students.

In contrast, Zambuk (2021) reported no significant relationship between interest and academic achievement, focusing on interest and self-efficacy as motivational variables. The study concluded that teachers' emotional support influenced students' interest in mathematics (Owora & Chika, 2019). Umar and Haruna (2021) also noted that interest might not necessarily be a predictor of mathematics performance, suggesting that personal factors (such as test anxiety and readiness) and environmental factors (such as instructional methods and materials) could come into play.

Given these mixed and inconclusive findings, there is a pressing need to investigate interest as a predictor of academic achievement in mathematics among senior secondary school students within the Bida educational zone. Such a study can shed further light on the complex interplay between interest, motivation, and academic performance in mathematics, providing valuable insights for educators and policymakers alike.

Purpose of the Study

The general objective of the study is to investigate whether interest is predictor of academic achievement of senior secondary school students in mathematic of Bida Education Zone, Niger State, Nigeria. Specifically, the study intended to: (1) determine the interest level of students towards learning of mathematics in senior secondary school, (2) determine the (the relationship between interest and) academic achievement in mathematics among senior secondary school students.

Research Questions

The following research questions were asked to guide the study: (RQ1) What is the interest level of students towards learning of mathematics in senior secondary school? and (RQ2) What is the relationship between interest and academic achievement in mathematics among senior secondary school students?

Hypothesis

The following null hypothesis was formulated at alpha 0.05 level of significance: (H_0) there is no significance relationship between interest and academic achievement among senior secondary school students.

Significance of the Study

This study's investigation into the role of interest as a predictor of academic achievement in mathematics among senior secondary school students in the Bida

Educational Zone holds significant promise for a wide range of education stakeholders. Students can gain insights into the importance of nurturing their interest in mathematics, potentially improving their academic performance. Teachers can use the findings to refine their teaching strategies and make mathematics more engaging for students, while school administrators can consider policy adjustments to support teachers and enhance the overall learning environment. Curriculum developers can benefit from insights into instructional materials and approaches that foster interest in mathematics, and policymakers can use the research to inform evidence-based decisions that improve mathematics education in the region, ultimately benefiting the entire education industry.

RESEARCH METHODS

This is a correlation research design which gives the association between two variables (interest and academic achievement) that were investigated. These designs are most suitable because it allows collection of data on the study variables, and systematically describes the facts and characteristics of entire population, as well as predict the relationship between them (Scholastica, 2020).

Population and Sample

The study's target population comprised 13,866 senior secondary school (SSS II) students, comprising 9,464 males and 4,402 females, all enrolled in public schools within the Bida Educational Zone. This educational zone encompasses five local government areas and houses a total of 46 senior secondary schools, all of which are state government owned. The selection of only government schools was based on their homogeneity. For this study, a sample size of 30% of the total target population was chosen based on central limit theorem which stressed that 30% of sample size viable for experimental research (Arhin & Yanney, 2020; Fraenkel et al., 2000). With assertion 30% of the total target population is 462 students. The sampling process employed to determine this sample size is through a multi-stage approach. In the first stage, simple random sampling was utilized to select three out of the five local government areas. In the second stage, one school was randomly chosen from each of the selected local government areas. Finally, in the third stage, students were selected from these three chosen schools using purposive sampling techniques.

Instrument

The questionnaire title Mathematics Interest Scales (MIS) comprising 20 items was adapted from 27-items mathematics interest inventory developed by Wong and Wong (2019). The MIS is a four-point likert type ranging from 1=Not True of me (NTM), 2=Slightly True of me (STM), 3=True of me (TM) and 4=Very True of me (VTM), which was employed for all statements in the MIS. Ten (10) statements from (1 to 10) had positive cue in the instrument, while from 11 to 20 had negative cue. These negative cued items were reverse scored before the scores were calculated at the data analysis stages. Furthermore, the four-point scales was reduced to two points after data collection, these are low interest and high interest and benchmark (X)=2.5, i.e. $X > 2.5$ is high interest and $X \leq 2.5$ is low interest.

Mathematics Achievement Test (MAT) was measured on the mock examination scores of the SSSII students in the selected schools. The mock examination is standard examination organized by Niger State Ministry of Education; hence, the examination questions were valid and reliable. The examination was scored at 100% with interpretation as 70-100= A (Excellent), 60-69= B (Very good), 50-59=C (Good), 45-49=D (Pass), 44-40=E (Just pass), 39-0= F (Fail). The variable has been interpreted as ordinal scale in Table 1.

Table 1. The ordinal scale to interpret Mathematics achievement

Score intervals	Grade	Remark
0 – 44%	C	Low achievement
45 – 59%	B	Average achievement
60 – 100%	A	High achievement

To ensure the instruments' reliability and validity, a rigorous process was undertaken. The instruments were subjected to both face and content validity assessments. Expert opinion was sought from professionals at Federal University of Technology, Minna, and Niger State College of Education, Minna, who reviewed and evaluated the instruments to ensure they effectively measured the intended variables. This expert feedback helped to refine and clarify any ambiguous statements and identify potential issues that could arise during the actual study, along with proposed solutions.

To establish the reliability of the instrument, a pre-test was conducted. This pre-testing phase allowed for the verification of the instruments' reliability by measuring consistency and stability. The reliability coefficient was determined to be 0.79 (and 0.92) through a test-retest approach, indicating a satisfactory level of reliability. Subsequently, the questionnaire designed to measure variables such as mathematics interest and academic achievement scores was administered to the study participants. The collected data were then subjected to a comprehensive statistical analysis to arrive at valid conclusions. The research questions were addressed using descriptive statistics, specifically means and standard deviations, which provided insights into the central tendencies and variations in the data. Furthermore, the hypothesis was analyzed using the Pearson Product-Moment Correlation Coefficient (PPMCC), which helped assess the relationship between the variables under investigation. This rigorous methodology ensures the quality and credibility of the study's findings by validating the instruments and employing appropriate statistical tools for data analysis, ultimately contributing to the robustness of the research outcomes.

RESULTS AND DISCUSSION

Research questions are answered in each section regarding the interest level of students towards learning of mathematics and the level of academic achievement in mathematics.

The Interest Level of Students towards Learning of Mathematics

In answering RQ1, descriptive statistics of mean and standard deviation (SD) was used and presented in Table 1.

Table1. Students' interest toward mathematics

Statements	Mean	SD	Remark
1. I like to answer questions in mathematics class	2.4	0.8	Low
2. I like mathematics	2.3	1.0	Low
3. I am interested in mathematics	2.1	1.0	Low
4. Knowing a lot about mathematics is helpful	3.1	0.7	High
5. I feel happy when it comes is works on mathematics	2.3	0.7	Low
6. I am more excited when new mathematics topics is introduced	2.4	1.1	Low
7. I went to learn more about mathematics	2.4	0.9	Low
8. I spend many hours working on mathematics	2.1	0.9	Low
9. I went to talk about mathematics with my friends	2.1	1.2	Low
10. I choose to work on mathematics	2.6	0.5	High
11. I am wasting my time on mathematics	1.4	1.2	Low
12. I am bored when working on mathematics	1.2	0.6	Low
13. I would rather be working on something else besides mathematics	2.6	0.2	High
14. I give up easily when working on mathematics	0.3	0.5	Low
15. I am always thinking of other subject when working on mathematics	2.1	0.4	Low
16. When working on mathematics, I want to stop and start working on something else	1.1	0.5	Low
17. I get mad easily when working on mathematics	0.9	0.7	Low
18. I have difficulty paying attention when working on mathematics	1.4	0.2	Low
19. I struggle with mathematics	1.3	0.8	Low
20. I prefer easy mathematics over mathematics that is herd	0.3	0.7	Low
Cummulative Mean Interest	1.81		Low

Table 1 revealed the interest level of senior secondary school students of Bida Educational Zone in mathematics learning. The result indicates that, out of the 20-item statements, the students showed low interest on 17-items, while 3 items on high interest. The mean of means (cumulative mean) of mathematics interest scale is 1.81 which is indicating the level of interest of students in the learning of mathematics. This implies students have low interest in mathematics.

The results of the descriptive statistics in this study indicate a notable pattern of low mathematics interest and poor academic achievement among senior secondary school students in the Bida Educational Zone. The cumulative mean interest score of 1.81, classified as "low interest," strongly suggests that enhancing students' interest could potentially lead to improvements in their academic achievement in mathematics.

The Level of Academic Achievement in Mathematics

In answering RQ2, descriptive statistics of frequency and percentage was used and presented in Table 2.

Table 2. Level of students academic achievement in mathematics

Mock Score Range	Achievement scale	Frequency	Percentage (%)
Less than 45%	Low achievement	259	56.06
Between 45- 59%	Average achievement	112	24.24
Between 60- 100%	High achievement	91	19.70
Total		462	100.00

Table 2 shows the rate of academic achievement in mathematics in the selected senior secondary schools in Bida Educational Zone. The results revealed that about 56% mathematics students had low achievement in their examination scores. About 24% had average achievement, while 20% had high achievement. This implied that 56% had poor achievement in mathematics.

To test the stated hypothesis, interest and academic achievement scores were subjected to Pearson Product Correlation test and the result is shown in Table 3.

Table 3. PPMCC analysis of relationship

Variables	N	Mean	SD	*df*	*r*	Remark
Interest	462	3.4	0.5	460	0.384	Significant
Achievement	462	3.6	0.5			

The results in Table 3 shows that the correlation is 0.384 which is very high compared to 0.05 level of significance. Hence, the null hypothesis is then rejected. This shows that there is significant relationship between interest and academic achievement. It means that students' interest in mathematics has positive relation with academic achievement. In addition, interest is a predictor of the academic achievement in mathematics.

The study identified a significant relationship between students' interest and their academic performance in mathematics. This suggests that as students' interest in mathematics increases, so does their academic achievement in the subject. Conversely, a decrease in students' interest is associated with lower academic achievement. These findings align with previous research conducted by Wong and Wong (2019), Scholastica (2020), and Zambuk (2021), which all support the notion that highly interested students tend to perform better academically. Being interested in mathematics, as defined in this study, involves displaying a genuine concern for and curiosity about the subject by actively engaging in all related activities.

It is important to note that these findings are in contrast to the results reported by Yu and Singh (2018), Owora and Chika (2019), and Umar and Haruna (2021). These studies suggest that interest alone may not directly predict mathematics achievement, as factors such as anxiety and self-efficacy in learning mathematics can potentially act as barriers to effective learning and performance in the subject. These conflicting findings highlight the complexity of the relationship between interest and academic achievement in mathematics and underscore the need for further research to delve deeper into the various contributing factors and their interplay in the learning process.

CONCLUSION

The findings from this study support a significant and meaningful correlation between students' interest and their academic achievement in mathematics among senior secondary school students. The results strongly indicate that when students' interest in mathematics increases, there is a corresponding improvement in their academic achievement in the subject. Conversely, a decline in students' interest is associated with lower academic achievement. These findings underscore the critical role of interest in shaping students' performance in mathematics. In practical terms, this suggests that efforts to enhance students' interest in mathematics could lead to improved academic outcomes in the subject. This study contributes valuable insights into the relationship between interest and academic achievement, which has implications for educators, policymakers, and other stakeholders in the field of education. Further research and initiatives aimed at promoting and sustaining students' interest in mathematics are warranted based on these conclusive findings.

Based on the findings of the study, several recommendations can be made to improve students' interest in and academic achievement in mathematics. Firstly, counseling for mathematics. Students should receive counseling sessions focused on mathematics to increase their interest and motivation in learning the subject. These sessions can help students understand the relevance and real-world applications of mathematics, making it more engaging and relatable. Secondly, encouraging perseverance, teachers should actively encourage students to develop perseverance when learning mathematics. This can be achieved through positive reinforcement, constructive feedback, and creating a supportive classroom environment where students feel comfortable making mistakes and learning from them. Thirdly, Mathematics teachers should work to create a stimulating and engaging learning environment that captures students' interest and curiosity. Incorporating real-life examples, interactive activities, and practical applications of mathematics can make the subject more appealing. Fourthly, teachers should adopt innovative teaching strategies that promote critical thinking and problem-solving skills. Interactive and hands-on learning experiences can help students recognize the importance of mathematics in their academic and everyday lives. Fifthly, motivated and well-prepared teachers are more likely to create a positive learning atmosphere that encourages student interest and achievement in mathematics.

By implementing these recommendations, educational institutions and policymakers can work toward improving students' attitudes toward mathematics and ultimately enhancing their academic performance in the subject.

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Analyzing Errors Pattern in Mathematics Achievement among Senior Secondary School Students: A Case Study

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Achievement; Errors pattern; Mathematics.

Abstract

Identifying student math errors is crucial as they hinder skill development in problem-solving, logic, and decision-making, given math's abstract nature. This study investigates mathematical errors among senior secondary school students in Owerri Municipal Council, Imo State. A descriptive survey research design was employed. The sample size comprised 150 senior secondary students in class three (SS3), randomly selected from five out of ten public senior secondary schools. It addressed three research questions and one null hypothesis tested. Data collection utilized two expert-validated instruments (Mock Mathematics Essay Score Sheet [MMESS] and the Mathematics Error Identification and Classification Checklist [MEICC]) with substantial reliability. The analysis involved frequency, percentage, and Chi-square methods. The findings revealed that the errors committed by students included conceptual errors, computational errors, defective algorithms, and wrong operational errors. Wrong operational errors were most common among male students, whereas female students were more prone to computational errors. A significant difference in the errors committed by male and female students was observed. Math teachers must address errors in class, engaging students to prevent recurrence. Findings suggest tailored interventions for diverse learning needs, highlighting gender-sensitive teaching. Future studies may explore long-term error trends and intervention efficacy.

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INTRODUCTION

Mathematics is a fundamental discipline that involves the study of quantity, structure, and space. It deals with numbers (quantities and values) and their operations, ranging from fundamental processes such as calculation, computation, systematic problem-solving, etc. (Yadav, 2019). These processes are essential for understanding and applying mathematical concepts in various practical situations across different fields. Mathematics is not only an academic subject but also a vital tool used in diverse fields like science, engineering, technology, finance, and healthcare (National Research Council, 2022). For example, it provides the framework for scientific models, powers algorithms in computers, helps predict market behavior, optimizes logistics, predicts weather patterns, and develops artificial intelligence. All these advancements take place within educational settings, where teaching and learning are essential for nurturing the understanding and application of mathematical principles.

In education, mathematics is considered a core subject taught from primary to secondary school, serving as a prerequisite for admission to higher education institutions (Federal Republic of Nigeria, 2013). It provides students with the necessary skills to analyze and solve complex problems, develop logical thinking abilities, and make informed decisions. A strong foundation in mathematics is vital for success in higher education and future careers, as it is often a prerequisite for fields such as science, technology, engineering, and mathematics (STEM). It is an essential subject that plays a pivotal role in students' academic success and future career prospects. By mastering mathematics, students gain confidence in their abilities to tackle challenging problems and develop a growth mindset, which is essential for lifelong learning and personal development.

A poor foundation in mathematics at the secondary school level can have significant implications for future achievement in the subject. Mathematics is a cumulative discipline, where concepts and skills build upon one another. Without a solid understanding of the foundational principles and fundamental concepts, students may struggle to grasp more advanced topics and apply mathematical reasoning effectively. A weak foundation can lead to difficulties in problem-solving, critical thinking, and logical reasoning, hindering students' ability to succeed in higher-level mathematics courses and limiting their academic and career opportunities that require mathematical proficiency (Wriston, 2015).

Despite the perceived importance of mathematics, there has been a lack of improvement in students' achievement in the subject at the final secondary school examination over the years, as observed and reported by WAEC Chief Examiners (West African Examinations Council, 2020). This indicates a pressing issue in mathematics education. Senior secondary school students face numerous challenges when learning mathematics, including difficulties in comprehending mathematical concepts, employing effective problem-solving strategies, and avoiding common errors. These errors include calculation mistakes, misconceptions, lack of attention to detail, misinterpretation of problem-solving prompts, etc. Such challenges significantly impact students' overall performance in mathematics and hinder their ability to apply mathematical knowledge and skills proficiently. Based on the report of the Chief Examiner of Mathematics (West African Examinations Council, 2020), it was observed that students commonly commit errors in specific areas of mathematics, including coordinate and circle geometry, trigonometry, three-set problems, word problems involving simultaneous equations, bearing and distance, and differential calculus. When students learn mathematics, they often make mistakes or errors in their calculations, reasoning, or problem-solving approaches. Identifying these errors is important because they can hinder the development of important skills needed for problem-solving, logical thinking, and informed decision-making.

The concept of an error is often employed with nuanced variations and is sometimes used interchangeably with related terms like misunderstanding, slip, and mistake. According to Gardee and Brodie (2015, 2022), a distinction can be made between errors and slips. They propose that errors occur at a deeper conceptual level compared to slips, which are typically caused by carelessness or momentary lapses in attention. Errors, as described by Gardee and Brodie, are systematic in nature and stem from misconceptions or incorrect interpretations resulting from overgeneralizations of prior knowledge. These errors are rooted in fundamental misconceptions and can lead to persistent misunderstandings or flawed reasoning. On the other hand, slips are often characterized by minor, unintentional mistakes that occur due to lapses in attention, lack of focus, or carelessness. Slips are typically not associated with conceptual misunderstandings and may be more easily rectified or corrected once recognized.

The presence of errors in various fields, such as mathematics, measurement, data analysis, programming, or other domains, has significant implications for the reliability and accuracy of results (Pressman, 2016). Errors can arise from a variety of sources, including human factors, limitations of measurement instruments, approximations, or misconceptions. These errors can lead to flawed conclusions, inaccurate predictions, or compromised system performance. Mathematical errors refer to those pervasive errors that students make based on the difficulties they have experienced when dealing with mathematical problems (Herholdt & Sapire, 2014). In mathematics, an error refers to a deviation or mistake made during calculation, measurement, or the interpretation of mathematical concepts or results. Errors can provide opportunities for learning if the reasoning and underlying errors can be identified and explored as part of learning activities.

Various types of mathematics errors have been described in the research literature depending on the research purposes and theoretical approaches: visual-spatial errors, comprehension errors, transformation errors, relevance errors, fact errors, procedural errors, measurement errors, presentation errors, conceptual errors, wrong Operational errors, defective algorithm and computational errors (Rong & Mononen, 2022). In this study, the following four errors were used: conceptual errors, wrong operational errors, defective algorithms, and computational errors.

Conceptual Error occurs because the student has misunderstood the underlying concept or has used the wrong logic (Chamundeswari, 2014). Conceptual errors could be classified into four which include; incorrect use of formula, misinterpreting concepts, mistyping formula and not writing equations to answer questions. Computational errors happen when students understand the concept but make careless errors in computation. These are mistakes made when multiplying, dividing, adding or subtracting. The process was completed correctly and the student usually has a solid understanding of the concept, but somewhere along the way, they miscalculated. These may seem like more simple errors but they can really weaken the performance of students. Defective algorithm is when correct operation is applied but error in the procedure. This procedural error occurs when different procedures are used to answer the question and provide slightly different answers. The error within a procedure or steps that causes the result not to be as intended. Wrong operation errors refer to errors that occur when an incorrect operation is performed in solving problems. When operation performed is different from the expected one. Students, regardless of gender commit mathematics errors.

Gender, as defined by the World Health Organization (2019), refers to the societal and cultural expectations, roles, behaviors, and activities that are attributed to individuals based on their perceived identity as male or female. Gender disparities in mathematics learning and academic achievement have been a longstanding issue in education. Research has shown that there are significant differences between male and female students' mathematics achievement (Oribhabor, 2019). These findings suggest that gender differences in mathematics achievement may be linked to differences in error patterns. Analyzing error patterns and gender differences may help to develop effective interventions to improve mathematics learning outcomes for all students.

The occurrence of errors in learning mathematics among secondary school students in Nigeria has raised concerns due to the subject's crucial role in the country's growth and development. Various researchers have identified factors contributing to the commission of these errors, including poor teaching methods, ineffective communication skills, and a lack of technical know-how in improvisation (West African Examinations Council, 2020). Unfortunately, teachers have struggled to address these errors adequately, as there is a scarcity of studies investigating the specific types of errors committed by students, leading to weak performance in senior secondary school examinations.

Research Questions

In attempt to diagnose error patterns of students mathematics achievement among senior secondary schools in Owerri municipal of Imo state, the following research questions guided the study: (RQ1) What are the types of errors committed by senior secondary school students in the achievement of mathematics?; (RQ2) What type of error is mostly committed by male students? (RQ3) What type of error is mostly committed by female students?

Null Hypothesis

Null Hypothesis (H0): There is no significant difference in the error patterns in mathematics achievement between male and female senior secondary school students in Owerri Municipal Council, Imo State

RESEARCH METHODS

The study adopted a descriptive survey research design, which is characterized by the systematic collection, analysis, and interpretation of data to describe a phenomenon. In this case, the focus was on analyzing and establishing the errors made by senior secondary school students in mathematics within the context of Owerri Municipal Council, Imo State. This study was carried out in Owerri municipal L.G.A which came into existence in 1996. This city was found due to the British influence and colonization in the early 1900s, Owerri town was the headquarters for Owerri Division and later old Owerri Province. Also, when Imo State was created on the 3rd of February 1976, Owerri city was chosen as its capital. On the 15th of December 1996 Owerri city attained municipal status. Owerri Municipal has an urban setting with one autonomous community made up of 5 indigenous kindred (Owerre Nchi ise) vis: Umuororonjo, Amawom, Umuonyeche, Umuodu and Umuoyima, under the rulership of one paramount traditional ruler. Its population is about 201,420 as at 2015 census. The other areas that make up Owerri Municipal include: Ikenegbu Layout, Shell Camp, Aladinma; Housing Estate, New Owerri as well as Trans-Egbu. Also, Owerri Municipal Council area shares geographical boarder with Owerri North and Owerri West Local Government Area. Most of the people in Owerri Municipal are traders, civil servants, politicians, artisans, academician farmers and different other professional field.

The study reviewed two theories: Thorndike's Trial and Error Theory, which suggests individuals attribute success to their abilities and failure to external factors, and Attribution Theory, which examines how individuals explain outcomes as either internal or external factors. The targeted population for the study comprised of only senior secondary class three (SS3) students in public schools in Owerri Municipal Council of Imo State, Nigeria. The total population of the SS3 students in Owerri Municipal Council is 2884. This formed the total population of the study. The sample was made up of 150 SS3 students in Imo State. A random sample of five (5) public secondary schools in Owerri Municipal using simple random sampling techniques (balloting without replacement). From each school, thirty (30) SS3 students' mock scripts was randomly selected for the study which is 5.2 percentage of the population.

Two instruments were employed for data collection: the Mock Mathematics Essay Score Sheet (MMESS) and the Mathematics Error Identification and Classification Checklist (MEICC). The test item (1-10) was the number of essay questions in mock examination. Mathematics Error Identification and Classification Checklist (MEICC) was used to identify the four types of errors 1 Conceptual Errors, 2 Computational Errors, 3 Defective Algorithm, and 4 Wrong Operational Errors. The instruments were validated by experts. The Cohen's Kappa yielded coefficient of 0.78 for MEICC indicates substantial reliability. The researcher analyzed the errors using the drafted Mathematics Error Identification and Classification Checklist (MEICC). The data collected were analyzed using frequency, percentage and Chi-square. Decision rule: p-value<0.05=α, we reject the null hypothesis. If p-value>0.05=α we accept null hypothesis.

RESEARCH RESULTS

The presentation of results followed the sequence of the research questions and hypothesis raised.

Table 1. Analysis of errors committed by all students in learning mathematics

Error types	Number of students	Frequency	Percentage (%)
Computational	150	411	36.86
Conceptual	150	203	18.21
Defective algorithm	150	190	17.04
Wrong Operational	150	311	27.89
Total		1115	100.00

Table 1 shows that among the errors made by students in learning mathematics, 36.86% were associated with computational issues, totaling 411 occurrences out of 1115. Conceptual errors accounted for 18.21% of the total errors, reflecting 203 instances out of 1115. Additionally, 17.04% of the errors were identified as defective algorithm errors, amounting to 190 occurrences. Wrong operational procedures constituted 27.89% of the errors, with 311 instances out of 1115.

Table 2. Analysis of errors committed by male students

Error types	Number of students	Frequency	Percentage (%)
Computational	64	133	31.00
Conceptual	64	66	15.38
Defective algorithm	64	80	18.65
Wrong Operational	64	150	34.97
Total		429	100.00

Table 2 reveals that computational errors, specifically issues related to calculations, were the most prevalent, accounting for 31.00% of their errors. This corresponds to 133 occurrences out of a total of 429 errors. Additionally, conceptual errors constituted 15.38% of the errors, with 66 instances, while defective algorithm errors were observed at 18.65%, totaling 80 instances. The highest percentage of errors, 34.97%, was attributed to wrong operational procedures, with 150 occurrences.

Table 3. Analysis of errors committed by female students

Error types	Number of students	Frequency	Percentage (%)
Computational	86	278	40.53
Conceptual	86	137	19.97
Defective algorithm	86	110	16.03
Wrong Operational	86	161	23.47
Total		686	100.00

Table 3 shows that among these errors, computational issues were the most prevalent, accounting for 40.53% of the total errors, with 278 occurrences out of 686. Conceptual errors constituted 19.97% of the errors, with 137 instances, while defective algorithm errors represented 16.03% of the total errors, totaling 110 occurrences. Additionally, wrong operational procedures comprised 23.47% of the errors, with 161 instances out of 686.

Table 4. Summary of Chi-square analysis

Error Types	Gender				χ^2
	Male		Female		
	Observed	Expected	Observed	Expected	
Computational	133	158.13	278	252.87	23.09
Conceptual	66	78.10	137	124.90	
Defective algorithm	80	73.10	110	116.90	
Wrong Operational	150	119.66	161	191.33	
Total	429	429	686	686	

Note: Degree of freedom $(r\text{-}1)(c\text{-}1)=3$; Chi-square table value at $\alpha=0.05$ is 7.815.

From the Chi-square analysis in Table 4, the statement of the hypothesis is rejected; implying that there is a significant difference in the errors committed by male and female secondary students in Owerri Municipal Council of Imo State.

This is because the Chi-square calculated is greater than the critical value at 0.05 alpha level.

DISCUSSION

From the results of the findings, shows that the major errors committed by senior secondary school students in learning mathematics are computational, conceptual, defective algorithm, and wrong operational errors. Computational errors were the most prevalent among senior secondary school students in Owerri Municipal Council, accounting for 36.86%, while 17.04% of the errors were identified as defective algorithm errors, indicating a lower occurrence. The findings corroborate with Omosewo and Akanbi (2013), who conducted research on the analysis of errors committed by physics students in secondary schools in Ilorin Metropolis, Nigeria. Both the study on senior secondary school students in mathematics and the research on physics students in secondary schools likely share similar educational contexts and challenges. Common issues such as curriculum structure, teaching methodologies, or educational resources may contribute to comparable error patterns across different subjects. These errors may be attributed to carelessness on the part of students. The study provides insights into error patterns in mathematics learning among secondary school students, informing evidence-based practices and policy decisions to improve teaching and learning outcomes.

The study's findings revealed that wrong operational errors were the most common among male students. These findings corresponded with the research conducted by Arhin and Hokor (2021), where they indicated that a substantial number of errors made by students occurred during the transforming, processing, and encoding stages. The challenges may arise from students' difficulties in accurately transforming mathematical problems into absolute results, leading to misinterpretations and misrepresentations in their solutions. This correspondence highlighted a shared theme between the errors identified in the present study and those emphasized by Arhin and Hokor (2021), emphasizing the need to address challenges related to the transformation and interpretation of mathematical problems to enhance overall understanding and accuracy in mathematical operations among students.

The study revealed that the most common error committed by female students is computational error. This implies that a significant portion of mistakes made by female students in the study pertains to inaccuracies or challenges in mathematical calculations. Computational errors may stem from challenges in mastering foundational arithmetic skills. If students have not fully grasped basic mathematical operations, it can result in inaccuracies during more complex calculations. Computational errors often arise due to a lack of attention to detail. Students might overlook or misinterpret specific numerical values or operational symbols, leading to miscalculations. Misunderstandings in the step-by-step procedures of mathematical problems can contribute to computational errors. Students may struggle with the correct sequence of operations or the application of mathematical rules.

There was a significant difference in the errors committed by male and female secondary students in Owerri Municipal Council of Imo State. The findings of the study revealed that the total frequency of errors committed by female students was significantly higher than that of their male counterparts. This finding contradicted Omosewo and Akanbi's (2013) research, where the total frequency of errors committed by male students was reported to be significantly higher than that of their female counterparts. This discrepancy in results emphasized the variability in academic performance and error patterns across different regions and contexts, highlighting the importance of considering local factors and nuances in educational research. It also prompted a deeper exploration into the specific factors that contributed to gender-based differences in error rates in mathematics education within the Owerri Municipal Council. The study reveals significant gender-based differences in error rates, with female students committing more errors overall compared to their male counterparts. This finding challenges conventional assumptions and highlights the need to consider gender as a factor in understanding and addressing error patterns in mathematics education.

CONCLUSION

The discussion highlights the major errors observed among senior secondary school students in mathematics learning in Owerri Municipal Council, Imo State, including computational, conceptual, defective algorithm, and wrong operational errors. While interviews were not conducted as part of the study, the analysis provides insights into potential root causes of these errors and their implications for education.

Based on the findings of the study, it was concluded that senior secondary school students predominantly commit major errors in computational, conceptual, defective algorithms, and wrong operational areas. The most common error among male students is the wrong operational error, whereas among female students, computational errors are most frequently observed. A significant difference in error patterns between male and female secondary students in Owerri Municipal Council of Imo State was also identified.

Recommendations Based on the findings of the study, the following recommendations are proposed. Firstly, adopt appropriate teaching methods. Teachers should employ suitable teaching methods, particularly for mathematical concepts requiring practical approaches. Practical demonstrations can aid students in visualizing and understanding the fundamental elements necessary for mastering complex concepts. Secondly, follow a sequential order in teaching. Teaching and learning should follow a sequential order, introducing mathematics concepts from simple to complex. Maintaining a logical progression is crucial to prevent students from feeling disconnected or overwhelmed in the learning process. Thirdly, provide feedback and follow-up. Mathematics teachers should actively engage in evaluating and providing feedback on errors made by students. Additionally, regular follow-ups after class or home activities are essential to reinforce learning and address any misconceptions. Fourthly, emphasize problem-solving skills. Teachers should expose students to problem-solving scenarios to enhance their problem-solving skills. Practical problem-solving experiences contribute to a deeper understanding of mathematical concepts. Fifthly, encourage cross-checking of work. Teachers should emphasize the importance of students cross-checking their work after examinations. This practice not only reinforces accuracy but also instils a habit of careful review, reducing the likelihood of errors. Sixthly, present topic content precisely. To avoid confusion, teachers should present topic content in a concise and clear manner. Clarity in instruction contributes to better comprehension and application of mathematical concepts among students.

The study's findings have important implications for science education and curriculum planning in Nigeria. It highlights the need for teachers to address specific errors in computational, conceptual, algorithmic, and operational areas among secondary school students. The study provides students with valuable insights into common errors in mathematical operations, allowing them to reflect on their own approaches and take proactive measures to avoid these errors. Curriculum planners can use the study's feedback on students' weaknesses to make necessary adjustments to the curriculum content, ensuring it remains flexible and responsive to the needs of teachers and students. The government also plays a crucial role in improving learning standards and supporting initiatives to overcome identified errors in mathematics education.

Further research could explore these issues through triangulation with interviews to enhance the depth of analysis and inform targeted curriculum and instructional design strategies. Additionally, longitudinal trends in error patterns and assess the effectiveness of intervention strategies in improving mathematical proficiency. The study focuses on Owerri Municipal Council in Imo State to understand the factors specific to the region that may influence error patterns in mathematics learning, which is important for developing targeted interventions for local students.

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Exploring the Students' Mathematical Communication Ability Related to Learning Style Appertaining to Junior High School

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Abstract

The scarcity of mathematical communication abilities needed attention along with students' learning styles as a personal characteristic causing these abilities to differ. This descriptive study aimed to determine the mathematical communication abilities of students with specific learning styles. Eighth-grade public junior high school students (N=23) in Lembah Gumanti participated in this study to complete a learning style questionnaire and a mathematical communication abilities test. The study found that the visual learning style was most dominant, with the highest percentages in the high and low ability categories, and equal to auditory in the medium category but lower than kinesthetic. Students with a kinesthetic learning style in the low and high ability categories both had the same percentage as students with an auditory. There were strong mathematical communication abilities in the dual learning style of auditory-kinesthetic. Auditory students, regardless of their ability levels, made errors in mathematical symbols, so their communication abilities varied based on understanding and symbol usage. Visual and kinesthetic learners generally excelled in articulating and solving problems. Based on these results, it is recommended that teachers consider students' learning styles to be able to use appropriate models to improve students' mathematical communication abilities.

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INTRODUCTION

Mathematics serves as a symbolic language that allows for fair and accurate communication. According to Astuti (2017), the purpose of learning mathematics is for students to be able to communicate ideas, make conclusions, and synthesize evidence in the form of sentences, complete tables, icons, diagrams, and so on to solve existing problems. Thus, communication abilities are required in mathematics learning to support learning achievement and to convey ideas or concepts related to subjects between teachers and students or between students and other students.

Communication is an important part of teaching mathematics (National Council of Teachers of Mathematics [NCTM], 2000; Widyanti et al., 2021). One of the five process standards highlighted in NCTM is communication. The others are problem solving, arguing and providing, communicating, connecting, and representing. As a result, when learning mathematics, students must have mathematical communication abilities in order to solve problems.

Mathematical communication is the ability to connect and explain one or more ideas using mathematical patterns such as sentences and mathematical equations, graphs and diagrams, and tables (Widyanti et al., 2021). Mathematical communication abilities are important in academic programs that aim to prepare students for the ability to construct and communicate mathematical thinking in English, the language of mathematics, to peers and teachers in a clear and accurate manner. To accomplish all of this, several factors must be carefully considered, one of which is the student's learning style, which will later facilitate and help these students.

According to Hariyanto (2017), students' mathematical communication abilities are still considered weak, particularly in conveying their mathematical ideas, being unable to reason well, understanding a situation, or expressing problems in the form of symbols, diagrams, or mathematical models. Meanwhile, Munawaroh et al. (2018) observes that the mathematical communication abilities of students' oral and written results are still relatively weak. The subject's facts also show that students' mathematical ideas are not properly conveyed when confronted with math problems.

Students' mathematical communication abilities are closely related to students' ability to solve story problems. Solving math problems in the form of word problems is one way to assess mathematical understanding and communication. Pritananda et al. (2016) and Wahyuddin (2017) emphasized that the task of presenting words is one of the tasks for problem solving. Word problems are math problems in which sentences in the form of stories must be converted into mathematical sentences or mathematical equations (Widyaningrum, 2016). Word problems frequently employ commonplace words or phrases in the form of a series of simple and meaningful sentences. Students understand how to solve math problems, including the steps to solving polya problems. The benefit of using polya steps is that students can be cautious when analyzing tasks based on the problem-solving process (Anwar & Amin, 2013). Therefore, at the final stage of Polya, a review of the calculations was carried out, the purpose of which was to find a solution to the problem and validate all data.

Every student has a unique way of comprehending and communicating the same information. According to Wulandari et al. (2014), students' ability to communicate their mathematical ideas is related to how they receive, organize, and process information. A person's learning style refers to how they receive, organize, and process information when learning (Wijayanti et al., 2019). Even if students are in the same school or class, they all have a different learning style, and their ability to communicate mathematical ideas varies. This also refers to how students absorb, process, and manage the information they are given during the learning process. Students' mathematical communication abilities influence students' ability to solve mathematics problems (Kusuma et al., 2020).

Students’ learning style influence students’ performance (Ramadoni, 2023). According to Syarifah et al. (2017), a person's learning style refers to their ability to absorb, assimilate, and process information. Learning styles are divided into three types: visual, auditory, and kinesthetic. Because visual learners are more likely to use sight to aid learning, they prefer to learn by seeing, observing, and describing things. Students with an auditory learning style use their listening abilities to help them learn. Students who learn actively use more physical parts as learning tools. Research by Sari (2017) supports this, demonstrating that learning styles can have a significant impact on mathematical communication abilities, as students who learn in this style generally have better mathematical communication abilities. Visual, auditory and kinestetic learning styles affect students' mathematical abilities (Handayani et al., 2023; Ikawati & Kowiyah, 2021).

The Pythagorean material is one of the mathematics subjects taught to junior high school students. The Pythagorean theorem is important to learn because it is a fundamental concept for calculating mathematical concepts and is useful for solving everyday problems (Alghadari & Noor, 2020; Manalu et al., 2020). According to Fajriah and Nor (2017) research on Pythagorean Theorem material, students' mathematical communication is severely lacking in terms of expressing mathematical ideas through writing and visual descriptions. According to Priyanto et al. (2015), students made 43% reading errors, 46% understanding errors, 49% problem transformation errors, 55% procedural skill errors, and 61% final answer writing errors when solving Pythagorean theorem questions. Another mistake made by students was discovered in Hasan et al. (2019) research, which revealed that at the concept stage, the subject made a mistake in drawing a right triangle and finding the hypotenuse, a procedural error in taking roots. Students often make conceptual errors when working on mathematics problems (Ramadoni & Shakinah, 2023). Whereas, Students' conceptual abilities are essential for students' success in learning (Ramadoni & Mustofa, 2022; Ramadoni & Chien, 2023).

RESEARCH METHODS

This study employs a quantitative descriptive approach with the goal of describing students' mathematical communication in solving Pythagorean theorem problems based on student learning styles. A quantitative approach is thought to be capable of explaining events or phenomena in their entirety (Mamik, 2015). The description is carried out through direct observation, specifically analyzing the results of tests administered to research subjects and the results of a learning style questionnaire to classify student learning styles, namely visual, auditory, and kinesthetic, as well as interviews conducted to obtain strong data regarding the results of tests administered to students.

A quantitative research method, according to Sugiyono (2017), is a research method based on the philosophy of positivism that is used to examine the condition of natural objects. This study was carried out in class VIII SMP N 05 Lembah Gumanti from January 19 to January 26 2023, during the even semester of the 2022/2023 Academic Year. The sampling technique used in this study was purposive sampling. Purposive sampling is a technique for selecting respondents to be sampled based on specific criteria (Siregar, 2014). The subjects of the study were eighth-grade students. The subjects were selected based on the scores of many students who were below the minimum ability criteria limit, namely 60%, as well as recommendations from the class VIII mathematics teacher at SMP N 05 Lembah Gumanti, so they became research subjects. There are 23 students in class VIII of SMP N 05 Lembah Gumanti.

In this study, questionnaires and written tests were used to collect data. The questionnaire used in this study is designed to categorize student learning styles. This questionnaire is written in the form of a statement, making it simple to identify students' learning styles, whether visual, auditory, or kinesthetic.

RESULTS AND DISCUSSION

Data on mathematical communication abilities and student learning styles were obtained as a result of the research. Data on students' mathematical communication abilities were obtained from processing test data, and data on learning styles were obtained from questionnaires and student interviews.

Students Learning Style

Table 1 shows data categories on learning style questionnaire results based on the total score of each visual, auditory, and kinesthetic learning style.

Table 1. Number of students in the learning style category

	Visual	Auditory	Kinesthetic	Auditory-Kinesthetic
Total	11	5	6	1
Percentage	47.83%	21.74%	26.08%	4.35%

According to Table 1, the majority students have visual learning style with 47.83% students, moreover 21.74% students have auditory learning style, furthermore 26.08% have kinesthetic learning style, and some had a dual learning style, specifically the auditory-kinesthetic learning style of 4.35%.

Student Distribution by Communication Abilities and Learning Styles

The mathematical communication ability test was administered. As respondents, 23 students took the test. Table 2 present the distribution of respondents in the categories of learning styles and mathematical communication.

Table 2. Respondents by communication abilities and learning styles

Learning Style	Communication Ability (%)			
	High	Medium	Low	Total
Visual	21.74	4.35	21.74	47.83
Auditory	4.35	4.35	13.04	21.74
Kinesthetic	4.35	8.70	13.04	26.08
Auditory-Kinesthetic	4.35	0	0	4.35
Total	34.78	17.39	47.83	100

Table 2 shows that mathematical communication abilities are based on varied learning styles; each student has a different learning style, and the most dominant was the visual learning style (47.83%), with a higher percentage than other types in the high ability category (21.74%) and low ability category (21.74%), while in the medium ability category (4.35%), it was not higher than the kinesthetic learning style (8.70%) and was equal to the auditory learning style. Students with a kinesthetic learning style comprised 26.08%, where the low ability category (13.04%) and the high ability category (4.35%) both had the same percentage as students with an auditory learning style. The auditory-kinesthetic learning style had a percentage of 4.35%, and that was with strong mathematical communication abilities. Based on this analysis, it can be concluded that the majority of students had a visual learning style but poor mathematical communication abilities.

Student Ability and Characteristics Analysis

The researcher chose the following research subjects after learning about the students' learning styles and mathematical communication abilities.

Table 3. Research subjects

Students Code	Learning Style	Communication Ability
KZ	Visual	High
RR	Visual	Medium
YD	Auditory	High
FRH	Auditory	Low
MP	Kinesthetic	High
H	Kinesthetic	Medium

High Communication Ability with Visual Characteristics

KZ subjects correctly answered all of the mathematical communication ability test by meeting all of the indicators on the given problem. The questions posed. The results of the mathematical communication abilities test will be analyzed on the KZ subject with the question "If the lengths of the sides of a right triangle are *x*, 15, and *x*+5, respectively, what is the value of *x*?"

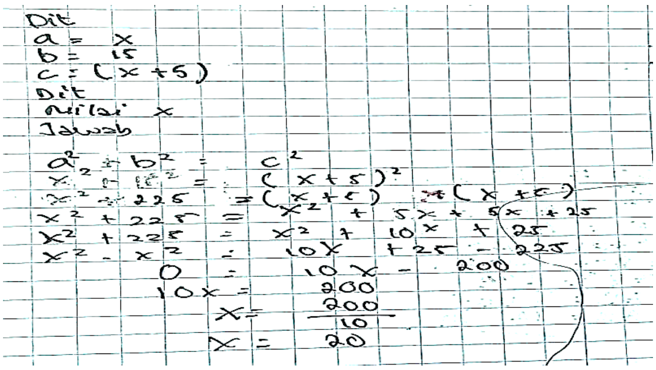


Figure 1. The KZ's answer

According to Figure 1, the KZ subject's answers were able to write down complete information about the Pythagorean theorem problem, where students were able to translate the information contained in the problem into the form of a mathematical model. Furthermore, students were able to express ideas or situations in mathematical form and solve them. This is consistent with the report of the study by Rezky et al. (2022) and Ugi et al. (2023).

Medium Communication Ability with Visual Characteristics

The RR subject correctly answered all of the mathematical communication ability test results, but there were errors in the symbols used. The results of the RR subject's mathematical communication ability test will be analyzed as question number 3 with the question: "A child will pick up a kite that is stuck on a wall directly adjacent to a gutter." The child wishes to retrieve the kite by placing the ladder's foot on the river's edge. If the width of the ladder is 9 cm and the length is 15 cm. Determine the height of the walls that meet at the end of the ladder where the kite has become entangled!

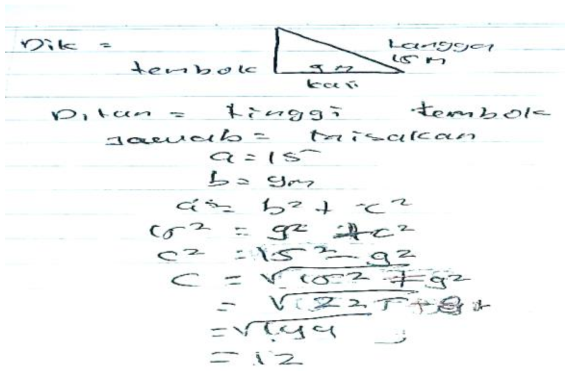


Figure 2. The RR's answer

According to Figure 2, the RR subject can write down known information, where students have been able to translate the information contained in the problem into a mathematical picture but have not been able to make a statement about the picture. Furthermore, students have been able to respond in writing by explaining ideas or situations in mathematical form. With a total score of 21, RR subjects can also write down information using writing, pictures, or other mathematical models. This is consistent with the report of the study by Rezky et al. (2022).

High Communication Ability with Auditory Characteristics

Subject YD correctly answered all of the questions on the mathematical communication ability test, but there were still errors in the symbols used. The results of the mathematical communication ability test on subject YD will be analyzed as question number 2 with the question: "A ship sails from port C to the south towards port A as far as 90m." Then return to the east, towards port B, for another 120m. Determine the shortest distance between ports B and C!"

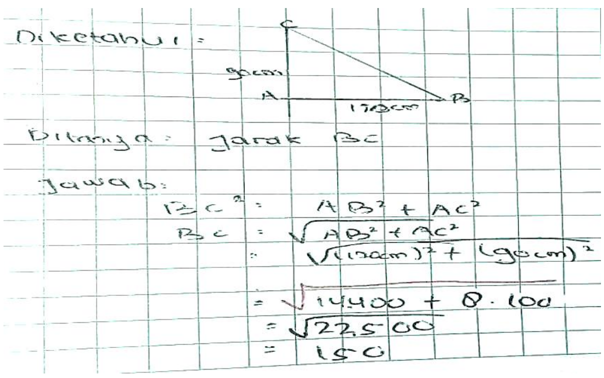
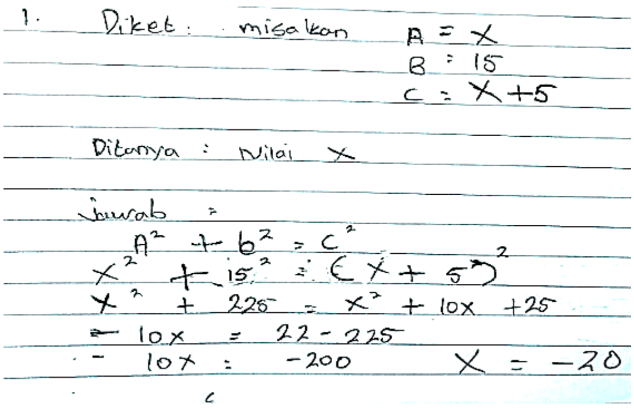


Figure 3. The YD's answer

Figure 3 shows that YD subjects can write down known information using pictures, and that students can translate the information contained in the problem into mathematical pictures and make statements about these pictures. Furthermore, students were able to write down and explain ideas or situations in mathematical form. This is not different from the study report by Nugroho et al. (2021). Besides that, YD can also write down information using writing, pictures, or other mathematical models, but in this problem, YD still makes mistakes in the symbols he uses when solving Pythagorean theorem questions, and his total score is 23, thus these findings differed from the study by Rezky et al. (2022).

Low Communication Ability with Auditory Characteristics

The FRH subject correctly answered all of the mathematical communication ability test results, but there were errors in the symbols used. The results of the FRH subject's mathematical communication ability test will be analyzed as question number 1 with the question: "If the lengths of the sides of a right triangle are x, 15 and x+15, respectively, determine the value of x!"


1. Diket : misalkan $A = x$

$B : 15$

$C = x+5$

Ditanya : Nilai x

Jawab =

$A^2 + b^2 = c^2$

$x^2 + 15^2 = (x+5)^2$

$x^2 + 225 = x^2 + 10x + 25$

$- 10x = 22 - 225$

$- 10x = -200$ $x = -20$

Figure 4. The FRH's answer

Figure 4 shows that FRH subjects can write down known information using examples to help them solve problems involving the Pythagorean theorem. Students were able to translate the problem's information into the form of a mathematical model. This is not different from the study report by Nugroho et al. (2021) and it was in contrast to the findings in the study by Rezky et al. (2022). Furthermore, students were able to write down and explain ideas or situations in mathematical form. With a total score of 23, FRH subjects continue to make errors in the symbols used when solving Pythagorean theorem questions.

High Communication Ability with Kinesthetic Characteristics

The MP subject correctly answered all of the mathematical communication ability test results. The results of the mathematical communication ability test, which will be analyzed on MP subjects, are question number one, with the question: "If the lengths of the sides of a right triangle are x, 15, and x+15, determine the value of x!"

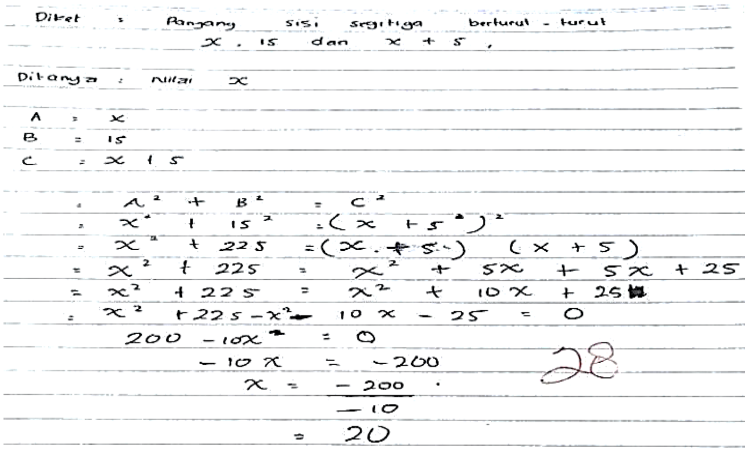


Figure 5. The MP's answer

Figure 5 shows that the MP subject can write down the known information by using an example to make solving problems involving the Pythagorean theorem easier. Furthermore, with a total score of 28, students were able to explain ideas or situations in written mathematical form. Such student abilities were also revealed in the findings of the studies by Rezky et al. (2022) and Abdillah et al. (2022).

Medium Communication Ability with Kinesthetic Characteristics

Subject H only responded to one result of the mathematical communication ability test by drawing pictures and writing captions on them. The results of the mathematical communication ability test that will be analyzed on subject H are question number 1 with the question: "If the lengths of the sides of a right triangle are *x*, 15, and *x*+15, calculate the value of *x*!"

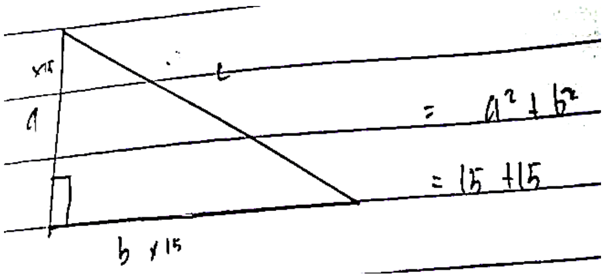


Figure 6. The H's answer

Figure 6 shows that subject H only took pictures and did not answer question number 1. As a result, the only ability fulfilled is the ability to express situations using mathematical writing and images on the Pythagorean theorem problem. Subject H did not work on questions 2 and 3, so his total score was 2. He only met the indicators of expressing situations using writing, pictures, or other mathematical models, as also stated by Rezky et al. (2022).

CONCLUSION

In accordance with research findings, the majority of students were in the visual learning style (47.83%), with a higher percentage than other types in the high mathematical communication ability category (21.74%) and low ability category (21.74%), while in the medium ability category (4.35%), it was not higher than the kinesthetic learning style (8.70%) and was equal to the auditory learning style. Students with a kinesthetic learning style comprised 26.08%, where the low ability category (13.04%) and the high ability category (4.35%) both had the same percentage as students with an auditory learning style. Additionally, the auditory-kinesthetic learning style had a percentage of 4.35%, and that was with strong mathematical communication abilities. This study revealed that auditory students in both the high and low ability categories made errors in the symbols they used in the solving process. Students with an auditory learning style exhibited variations in mathematical communication skills, depending on the level of understanding and the use of mathematical symbols. Students with visual and kinesthetic learning styles generally demonstrated better abilities in articulating and solving problems.

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Comparative Analysis of Data Analysis and Probability Topics between IB and Non-IB Mathematics Textbooks

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Abstract

It is imperative to explore the organization of contemporary teaching and learning methods in data analysis and probability within mathematics curricula, with a specific focus on comparing non-IB and IB approaches. This study analyzed how the contemporary teaching and learning of data analysis and probability was organized through an analysis of two textbooks as an intended mathematics curriculum (non-IB and IB respectively) by discussing similarities and differences between the two. It employed content analysis method to examine structural features, technology usage, and real-life connections by focusing on the topic in depth, exploring content, organization, and representation. This study results disclosed that both open-ended and closed-ended item formats were recommended, without clear superiority. Descriptive examples and percentages were provided to guide curriculum developers and support teachers in enhancing student learning outcomes. The study hopes to assist middle school students in achieving higher scores in international assessments such as PISA and TIMSS. It emphasizes the potential for revising mathematics curricula and textbooks to better meet students' needs, drawing inspiration from the success of the IB program.

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INTRODUCTION

Textbooks play a significant role in shaping the curriculum and teaching practices in classrooms (Weinberg & Wiesner, 2011). It is important to investigate the similarities and differences between Turkish mathematics textbooks recommended by the Ministry of National Education's (MoNE) Middle School Mathematics Programme and the Middle Year Programme mathematics textbooks used in international schools following the International Baccalaureate (IB) programme. Given the need, the focus of a needed study should specifically be on the treatment of data analysis and probability concepts, with the knowledge of consistently reported students' difficulty with this topic (Andini & Jupri, 2017; Buforn et al., 2022).

Data analysis and probability is a popular concept of mathematics. The first foundations of knowledge of data analysis are laid starting from primary school, and in high school (i.e. upper secondary education) (the K-12 curriculum), it culminates into great detail with an emphasis on probability concept (Altunsaray & Baltacı, 2023). Data analysis and probability is related to daily life. We use the knowledge and skills of this concept to calculate and solve problems in different sciences. According to the National Council of Teachers of Mathematics (2000), it is emphasized among significant mathematics content standards: (a) Numbers and operations, (b) Algebra, (c) Geometry, (d) Measurements, and (e) Data Analysis and Probability. Each concept should be taught and learnt based on the child's age, developmental level and concept specific needs. Mathematics teachers use different instructional activites, real life examples, make students engaged in hands-on or technology-based activities, 3D and concrete materials, create mathematical tasks to cultivate students, and technology supported learning activities (e.g., Lavidas et al., 2022; Zorzos & Avgerinos, 2022) so that students can develop mathematical knowledge and learn mathematical thinking skills in an effective and efficient way. Hence, the paradigm shift adopts from teacher-centered to student-centered teaching and learning.

In an increasingly interconnected world, active participation in a global community is crucial, starting with individual human engagement. A collaborative society that continually strives for self-improvement can generate added value in the development process. As individuals enhance their knowledge and skills, they also benefit from the global knowledge and skills that have been developed, leading to mutual growth and exponential development within the society at large. Mathematics education plays a vital role in this process, as it equips individuals with essential problem-solving and critical thinking skills (Hoyles et al., 2022; Saralar, 2020). However, expectations and performance in mathematics vary among students, influenced by factors such as teachers, government policies, and educational systems, which differ from country to country. Various elements, including school climate, teacher beliefs, teaching methods, textbooks, and students' preconceptions, have been proposed to impact mathematics performance (Hoyles et al., 2022; Saralar, 2020). Assessing students' performance on an international scale allows for comparison and evaluation of educational systems worldwide. Two notable international assessments, the Trends in International Mathematics and Science Study (TIMSS) and The Program for International Student Assessment (PISA), are used to evaluate students' mathematics performance. These assessments measure students' knowledge and skills through test responses, providing valuable insights into the strengths and weaknesses of different educational systems.

In the case of Türkiye, the TIMSS 2019 examination revealed that Türkiye ranked 20th out of 39 participating countries at the 8th-grade level (MoNE, 2020). The assessment highlighted that 20% of participating students achieved the highest levels of mathematics proficiency, while another 20% failed to reach even the lowest level of proficiency. Similarly, in the PISA 2018 assessment, Türkiye ranked 42nd out of 79 participating countries (MoNE, 2019). In data analysis and probability, Turkish students demonstrated a diverse range of proficiency levels according to the TIMSS 2019 examination (MoNE, 2019). Approximately 20% of participating students excelled in applying analytical methods and understanding probability concepts effectively. However, a concerning 20% of students struggled to grasp even the foundational aspects of these mathematical domains, reflecting a notable gap in attainment levels across the cohort. These results indicate the need for improvement in Turkish students' mathematical success.

To understand the potential factors contributing to these disparities, it is essential to examine the influence of textbooks on mathematics education outcomes. They provide a structured framework for learning and serve as a primary resource for teachers and students. The content and organization of mathematics topics covered in textbooks can significantly impact students' understanding and performance.

This study analyzes textbooks to identify disparities in data analysis and probability. Its findings could help curriculum developers, teachers, and policymakers enhance mathematics education in Türkiye and elsewhere. Unlike other studies that evaluate the IB curriculum broadly, this research delves into a specific area of mathematics, aiming to improve student outcomes through collaboration between textbook writers and educators.

In conclusion, understanding the challenges and disparities in mathematics education is crucial for developing effective strategies to enhance students' mathematical abilities. This research contributes to this endeavor by examining the content and organization of data analysis and probability topics in Turkish and international school mathematics textbooks (Shukur, 2023). By bridging the gaps and implementing necessary improvements, mathematics education in Türkiye can be strengthened, fostering a more knowledgeable and skilled society ready to tackle the challenges of the global community.

Teaching Non-IB Programmes: Case of Türkiye

The MoNE's mathematics programme, as an example of a non-IB programme, is designed for middle school students, with a specific focus on developing mathematical knowledge and skills across various learning areas. On the other hand, the IB programme offers a comprehensive and interdisciplinary approach to mathematics education, emphasizing critical thinking, inquiry-based learning, and real-world applications. By exploring the features and characteristics of these programmes, we can gain valuable insights into their respective approaches to mathematics instruction and the potential implications for students' academic success and achievement.

The MoNE's Turkish Middle School Mathematics Programme

"Non-IB" is a term used to refer to educational materials, courses, or programs that are not aligned with the IB curriculum. The non-IB programme, in this context, designed for students aged 11 to 14, spans a four-year duration. Unlike the interdisciplinary approach found in IB programmes (which will be discussed in detail below), the non-IB programme outlines specific objectives for each subject area (see Table 1), including Numbers and Probability. The focus of our study, the middle school mathematics programme, encompasses five key learning areas: numbers and operations, algebra, geometry and measurement, data analysis and probability. The stated purpose of the mathematics programme is to foster students' metacognitive knowledge and skills, enabling them to effectively utilize mental prediction and operations, and develop their mathematical literacy skills.

The MoNE in Türkiye provides freely available textbooks for students, which teachers are required to follow when teaching topics within the middle school programme, spanning grades 5 to 8. These non-IB mathematics textbooks employ a multifocal assessment approach, evaluating students' performance at the end of each learning area (presented as units in the textbooks, listed in Table 2). The middle school mathematics programme recommends allocating 180 hours of instructional time each year to teach these learning areas, with specific allocations for each learning objective. Teachers are expected to adhere to the programme guidelines and utilize the suggested textbooks, delivering the units within the prescribed 180-hour timeframe. It is worth noting that the MoNE provides students with freely available textbooks for use across all grade levels, from 1st grade to 12th grade.

Table 1. Non-IB vs. IB textbook contents

Theoretical Frameworks	
Non-IB	Educational philosophy: Pragmatism Approaches: Student-centered learning Technology-enhanced instruction Realistic education
IB	Educational philosophy: Constructivism, Reconstructionism Approach: Inquiry-based learning (to help students develop their personal understanding, their emerging sense of self and responsibility in their community)
Function/Principles (Main aims/ goals)	
Non-IB	"To raise individuals with knowledge, skills and behaviors integrated with our values and competencies." "To give the students the mathematical knowledge and skills required by daily life and to teach problem solving."
IB	"To equip all students with the knowledge, understanding and intellectual capabilities to address further courses in mathematics." "To prepare those students who will use mathematics in their studies, workplaces and everyday life."
Units in the Programmes	
Non-IB	Numbers and Operations, Algebra, Geometry and Measurement, Data Processing and Probability
IB	Number, Algebra, Geometry and Trigonometry, Statistics and Probability
Significance of Subject Area	
Non-IB	While shaping this learning area, the points emphasized in the international exams at middle school level were taken into consideration with the knowledge that data analysis is a part of them.
IB	The significance of data analysis in the IB Programme Mathematics lies in its ability to develop critical thinking skills and provide students with real-world applications of mathematical concepts.

To sum up, the non-IB mathematics programme is structured to provide a comprehensive framework for mathematics education, emphasizing the development of students' metacognitive skills, effective mental operations, and mathematical literacy. The programme's reliance on prescribed textbooks and the allocated instructional hours underscores the importance placed on standardized curriculum delivery across schools in the country.

IB Mathematics Programme

The IB Middle Year Programme (MYP) is designed for students aged 11 to 16 and focuses on fostering the development of creative, critical, and reflective thinkers (IB Programme, 2017). The programme aims to cultivate students' abilities to seek creative and practical solutions, nurture their inquiry skills, promote knowledge acquisition, critical thinking, effective communication, and risk-taking capacities. Mathematics education within the MYP is aligned with these objectives and covers various topics, including statistics (including data analysis), and probability.

In contrast, the non-IB Mathematics Programme in Türkiye is grounded in a pragmatist educational philosophy, emphasizing student-centered learning, technology-enhanced instruction, and realistic education. The program aims to equip students with mathematical knowledge and problem-solving skills relevant to daily life. The specific learning areas include numbers and operations, algebra, geometry and measurement, and data processing and probability.

This study aims to compare the treatment of data analysis and probability subjects in two different textbooks: those aligned with the non-IB mathematics programme and those following the IB mathematics programme. The focus on data analysis and probability stems from research studies indicating lower student success rates in these areas compared to other mathematical topics (Birgili & Aydin, 2020; Mills & Holloway, 2013). Moreover, international examination results have highlighted the need for additional support in these concepts (MoNE, 2015, 2019, 2020).

The background regarding textbook analysis studies in general and data analysis and probability concept in particular illuminated only 2% of the mathematics textbook studies conducted in the last 5 years covering data analysis and probability topics. Having expanded the literature a little further, between the years of 2014-2024, it is seen that the ratio is almost 2.6%. In other words, the current studies could expand the literature with an increase of only 6 per thousand.

It is descriptively obvious that, depending on the importance of the concepts, there is an urgent need for more literature review and evidence based indept textbook analysis to fill the knowledge gap of comparative textbook analysis on the concept of data analysis and probability. To illustrate, Ulusoy and Incikabı (2020) investigated middle school mathematics teacher’s preferences and use of textbooks in their teaching. As a case study, data were collected from 17 teachers in six public schools via semi structured interviews and classroom observations. Because these teachers predominantly relied on textbooks instead of enhancing the learning experience, there was minimal focus on encouraging students to delve deeper into their understanding or explore conceptual meanings, such as reading to solidify or investigate theoretical knowledge of data analysis. Another textbook analysis study between Greece and Singapore conducted by Zorzos and Avgerinos (2022), examined variations in the multidisciplinary approach within the exercises found in those school textbooks. This study found out a need for increasing the number of exercises in Greek textbooks while the variety of frameworks in Singapore books is evident. And both demonstrated a significant degree of incorporating a multidisciplinary approach into their activities during the explanation of data analysis concepts.

By examining the content and approach of textbooks in Australia, Singapore, Türkiye (e.g., Gökçek & Çelik, 2020; Incikabi et al., 2023; Toprak & Özmantar, 2019), we can gain insights into how scientific principles are conveyed and taught, shedding light on their educational system's effectiveness in fostering scientific understanding and methodology. So, the unique contribution of this study is to the comparative textbook analysis literature, we aim to provide insights into the strengths and weaknesses of IB and non-IB textbooks in data analysis and probability concept.

Research Questions

This research aims to address the following questions: (1) How are non-IB and IB’s maths textbooks approached in terms of content related to data analysis and probability?; (2) How is the data analysis and probability unit organized within these mathematics textbooks?; (3) What presentation methods are employed in the data analysis and probability unit of these mathematics textbooks?

RESEARCH METHODS

Research Objectives

The research objectives to be achieved are as follows: (1) to compare and contrast the content related to data analysis and probability in non-IB and IB mathematics textbooks; (2) to examine the organizational structure of the data analysis and probability unit within both non-IB and IB mathematics textbooks; (3) to identify and analyze the presentation methods utilized in the data analysis and probability unit of non-IB and IB mathematics textbooks.

Data Generation and Data Analysis

A systematic and transparent approach known as content analysis was utilized in this study to examine and compare textbooks from two different educational programs: the non-IB mathematics program (MSMP) and the IB mathematics program (IB MP). Following a similar analysis framework of Sağlam and Alacacı's (2012) study, the analysis focused on the structure, thematic emphasis, and special learning assists present in the textbooks. To maintain clarity in this paper, the non-IB mathematics textbook aligned with the Turkish middle school mathematics program will be referred to as "MoNE's maths textbook," while the textbook corresponding to the IB Middle Year Mathematics Program will be referred to as "IB's maths textbook."

Textbooks Used in the Research

The research examined specific textbooks utilized in a non-IB mathematics programme and the IB's mathematics programme. In the non-IB mathematics textbooks, the topic of data analysis is covered in a specific sequence each year, from the 5th to 8th grades in middle schools, with probability introduced in the 8th grade. The textbooks reviewed, along with their corresponding data analysis and probability chapters, are presented in Table 2.

Table 2. Non-IB mathematics textbooks

5th grade	Cırıtcı, H., Gönen, İ., Araç, D., Özarslan, M., Pekcan, N., & Şahin, M. (2019). *Middle School and Imam Hatip Middle School Mathematics 5 Textbook* (pp. 251-263). MoNE Publications.
6th grade	Bektaş, M., Kahraman, S., & Temel, Y. (2019). *Middle School and Imam Hatip Middle School Mathematics 6 Textbook* (pp. 225-256). MoNE Publications.
7th grade	Keskin Oğan, A., & Öztürk, S. (2019). *Middle School and Imam Hatip Middle School Mathematics 7 Textbook* (pp. 255-275). MoNE Publications.
8th grade	Böge, H., & Akıllı, R. (2019). *Middle School and Imam Hatip Middle School Mathematics 8 Textbook* (pp. 63-74). MoNE Publications.

On the other hand, in the IB's maths textbooks, the topic of data analysis is divided into three parts to be taught over five years, namely MYP1, MYP2 and MYP3, where MYP represents the Middle Years Programme. Data analysis is covered in all MYP1, MYP2, and MYP3 books, while probability is included solely in the MYP2 book. The textbooks reviewed, along with their respective data analysis and probability chapters, are presented in Table 3.

Table 3. IB's maths textbooks

MYP 1	Weber, D., Kunkel, T., Simand, H., & Medved, J. (2019). *Middle Years Programme Mathematics 1* (pp. 202-247). Oxford Publications.
MYP 2	Weber, D., Kunkel, T., Martinez, A., & Shultis, R. (2019). *Middle Years Programme Mathematics 2* (pp. 44-87 and pp. 258-301). Oxford Publications.
MYP 3	Weber, D., Kunkel, T., Harrison, R., & Remtulla, F. (2019). *Middle Years Programme Mathematics 3* (pp. 204-255). Oxford Publications.

Procedure of Data Analysis

The initial phase of our data analysis involved thorough examination of both Non-IB and IB textbooks. Subsequently, the unit of analysis was determined to encompass sentences, examples, phrases, and visual representations corresponding to content, organization, and presentational facets within each textbook. Following this, analytical categories were established to identify and categorize elements pertaining to student-centered activities, real-life connections, and technology integration present in the textbooks. The coding and analytical procedures were executed meticulously and systematically, adhering to a predefined framework. This process was conducted by authors possessing expertise in mathematics textbook studies and proficiency in both Turkish and English languages. Finally, the analysis of mathematical items within the textbooks was conducted in accordance with the predetermined analytical framework.

Based on the intra-class correlation coefficient (ICC) measuring absolute agreement, the coders demonstrated reliability ranging from 0.84 to 0.96 across classifications, averaging at 0.93. In instances of disagreement among the three coders, two researchers (experts) in the field acted as consultants. The divergences in analyses were deliberated and resolved through discussions with the two experts, ultimately leading to a consensus (see Table 4 for analysis segments).

Table 4. Distribution of segment assets in two textbooks

Grades (learning outcomes)	Non-IB textbooks (180 hours)	IB textbooks (187 hours)	Grades (learning outcomes)
5th (3)	5.55% (10 hours)	9.60% (18 hours)	MYP 1 (5)
6th (5)	6.10% (11 hours)	7.50% (14 hours)	MYP 2 (4)
7th (4)	8.30% (15 hours)	4.30% (8 hours)	MYP 3 (4)
8th (2)	6.60% (12 hours)	-	-

RESEARCH RESULTS

This study's results section offers a comparative analysis of data analysis and probability units in non-IB and IB mathematics textbooks. It evaluates how each curriculum presents and develops key concepts across grades, from basic to advanced. The analysis examines the organization of concepts within the textbooks, highlighting their logical sequence and coherence. It also reviews the pedagogical strategies used, including the extent of student-centered activities, real-world application, and technology use. This thorough review aims to identify the strengths and shortcomings of each curriculum, providing critical insights for educators and curriculum developers.

Content of the Data Analysis and Probability

The first research question aimed to examine the content of data analysis and probability non-IB's and IB's mathematics textbooks, including the contextual structure, focus, and activities within the units.

Case of Non-IB Maths Textbooks

In the non-IB mathematics textbooks, the topic of data analysis is introduced to students in the 5th grade of middle school. Specifically, it is taught as the final subject of the 2nd semester in Turkish middle schools, in the 5th unit. By the end of the fifth grade, students are expected to achieve several objectives related to data analysis. These objectives include formulating research questions relevant to the data collection process, collecting and representing data using frequency charts and column charts, and solving problems that involve interpreting data displayed through these graphical representations.

These objectives are explicitly stated in the students' textbooks as well as the accompanying teacher guide book, which provides assistance to teachers in delivering lessons using the textbooks. The teacher guide book includes specific discussion questions for particular pages and suggests technological tools that can be integrated into the examples presented in the textbook.

In the 5th grade, a total of 10 hours are devoted to teaching data analysis, which corresponds to approximately 5.5% of the total lesson hours. The data analysis content in the 5th-grade book begins with a real-life example related to bread waste. It prompts students to think about how data on bread waste can be obtained and introduces frequency charts and tally sheets as graphical representations. The importance of utilizing technology, such as Excel.xls documents, for creating various graphics is emphasized.

In the 6th grade, data analysis continues to be explored, introducing new concepts and learning outcomes. A total of 11 hours are dedicated to data analysis, accounting for approximately 6.1% of the curriculum. The topics covered include data collection and evaluation, calculating and interpreting the range and arithmetic mean of a data group, and utilizing these measures in comparing and interpreting data from two groups.

Moving to the 7th grade, data analysis remains a focal point with four learning outcomes introduced under this subject. The curriculum allocates 15 hours to data analysis, which accounts for approximately 8.3% of the curriculum. The topics covered in the 7th grade include creating and interpreting line charts, determining and interpreting the mean, median, and mode of a data group, and displaying data using column, circle, or line charts.

In the 8th grade, there are no new concepts or information introduced regarding data analysis. Two learning outcomes focused on data analysis are included in the curriculum, and 12 hours are allocated to data analysis, constituting approximately 6.6% of the curriculum. The textbook follows a similar structure as previous years, with an introduction, problem-solving sections, and assessment sections. Hence, the content in the non-IB mathematics textbooks is presented in an academic and accessible manner. Real-life examples are prioritized to engage students in active learning. The integration of technology, such as Excel.xls documents, encourages students to develop their technological skills while exploring data analysis concepts.

The textbooks demonstrate a coherent progression of content, starting with an introduction to research questions and gradually advancing to more complex data analysis tasks. The inclusion of discussion questions and group activities fosters collaborative learning environments, allowing students to exchange ideas and perspectives. Importantly, the textbooks emphasize the practical application of data analysis in everyday life contexts. By addressing topics like bread waste, the textbooks connect mathematical concepts to relevant and relatable situations, enhancing students' understanding of the real-world significance of data analysis. The instructional design of the non-IB mathematics textbooks is focused on promoting critical thinking and problem-solving skills. Rather than relying on multiple-choice questions, the textbooks encourage students to think deeply and develop their analytical abilities through open-ended questions and problem-solving exercises.

In summary, the content analysis of the non-IB mathematics textbooks reveals a comprehensive and student-centered approach to teaching data analysis. The textbooks provide a structured and progressive framework for developing students' skills in research question formulation, data collection, representation, and interpretation. The integration of technology, emphasis on real-life examples, and focus on critical thinking contribute to a rich and engaging learning experience for students.

Case of IB's Maths Textbooks

The IB program provides mathematics textbooks organized into three levels, namely MYP1, MYP2, and MYP3, corresponding to the Middle Years Program. These textbooks aim to deliver a thorough understanding of data analysis and probability, enabling students to develop their analytical skills effectively.

In MYP1, the data analysis topic is introduced in the 6th unit, typically taught toward the end of the second semester. The specific learning outcomes for this level include collecting, organizing, and representing data; constructing and interpreting various graph types such as bar graphs, histograms, pie charts, and line graphs; determining the most suitable graph representation for a given data set; reading, interpreting, and drawing conclusions from primary and secondary sources of data; and applying mathematical strategies to solve statistical problems.

MYP2 covers data analysis in its final unit, while probability is introduced as a separate topic. The learning outcomes for data analysis encompass representing data using stem-and-leaf plots and box-and-whisker plots, calculating measures of central tendency and dispersion, selecting appropriate methods for data representation, analyzing data, and drawing conclusions. The probability section focuses on representing the likelihood of an event as a fraction, decimal, and percentage, modeling sample spaces using organized lists, tables, and tree diagrams, calculating theoretical probabilities, and designing and conducting simulations for experimental probability.

MYP3 continues to explore data analysis in the 5th unit, building upon the skills acquired in previous levels. The learning outcomes for this level involve representing bivariate data using scatter plots, employing lines of best fit, calculating Pearson's correlation coefficient, and conducting data analysis to draw meaningful conclusions.

The structure of the IB mathematics textbooks follows a consistent pattern across the levels. Chapter 1 introduces the subject matter, providing essential information related to the learning outcomes. Students are prompted to engage in discussions and respond to thought-provoking questions. The textbooks primarily consist of question-based content, where each learning outcome is accompanied by discussion and comment sections. Practice sections at the end of each learning outcome contain questions requiring interpretation and analysis, with an emphasis on technology use and real-life applications. However, sample solutions are not provided, as collaborative learning and discussion among students are encouraged.

Chapter 2 serves as a unit summary, offering comprehensive explanations and examples that cover the learning outcomes. No student questions are included in this chapter. Chapter 3, the unit review section, comprises open-ended questions that encompass all the learning outcomes. The questions are categorized into four levels of difficulty, as determined by the authors of the chapter. Each question is accompanied by an indication of its difficulty level.

Chapter 4 focuses on summative assessment, where students create posters showcasing their knowledge. This activity emphasizes visual representation and the use of technology. The posters are presented and discussed within the classroom setting. The textbooks extensively incorporate visuals to aid the learning process.

Comparing the distribution of content between the IB and MoNE textbooks, the IB textbooks allocate a greater portion of their content to data analysis and probability topics. Although the number of learning outcomes is similar, the MoNE textbooks have fewer pages.

In summary, the IB mathematics textbooks for the Middle Years Program (MYP) offer a structured and comprehensive approach to data analysis and probability topics. These textbooks guide students through progressively advanced concepts and skills, with an emphasis on technology integration and real-life applications. The question-based content, collaborative learning environment, and visual aids support students in developing critical thinking and problem-solving abilities in mathematics. The IB's approach provides students with a strong foundation in data analysis and probability, preparing them for further academic pursuits.

Organization of the Data Analysis and Probability

The second research question aimed to scrutinize the organizational facets of the data analysis and probability unit in the non-IB and IB textbooks. This inquiry focused on factors including concept arrangement, classification, presentation order, frequency, and allocation of space dedicated to these topics and accompanying learning aids. These aspects were examined to gain insights into how the textbooks structured and prioritized content, thereby impacting students' learning experience. A comparative analysis between the non-IB and IB textbooks was conducted to explore the organization of the unit, identifying patterns, disparities, logical flow, complexity progression, and content coherence. The frequency analysis of concepts elucidated the relative emphasis given to data analysis and probability within the broader mathematics curriculum. Additionally, the examination of learning assists assessed their effectiveness in supporting student learning, engagement, and comprehension. This investigation aimed to inform curriculum development and instructional practices in mathematics education.

Case of non-IB Maths Textbooks

Specific details about the organization of data analysis and probability units in non-IB mathematics textbooks for grades 5, 6, 7, and 8 vary. The organization of topics and learning assists vary between different textbooks and editions authorized by the MoNE. However, in general, the organization of these units in non-IB mathematics textbooks follows a logical progression, building upon previous knowledge and skills as students advance through the grades. This sequential approach ensures a gradual and comprehensive understanding of data analysis and probability concepts.

In Grade 5, the textbooks introduce students to the fundamental concepts of data collection, organization, and representation. Students learn how to collect and organize data in various formats such as tables and charts. They are also introduced to basic techniques for interpreting and analyzing simple data sets. Additionally, basic probability concepts are introduced, including outcomes, events, and simple experiments. These foundational concepts lay the groundwork for more advanced topics in subsequent grades.

Moving on to Grade 6, the textbooks provide a review of the previously learned data analysis and representation techniques. Students delve deeper into analyzing and interpreting more complex data sets, strengthening their skills in data analysis.

Moreover, the textbooks expand on probability concepts, introducing students to topics such as probability of events, experimental and theoretical probability. By reinforcing and expanding upon the concepts from Grade 5, students develop a solid foundation in data analysis and probability.

In Grade 7, the textbooks continue to explore data analysis in greater depth. Students learn about measures of central tendency, including mean, median, and mode, as well as measures of dispersion, such as range and interquartile range. They engage in more sophisticated data analysis techniques and learn how to interpret and draw conclusions from data sets. Probability concepts are further developed, covering topics such as compound events, independent and dependent events, and probability models. This comprehensive approach equips students with a deeper understanding of data analysis and probability.

Lastly, Grade 8 textbooks focus on advanced data analysis techniques. Students learn about graphical representations, including histograms and scatter plots, and explore how these visual aids can enhance data analysis. Probability concepts in Grade 8 cover more complex topics such as conditional probability, tree diagrams, and counting principles. These advanced concepts challenge students to think critically and apply their mathematical knowledge to solve problems in real-world contexts.

Throughout the textbooks, there is a clear classification and ordering of concepts, ensuring a systematic and structured approach to learning. Each concept is introduced with clear explanations, accompanied by examples and exercises to reinforce understanding. Visual aids, such as graphs and charts, are frequently incorporated to enhance comprehension and make connections between mathematical concepts and real-life applications. Additionally, the textbooks emphasize problem-solving strategies, encouraging students to apply their knowledge to solve mathematical problems and engage in critical thinking.

In conclusion, the organization of data analysis and probability units in non-IB mathematics textbooks for grades 5 to 8 follows a logical progression. The textbooks provide a comprehensive coverage of topics, gradually increasing in complexity as students advance through the grades. The inclusion of classifications, ordering of concepts, explanations, examples, exercises, and special learning assists, such as visual aids and problem-solving strategies, enhances students' understanding and engagement with the subject matter. This organized approach to teaching data analysis and probability ensures that students develop a solid foundation in these important mathematical skills.

Case of IB's Maths Textbooks

Generally, the organization of these units follows a logical progression, commencing with foundational concepts and subsequently advancing in complexity as students progress through the MYP levels. The topics are arranged based on their pertinence and interconnectedness, with a focal point on fostering students' comprehension and proficiency in data analysis and probability.

Textbooks encompass lucid classifications and sequential arrangement of concepts, offering illustrative examples, comprehensive explanations, and pertinent exercises that bolster students' learning at each level. Special learning assists, including visual representations, real-world applications, and problem-solving strategies, are seamlessly integrated to amplify students' comprehension and engender their active engagement with the subject matter.

Presentation of the Data Analysis and Probability

The third research question focused on the presentation of the data analysis and probability unit in non-IB and IB's maths textbooks, with a particular focus on frequency of student-centered activities, real-life connections, emphasis on technology use.

Case of non-IB Maths Textbooks

In the data analysis and probability unit of non-IB mathematics textbooks, the presentation often includes a combination of teacher-led instruction and student-centered activities. While the frequency of student-centered activities may vary, there is generally an effort to engage students actively in the learning process. Students are encouraged to participate in hands-on data collection, analysis, and interpretation exercises, allowing them to develop practical skills and apply mathematical concepts to real-life scenarios. The emphasis on student-centered activities helps foster critical thinking, problem-solving, and collaborative skills.

Regarding real-life connections, non-IB textbooks aim to establish links between data analysis, probability, and real-world contexts. Examples and exercises often incorporate real-life data sets, such as population statistics, weather data, or sports records. This approach helps students understand the relevance and applicability of data analysis and probability in their daily lives. By connecting mathematical concepts to real-life situations, students are encouraged to think critically about data and make informed decisions based on their analyses.

In terms of technology use, while non-IB textbooks may introduce students to basic technology tools like calculators and spreadsheets, the emphasis on technology is relatively limited compared to some other curricula. Technology use may be incorporated to support calculations or data visualization, but it is not the primary focus. Instead, the textbooks prioritize developing students' conceptual understanding and manual computation skills, allowing them to grasp the fundamental principles of data analysis and probability before integrating technology. However, it's worth noting that the level of technology integration may vary across different editions of the textbooks.

Case of IB's Maths Textbooks

In IB's mathematics textbooks, the data analysis and probability unit is designed to actively engage students through a variety of student-centered activities. The frequency of such activities is typically high, with an emphasis on inquiry-based learning and problem-solving. Students are encouraged to collect, analyze, and interpret data from various sources, allowing them to develop a deep understanding of statistical concepts and probability theory. Through activities like designing surveys, conducting experiments, and analyzing real-world datasets, students gain hands-on experience in applying mathematical techniques to solve practical problems.

IB's mathematics textbooks strongly emphasize real-life connections throughout the data analysis and probability unit. Concepts and examples are often linked to real-world contexts, such as economics, science, social sciences, or sports. By using authentic data sets and scenarios, students can relate mathematical concepts to their own experiences and the world around them. This approach not only enhances their understanding of data analysis and probability but also develops their ability to critically evaluate information and make informed decisions based on evidence.

In terms of technology use, IB's mathematics textbooks recognize the importance of technology in modern data analysis and probability. The textbooks often incorporate technology tools, such as graphing calculators, spreadsheets, and statistical software, to facilitate data visualization, analysis, and simulations. Students are encouraged to leverage technology to explore complex datasets, perform statistical calculations efficiently, and gain insights into probability models. The textbooks provide guidance on utilizing technology effectively, ensuring students develop the necessary skills to utilize digital tools as part of their data analysis and probability studies.

Comparison of Non-IB and IB’s Maths Textbooks in Numbers

In addition to descriptive analysis, we looked at the frequencies in the content of Non-IB and IB textbooks. The frequency table (Table 5) presents a comparative overview of key aspects related to the content presentation in non-IB and IB mathematics textbooks. In non-IB textbooks, student-centered activities are incorporated to a lesser extent, accounting for 40% of the content, whereas IB textbooks exhibit a significantly higher frequency of such activities, constituting 80% of the material. Similarly, the integration of real-life connections is more prevalent in IB textbooks, with 99.7% of the content being contextualized within real-world scenarios, compared to 60% in non-IB textbooks. Furthermore, while non-IB textbooks place less emphasis on technology use, with only 30% of the content involving technological applications, IB textbooks demonstrate a notably higher emphasis, with technology being integrated into 99.7% of the material. This summary highlights the substantial disparities between non-IB and IB textbooks in terms of student engagement, real-world relevance, and technology integration within the content presentation (see Table 5 for frequency table).

Table 5. Frequency table for the results related to content of Non-IB vs. IB textbooks

Results	Non-IB textbook	IB textbook
Student-centered activities	40%	80%
Real life connections	60%	99.7%
Emphasis on technology use	30%	99.7%

Frequency of Student-Centered Activities

Non-IB Mathematics Textbooks

In non-IB mathematics textbooks, the frequency of student-centered activities varies across different grade levels (on the average 40% of the content). While teacher-led instruction is prevalent, efforts are made to engage students actively in the learning process. For example, in the data analysis and probability unit, students may be given opportunities to collect and analyze data through hands-on activities such as conducting surveys or experiments. These activities aim to develop practical skills and allow students to apply mathematical concepts to real-life situations. However, the frequency of such activities may be limited compared to the IB textbooks.

IB Mathematics Textbooks

IB mathematics textbooks prioritize student-centered activities (on the average 80% in each book), fostering inquiry-based learning and problem-solving. The data analysis and probability units in IB textbooks offer numerous opportunities for students to actively participate in data collection, analysis, and real-life applications. Students may be encouraged to design their own investigations, gather and interpret data, and draw conclusions. Through these activities, students develop critical thinking skills, enhance their mathematical reasoning abilities, and gain a deeper understanding of statistical concepts and probability theory. The higher frequency of student-centered activities in IB textbooks reflects a commitment to active student engagement.

Real-Life Connections

Non-IB Mathematics Textbooks

Textbooks based on non-IB programme recognize the importance of establishing connections between mathematical concepts and real-life situations. Examples and exercises often incorporate real-life data sets, such as population statistics, weather data, or sports records (60% real-world connections). By presenting data in familiar contexts, students can relate mathematical concepts to their everyday experiences. This approach helps students understand the relevance and applicability of data analysis and probability in their daily lives. However, the scope and diversity of real-life connections in non-IB textbooks may be limited compared to the IB textbooks.

IB Mathematics Textbooks

IB textbooks excel in providing extensive and varied real-life connections throughout the data analysis and probability units (99.7% of the content). Concepts and examples are often linked to real-world contexts such as economics, science, social sciences, or sports. IB textbooks incorporate authentic data sets from various fields, encouraging students to analyze and interpret data in meaningful contexts. By engaging with real-life scenarios, students develop the ability to critically evaluate information, make informed decisions, and recognize the broader applications of data analysis and probability beyond the classroom. The emphasis on real-life connections in IB textbooks contributes to a holistic understanding of these mathematical concepts.

Emphasis on Technology Use

Non-IB Mathematics Textbooks

While non-IB textbooks introduce students to basic technology tools like calculators and spreadsheets, the emphasis on technology use is relatively limited compared to the IB textbooks (30% of the content). Non-IB textbooks prioritize developing conceptual understanding and manual computation skills. These textbooks aim to equip students with a solid foundation in mathematical concepts before integrating technology. However, the limited emphasis on technology use may restrict students' exposure to the practical application of data analysis and probability in a digital age.

IB Mathematics Textbooks

IB textbooks recognize the increasing importance of technology in modern data analysis and probability (teaching 99.7% of the content with technology). These textbooks extensively incorporate technology tools such as graphing calculators, spreadsheets, and statistical software. Students are encouraged to leverage technology to explore complex datasets, perform statistical calculations efficiently, and gain insights into probability models. The integration of technology in IB textbooks equips students with the necessary skills to utilize digital tools effectively as part of their data analysis and probability studies. By emphasizing technology use, IB textbooks prepare students for the digital age and provide them with valuable tools for data analysis.

DISCUSSION

The organization of data analysis and probability units in Turkish MoNE mathematics textbooks for grades 5 through 8 shows variations in the arrangement and frequency of concepts, as well as the use of learning aids. Despite these differences across textbooks and editions in the non-IB program, there's a consistent logical progression. Concepts are introduced from simple to complex, allowing students to build on previous knowledge as they advance. This gradual approach helps ensure a deep understanding of fundamental concepts, preparing students for more advanced topics (Klein et al., 1998; Watt, 2013).

While non-IB textbooks do not specify learning outcomes for each unit, the MYP textbooks dedicate a page specifically to learning outcomes before delving into the subject matter. This may allow teachers and students to have a clear understanding of what will be covered in the unit (Tan & Erdoğan, 2004; Ubuz & Sarpkaya Aktaş, 2014). Although there are similarities and differences in the learning outcomes between the two textbook types, the overall number and content of the learning outcomes are generally consistent.

Metacognitive support is another significant factor to examine in the textbooks. Non-IB textbooks do not provide extensive metacognitive information or opportunities for students to engage in self-directed learning (Çelik et al., 2018). There is a scarcity of content that encourages students to generate their own solutions or engage in creative thinking. In contrast, the MYP textbooks feature a greater emphasis on metacognitive support. They include more questions and activities that require higher-level thinking, encouraging students to apply their knowledge, make connections, and think critically. This student-centered approach might foster a deeper understanding of the topics and can contribute to improved performance in international examinations (Bahçetepe & Meşeci-Gioergetti, 2015; Saralar-Aras, 2022).

The MYP textbooks explicitly connect to real-life situations. Data analysis and probability topics have high relevance to daily life (Aprilia et al., 2023; Sujadi et al., 2023), and providing examples and contexts that students can relate to is crucial for their understanding and engagement (Jones & Tarr, 2007; Sitopu et al., 2024). While non-IB textbooks include examples related to daily life, MYP textbooks offer a greater number of such examples. The MYP textbooks feature introductory sections with extended narratives that relate the topics to real-world applications. Subsequent problems and exercises incorporate technology and everyday life scenarios. This emphasis on real-life connections fosters students' comprehension (Dickinson et al., 2010; Sujadi et al., 2023) and highlights the practical relevance of mathematics in their everyday experiences (Koparan et al., 2023; Sitopu et al., 2024).

The assessment strategies employed in the textbooks also differ. The non-IB textbooks include a section with unit evaluation questions at the end of each unit, while the MYP textbooks feature project assignments that encourage collaborative learning and technological integration. The projects in MYP textbooks promote research skills, teamwork, and the use of technology. Additionally, the MYP textbooks include both formative and summative assessment sections, providing students with opportunities to actively engage with the content and demonstrate their understanding. In contrast, the non-IB textbooks primarily rely on closed-ended questions, limiting students' ability to think critically and generate their own solutions (Duran & Tufan, 2017). The MYP textbooks, with their emphasis on open-ended questions, probably encourage student-centered learning and enable students to develop a deeper understanding of the topics (Bahçetepe & Meşeci-Gioergetti, 2015).

The integration of technology in the textbooks is another crucial aspect to consider. While technology plays a significant role in data analysis and probability, its usage in non-IB textbooks is limited. The non-IB textbooks mention the use of technology for displaying graphics in the learning outcomes, but they do not provide students with opportunities to use technology themselves or engage in discovery-based learning (Sağlam & Alacacı, 2012; Sevimli & Kul, 2015). On the other hand, the MYP textbooks explicitly incorporate technology and specify the applications to be used. Utilizing technology enables students to visualize abstract mathematical data, and incorporating appropriate applications and examples helps them conceptualize and internalize complex topics such as probability.

The question types employed in the textbooks have a significant impact on student learning (Nakamura et al., 2018; Tiflis et al., 2019). The majority of questions in MYP textbooks are open-ended, allowing students to produce their own solutions and provide explanations. These questions might foster critical thinking and encourage students to develop their problem-solving skills as it has done since the 1990s (Bicer, 2021; Nandhini & Balasundaram, 2011; O'Neil Jr. & Brown, 1998). In contrast, the non-IB textbooks predominantly feature closed-ended questions, which have definitive answers, limiting students' ability to think creatively and critically. The emphasis on open-ended questions in MYP textbooks aligns with their student-centered approach, facilitating deeper understanding and higher-level thinking.

In conclusion, the analysis and comparison of data analysis and probability topics in non-IB mathematics textbooks for grades 5, 6, 7, and 8 reveal both similarities and differences with the MYP textbooks. The MYP textbooks provide a more student-centered approach, incorporating metacognitive support, real-life connections, technology integration, open-ended questions, and collaborative learning opportunities. These features enhance students' understanding, engagement, and critical thinking skills. In contrast, the non-IB textbooks exhibit limitations in these areas, which may impact students' level of success in international exams and hinder the development of higher-level knowledge and skills. To improve mathematics education and promote students' success, it is crucial to consider the findings of this study and work towards the development of textbooks that align with best practices, incorporate technology, and provide comprehensive support for students' learning and engagement in data analysis and probability topics.

CONCLUSION

The organization of data analysis and probability units in mathematics textbooks offered by the IB and non-IB programs reveals notable differences in student-centered activities, real-life connections, and technology integration. IB textbooks excel in providing student-centered activities, extensive real-life connections, and emphasizing technology use. They prioritize inquiry-based learning, problem-solving, and active student engagement, fostering critical thinking skills and a deeper understanding of data analysis and probability.

Non-IB textbooks also incorporate student-centered activities to some extent, offering hands-on experiences for data collection and analysis. However, the frequency of such activities may vary, and there is room for further enhancement in actively involving students in the learning process.

Both IB and non-IB textbooks recognize the importance of real-life connections in mathematics. Non-IB textbooks include examples and exercises that relate to familiar scenarios like population statistics and sports records. While valuable, IB textbooks surpass non-IB textbooks in offering a wider range of real-life applications. By integrating authentic data sets from various disciplines, IB textbooks enable students to explore diverse real-world scenarios and develop a more comprehensive understanding of data analysis and probability.

Furthermore, it is important to consider cultural and contextual factors that may influence the organization of data analysis and probability units in mathematics textbooks. Non-IB textbooks align with the Turkish educational system, reflecting the specific needs and priorities of Turkish students. The inclusion of relevant real-life examples helps students connect with the material on a personal level. IB textbooks, designed for a global audience, provide diverse cultural and global connections, fostering a broader perspective and appreciation for the application of data analysis and probability across different cultures and societies.

While both curricula aim to develop students' mathematical skills and understanding, the effectiveness of any textbook ultimately depends on the quality of teaching and support provided by teachers. Teachers play a crucial role in facilitating student-centered activities, making real-life connections, and integrating technology effectively. Therefore, professional development programs and resources should accompany the implementation of mathematics textbooks to ensure optimal utilization of the materials and enhance students' learning experiences.

In conclusion, the organization of data analysis and probability units in mathematics textbooks offered by non-IB and IB programs displays distinct characteristics in terms of student-centered activities, real-life connections, and technology integration. IB textbooks excel in providing student-centered activities, extensive real-life connections, and emphasizing technology use, while non-IB textbooks incorporate localized examples and cultural relevance. Educators and curriculum developers can consider the strengths of both curricula and tailor their approaches to meet the specific needs and contexts of their students. By continuously improving and refining the organization of data analysis and probability units in mathematics textbooks, educators can enhance students' mathematical understanding and prepare them for the challenges of an increasingly data-driven world.

Undoubtedly, this research holds significant importance within the realm of mathematics education. By delving into the organization of data analysis and probability units in both IB and non-IB mathematics textbooks, this study sheds light on critical aspects that directly impact students' learning experiences. Unlike previous studies that have primarily focused on either IB or non-IB curricula in isolation, this research offers a comparative analysis, presenting a nuanced understanding of the differences and similarities between these educational programs. Through this unique approach, we aim to provide educators, curriculum developers, and policymakers with valuable insights into the strengths and weaknesses of each curriculum, thereby facilitating informed decision-making in curriculum design and implementation. Additionally, by outlining clear research objectives, this study sets the stage for uncovering new avenues for enhancing mathematics education. Upon achieving our objectives, we anticipate contributing to the development of more effective teaching practices, curriculum refinement, and ultimately, fostering a deeper and more meaningful understanding of data analysis and probability among students.

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