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Abstract

Inclusive education was once known as an approach where students with special needs and disabled are separated and given special attention. Recently, inclusivity is no longer defined restrictively by physical and cognitive disabilities but also addresses needs of full range of human diversity with respect to ability, language, age, culture, gender and other human differences. This article discusses basically the problems and barriers of inclusive education, the roles of teachers of mathematics in prioritizing inclusive education, teaching strategies necessary to uphold inclusion in the classroom. All the aforementioned were discussed with the view of highlighting how to make inclusion paramount and workable in the classroom. Inclusive education willgenerally work better in class if the teacher recognizes that the needs of the students are to be put first. The class environment needs to be more accommodating for all category of students and less hostile. Students need to know that the purpose for encouraging this form of education is to satisfy their academic needs and give them teaching support and atmosphere that is more relaxed and freer from all forms of prejudice, and bias because children regardless of their personal characteristics, background or physical challenges must have opportunities to study and be supported to learn mathematics.

Keywords: Inclusive education, disability, physically challenged, able-bodied persons, cognitive disability

Introduction

Globally, children living with one form of disability or the other are denied an education either by parents or society because they are the most vulnerable and excluded people in their communities. Children with disability are 10 times less likely to attend schools than those without disability. For nearly 20 years, the Global Campaign for Education (GCE, 1999) has promoted the right to "education for all". However, the global discussion on inclusive education has changed significantly over time. The concept of inclusive education originated from the phenomenon of 'respect for an inherent dignity of all human beings' (Masalesa, 2022). Under the inherent nature of human dignity as a construct, the active participation of all the people in the society irrespective of their characteristics has been emphasized for decades now (Hayes & Bulat, 2017). The concept of inclusive education was understood as focusing narrowly on children with disability alone. Inclusive education has gone beyond that and has also embraced all able-bodied children including students with special needs and the physically challenged (United Nations Children Fund (UNICEF), 2017).

In 1960, the UNESCO convention against discrimination in education and other international human right treaties prohibited any exclusion from or limitation to educational opportunities on the basis of socially ascribed or perceived differences, such as sex, ethnicity/social origin, language, religion, nationality, economic condition and ability. To further build up this principle, the 2030 Agenda for sustainable development goal 4 on education and education 2030 framework for action, emphasized "education for all" as a way to conceptualize inclusive education and make a pledge to "leave no one behind". Education for all hinges on "the needs of the poor and the most disadvantaged, including working children, remote rural dwellers and nomads, ethnic and linguistic minorities, children, young people and adults affected by conflict, HIV/AIDS, hunger and poor health and those with special learning needs. Furthermore the sustainable development goals (SDGs) 4.5 specifically reaffirms the need to ensure equal access to all levels of education and vocational training for the vulnerable including persons with disabilities, indigenous people and children in vulnerable situations. (United Nations, Department of Economic and Social Affairs, 2015).

Hence, inclusive education defined by Alquraim and Gut (2012) is all students, regardless of any challenge they may have are being placed in age appropriate general education classes that are in their own neighbourhood schools to receive high quality instruction, intervention and support that enable them to meet success in the core curriculum. National Commission on Special Needs in Education and Training (NCSNET, 1997) defined inclusive education as a learning environment that promotes the full personal, academic and professional development of all learners irrespective of race, class, colour, gender, disability, learning styles and language. As the yearn for inclusive education becomes prominent, principles governing inclusive education becomes pertinent and they are: No discrimination among students, equal educational opportunities for all, schools adapting to the need of students, equal educational benefits for all students, upholding of students views and taking them seriously, finally recognizing individual differences between students as a source of richness and diversity and not as a problem (Ministerial Advisory Committee: Children and students with disability, 2017). These listed principles as stated describe the severity in which students' needs is to be considered in order to promote smooth progress in class routine.

Theories of inclusive education

Vygotsky theory which highlights the zone of proximal development (1962) postulated what he later referred to as the theory of mathematics learning in 1993. He asserted that knowledge is constructed based on personal experience and hypotheses of the environment. Vygotsky, a constructivist, proposed that learners construct their knowledge through the personal experiences, reflecting on those experiences and reconciling against previous knowledge. Learners gain more knowledge when a more knowledgeable other tries to guide or teach learners. The theory claims that children are born with the basic materials/abilities for intellectual development – which is referred to as “elementary mental functions”. Eventually, through interaction within the socio-cultural environment, these are developed into more sophisticated and effective mental processed strategies which are now referred to as “higher mental functions”. These interactions may only be aided through inclusive education in a mathematics classroom to help build on the potential of learners.

A More Knowledgeable Other (MKO) is an important postulation of the theory. It refers to someone who has a better understanding or has higher ability level with respect to a particular takes, process or concept in mathematics learning (Vygotsky, 1962). The MKO could be a teacher, a parent, sibling or the learner's peers. Another integral part of the theory is the concept of the “Zone of Proximal Development” which demonstrates what a wide category of learners can achieve independently and what a child can achieve through guidance and encouragement in a mathematics classroom. This nature of inclusiveness is a major feature of collaboration to achieve set classroom objectives.

Maslow's theory of motivation (1943)

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culture. Every organization passes through a lower order stage in which they struggle with basic survival needs. The positive interaction of organizational culture, in this case, the school and its teachers would eventually result in enhancing self-esteem and self-actualization. Generally, it is agreed that dispositions such as motivation, curiosity and perseverance can be recognized when students persist at difficult tasks, take risks and exhibit open-mindedness. This is manifested through the learner's performances which showcase the strength and reliability of what the school environment has been able to offer in terms of equal opportunities for all category of learners – slow or fast, gifted or struggling; the dyslexic and those with dyscalculia challenges etc. It is also essential that mathematics teachers exhibit the highest level of confidentiality as well as plan their teaching with the appropriate materials and thoughtful dialogue in order to maintain a safe and secure environment for inclusive students.

Barriers to inclusive education in the classroom (Choudhary, 2015)

a. Negative approach – refusing to accept the presence and accommodating inclusive education. This can be a situation which affects both students and mathematics teachers. For instance, a mathematics teacher who deliberately refuses to alter or alternate teaching approaches and styles during teaching to benefit students with dyscalculia or ADHD and those with physical disability is simply repudiating inclusive education in the classroom. Such teachers may support their actions as a function of lack of time or may even be incompetent in handling students with such diverse problems. Students who decide to segregate and shun students with disability when it comes to choosing pairs or teams for class activity or pairing/ collaborative mathematics exercises, are spurning inclusive education and hence inhibiting its success in the classroom.

b. Lack of physical/technological facilities. Unavailability or shortage of assistive technological facilities such as computers, projectors, manipulatives or measuring devices that will help facilitate and simplify learning of mathematics and communication in class for students with disability, dyslexia and ADHD, is another problem that can hinder inclusive education.

c. Lack of funds to purchase the needed equipment to facilitate and support teaching and learning. Students with special needs and disability need variety of equipment and teaching tools (such as mobile technologies, magnifiers, screen reading software, talking devices, etc) to foster learning and class participation. If the government and school authorities do not provide funds to procure these necessary mathematics equipments, then implementation of inclusive education in such schools is abortive.

d. Inadequate trained teachers to work with special needs students. Mathematics teachers who have not acquired adequate training and requisite experience/knowledge to engage and teach special needs students, will wreck inclusive education in the classroom. Teachers will need to continually attend training exercises and programmes that will equip them with the know-how to align themselves with inclusive education.

e. Social discrimination - Adjustment problems, isolation, lack of expression are some of the problems students face in inclusive education. Especially students with disability and special needs who are trying to fit into a system where they see or rate themselves differently in the negative sense of it, can obstruct inclusive education. Mathematics teachers can really help in this kinds of situation by talking students out of these problems or aligning their teaching styles and methods to suit the needs of inclusive students.

f. Emotional problems (inferiority complex, introverted nature, shyness)- students with special needs and disability will at some point exhibit traits of inferiority complex, introverted nature, shyness due to their conditions especially when they find it difficult to cope with mathematics lessons and solve mathematics problems. This can mar the success of inclusive education since such students may begin to loose focus and concentration in class. Mathematics teachers can serve as counselors or even give such students individual attention.

g. Communication barriers (language disorders, speech disorders). Disability can come in the form of speech disorders and language disorders which can dampen communication in mathematics class and inhibit inclusive education. In mathematics class communication is key, if a student can not communicate by expressing his or her learning needs, then the essence of learning is futile. If a student with disability fears that his or her communication issue can make him or her a laughing stock, then participation in class is dampened. It is not surprising to find students with disability or special needs falling into this category because of their condition. To help forestall this problem teachers can list out guiding rules that hinge on empathy and respect for fellow students' class communication barriers.

h. Educational problems (feeling as extra burden to peers, lagging behind in class activities, lack of understanding, learning disability, non-standard learning styles, attention disorders.

i. Mobility barriers (difficulty in movement from school to home or vice-versa for extreme physical disabilities). Students with this form of disability may decide to forfeit school, hence the essence of inclusive education is defeated. The government or school authority in their capacity can find ways of transporting and easing movement of such students inorder to encourage them stay in school.

j. Print barriers (vision impairments, reading difficulties for instance beginning readers, learning disabled students and English as second language students). Magnifiers and projectors are necessary in mathematics classrooms where students with such impairment are found. Without these equipment, learning of mathematics is obstructed for these students and the objective of inclusive education is hindered.

Even with barriers to inclusive education there are underlining benefits of the programme.

Benefits of inclusive education in a mathematics classroom

There are practicable benefits derivable in an inclusive mathematics classroom that are healthy for both the learner and the teacher, these include: Academic benefits, Social benefits of inclusive education and Communication benefits.

Academic accomplishments of students

with severe disabilities increase through interaction with typically developing peers in an integrated environment and they meet the goals of their individual education program (Westling & Fox, 2009). When placed in the same academic environment, students with disabilities increase in academic performance in academic skills such as in reading and mathematics in the context of cooperative learning groups in an inclusive environment (Cole, Waldron, Majd & Hasazei, 2004).

As affirmed by Westling and Fox (2009) that inclusive education provides an opportunity for students with severe disabilities to build social skills in terms of establishing relationship with their typically developing peers. The authors further stress that students with severe disabilities in inclusive education classrooms experience a higher level of interaction with peers, than when students with severe disabilities are placed in separate classrooms. Furthermore, students with severe developmental disabilities in inclusive classrooms over a 2-year period progressed on a measure of social competence, whereas matched counterparts in segregated settings regressed (Westling & Fox, 2009).

From the work of Alquraim and Gut (2012) it is confirmed that students with severe disabilities improve their communication skills in inclusive settings when compared with students with the same disabilities in self-contained classrooms. This can be exemplified in an inclusive mathematics classroom.

Broad-based categorization of inclusive education

According to the National Strategies (2008), if inclusive education is beneficial, the beneficiaries may be include the following:

1. **Students with English as an additional language (EAL):** This category of students needs support to develop language skills to access the mathematics curriculum. If not it becomes easy to underestimate their capabilities in what they can do mathematically. Language learning styles vary and students may not want to speak until they gain confidence that they can produce accurate and meaningful utterances. Teachers of mathematics should adapt questioning styles that will make EAL learners feel included and encourage them to contribute orally when they become confident enough.

2. **Students with special Education Needs (SEN):** Students in this category have underlining learning difficulties linked to social deprivation, while some will also have disabilities. The learning difficulties here are not always associated with literacy, and numeracy development but are sometimes aggravated by missed or interrupted schooling, which could be due to long-term medical conditions. In this case, teachers of mathematics will need to set up appropriate interventions including differentiation of tasks and materials. Teachers should also make sure the plan lessons with a suitable range of objectives and afterwards monitor the learning progress of students through assessment.

3. **Students with disabilities :** schools are expected to make reasonable adjustments to accommodate students with physical difficulties to enable them access the statutory curriculum. Support for students in this category is expected to take place in a mainstream lesson as they work on the same mathematics programme as their peer group. Teachers of mathematics should be ready to make modifications to materials, equipment and furniture in order to meet particular needs of these students so they can work alongside their peers. For example some students with visual and hearing impairments will need to use ICT to assist in reading and recording

their work.

4. **Students with emotional and behavioural difficulties**- students under this category are often prone to having poor literacy and numeracy skills due to their inability to maintain proper concentration and persevere with tasks. Teachers of mathematics ought to alert these students that expectations on them are high, hence they need to give in their best. Teachers need to structure lessons so that students work at their pace while giving opportunities for independent working with variety of activities. Use extrinsic motivation to reward good behaviour and also make teaching of mathematics relevant by relating it to real world situations.

5. **Students with communication difficulties** – students in this category need clear, outlined and effective teaching which builds their confidence and participation. For instance students with autistic spectrum disorders will require well-structured lessons with clear routines and predictable parts. They respond best when teaching is explicit, language is concise, and well-focused. Mathematics teachers should make sure their expectations for every lesson is made clear. They should also be explicit about what they want students to learn and what is expected of them to do.

6. **Students who are working way below national expectations for their age group**: This occurs where schools have large number of students enrolled into lower classes based on knowledge formation and cognition and not age wise. Mathematics teachers can adapt preceding yearly programme by incorporating areas of particular difficulty or relative strength. This helps provide guidance on progression from lower levels, although contents may need to be adapted to reflect the older age.

7. **Students who are very able at mathematics** – able students in this category deal with abstract mathematics more readily than other students do. They find it easier to progress quickly but will need extension and enrichment activities to develop the breadth of their mathematics knowledge and depth of their thinking. They can even be given extra challenging and daunting tasks to stretch their mental reasoning. Teachers can give students extra challenging homework where possible identified gifted or very able students should be made to follow individualized programmes at appropriate times.

Role of Mathematics teachers in prioritizing inclusive education

Since students in inclusive education need special and dedicated attention, teachers need to know how to function accordingly. Below are itemised interpersonal ways to achieve a good understanding of a wide variety of learners.

a. Interact with students' family - Mathematics teachers should have a good rapport with students' family members this will help decipher problematic issues of their students and even make them understand the students better.

b. Encourage the student to develop self-confidence – from the right teaching approach used by the mathematics teacher, students can gain self-confidence in solving mathematics problems and work confidently with peers.

c. Help students identify their hidden talents -when teaching embraces variety in teaching style and strategies, students can grow out of their comfort zone and want to face mathematics task headlong. This can help teachers identify what a

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student can do and how they can do it better.

d. Identify students with disabilities in the classroom and give them the needed support and care that will enable them be part of the teaching and learning activities.

e. Referring the identified students with challenges to experts for further examination and treatment.

f. Accepting students with disabilities – teachers must accept that students with disability have underlining learning situations that can breach their free/smooth flow of lesson comprehension. This should not be seen by the teacher as a disastrous situation hampering the success of class activity but should be seen as an opportunity to salvage and fix a situation of a child in need.

g. Develop positive attitude between normal and disabled students- The may really be no need to begin to separate or segregate students in class based on their conditions. Students should not be allowed to address themselves based on their deficiencies. Student should treat each other alike with respect and dignity while disregarding all forms of unnecessary empathy that could cause students with challenges to sulk.

h. Students should be placed in the classroom in proper places where the feel comfortable and are benefiting from the classroom interaction.

i. Remove architectural barriers wherever possible so that students with disabilities move freely and independently.

j. Involve students with disabilities in almost all activities in the classroom. Avoid making them feel incapable.

k. Make suitable adaptation in the curriculum so that students with disabilities can be featured so as to learn according to their abilities.

l. Teachers should prepare and adapt teaching resources capable of handling every learner's need so that learning does not become a barrier for the disabled.

m. Teachers should construct before beginning of lessons, achievement and diagnostic tools to test learners and know what has been learned and what is considered unlearned.

n. Teachers should provide remedial instruction for students who are finding it difficult to cope with regular lesson periods.

Teaching strategies used in mathematics classes to prioritize inclusive education

There some suggested teaching strategies that help prioritize inclusive education in a mathematics classroom, some as discussed as follows:

1. Cooperative learning – refers to the practice of having a small group of students with mixed ability levels working together, with each member having equal statute within the group to help each other accomplish a specified learning task. This is clear that students with disability and those with mild disabilities can benefit from each other using this strategy. The group is like a team, the failure of the team is failure of each member of the team. Hence team members need to be carried along in conducting the given tasks in order for the team to succeed.

2. Response prompting – this occurs when an instructor helps a student find the correct answer with verbal or non-verbal cues while the student is trying to think of the correct answer or after the student has already given an incorrect answer (Copeland & Cosbey, 2009). From the authors view point, this strategy has helped students with severe disability gain academic skills and confidence. Response prompting can come in form of spoken, body language or complete assistance which is gradually withdrawn as the students show they no longer require that assistance (Copeland & Cosby, 2009).

3. **Assisted Technology (AT)** – this encourages students with severe disabilities to more effectively participate in various activities. There are two types of assisted technology devices that is useful for students with severe disabilities and aids in facilitating their various activities. There are low-tech devices, which includes adapted spoons, switches, and picture boards. The other is high tech which includes: computers, augmentative and alternative communication and power wheelchairs. Others are touch screen and alternative keyboards (Sigafoos, 2010).

4. **Embedded instruction** – this strategy provides strong personally focused help to students with severe disabilities in the general education settings and assist students with learning difficulties during an entire class period. According to Coperland and Cosbey (2009), this strategy uses response prompts and time management allowing learners and instructors to achieve their objectives during class rather than outside the classroom. It helps students with severe disabilities to learn at the same time as their typical developing peers without giving them different tests or interrupting regular class time, practices that can make the student with severe disabilities feel isolated or singled out. Embedded instruction introduces students with disability in acquiring academic skills. It also introduces students to new techniques to develop their abilities and learn information.

5. **Multi-sensory teaching technique** – this technique is used for learners with learning differences. This teaching technique stimulates learning by engaging students on multiple levels. It encourages students to use some or all their senses to gather information about a task, link information to ideas they already know and understand, perceive the logic involved in solving problems and understand the relationships between concepts. This mean using more than one sense, which could either be sight or hearing. Students with learning difficulties typically have difficulties in one or more areas of reading, spelling, writing, mathematics, listening comprehension and expressive language. Multisensory techniques enable students to use their personal areas of strength to help them learn.

How to make inclusive education paramount in a mathematics classroom

1. The use of students' interest in contextualized task is said to be a potent approach to realizing inclusive education. What areas of learning communications are represented in the problems you assign to students? How does background knowledge of issues in classroom align with students' interest? Research has shown that students are more motivated in teaching materials when it is applicable to their own interests and communities (Jones, Howe & Rua, 2000). In order to identify the interest of students, consider giving your students a survey to ask for their hobbies, motivations for taking mathematics seriously. Then use what you learnt about your students to frame mathematical test problems. Be sure that the tasks you assign represent all of those interest gathered in your classroom and which students might be left out. If students with disabilities or difficulties do not see areas/professions of interest to them in test problems, they may become reclusive in class.

2. Exposing students to a diverse group of mathematicians is another measure for inclusivity in a mathematics classroom. Stereotypes about certain mathematics sages tend to make students who do not identify which such qualities to feel they do not belong in mathematics (Cheryan & Plaut, 2010; Thoman, Arizaga, Smith, Story & Soncuya, 2014). Diversify your student's image of mathematicians by highlighting mathematicians who do not fit the typical stereotype. Describe mathematicians as multidimensional individuals with struggles, hobbies and families, communicating short biographies/stories to students. Showing students pictures of mathematicians from underrepresented groups is a great way of approaching this situation. If students are able to see mathematicians as genuine individuals, they are more likely to identify with mathematics which will help enhance quality education.

3. Another approach is the design of assessments and assignments with a variety of response types – try to diversify assessments. Some teachers have found success with traditional mathematics assessments in traditional setting. However not all students succeed in such environment. It is good to create and structure assignments to include a variety of types of problems as well as settings. For example, consider including problems that ask students to write long responses to explain their thinking or draw a visual to demonstrate an argument. Vary the test environment by allowing students to work in groups or give a take home assignment in order to give students flexibility in the amount of time for completion. Even consider allowing students to retest. This approach as suggested by Juhler, Rech, Form & Brogan (1998) has shown to provide students who experience mathematics anxiety with a mental “safety net” that can help alleviate some of the pressures involved in testing and improving their test performances for quality education.

4. Furthermore, the use of systematic grading and participation methods. What category of students do you expect as a teacher to succeed? Who are the students whose contributions you encourage in class? Teachers often have expectations and judgments of different groups of students based on students' identity (Vandenbergh, Denessen, Hornstra, Voetten & Holland, 2010; Riegle – Crumb & Humphries, 2012). Teachers sometimes provide a warmer academic climate to students for whom the hold higher expectations in the form of in-class interactions and assignment feedback. Such treatment may have positive effects on some students' performance and participation but not all. Attempt to hold all of your students to the same high standards, consider implementing systematic ways of getting students' participation and method grading by keeping record of which student participated in your class and make an effort to elicit contributions from all students. While grading, create a rubric to evaluate students' work. After grading, look over the comments and feedback you gave your students. Check and see that all students have similar depth and specificity of feedback. Consider asking a colleague who is unfamiliar with identities of your students to look over a sample of the work you have graded and provide feedback on the types of responses you give to your students. This is done to improve quality education.

5. Encourage students to embrace a growth mindset. Students' mindset regarding intelligence can likely influence their academic performance and motivation. Students with a growth mindset can triumph in the face of challenges and setbacks and grow in the process compared to students with a fixed mindset. Remind your students as a teacher that mistakes are an essential part of learning and a vehicle for growth. Provide feedback on students' strategies and reasoning rather than just their answers. Celebrate students' effort and persistence and avoid praising a student for getting an answer quickly. Treat examinations as an opportunity for students to demonstrate their efforts and understanding rather than their intelligence, capability and ability. Allow students to engage in productive failure by proving limited scaffolding and challenge students to collaborate with each other (Kapur & Brelaczyc, 2012). Students should be allowed to give a short reflection on classroom activities, what they enjoyed and what they did not which may have caused them to be withdrawn in class. This will enable the teacher create a more positive and professional atmosphere for students.

6. Mathematics teachers must desist from patronizing students outrightly due to their disability or deficiency. Exposing students openly to classmates as a "pitiable situation" based on their challenges should be avoided. In as much as the teacher has a clear understanding of students' predicament does not mean fellow students should be given the free will to empathize with students who are disabled. Teachers should teach all students alike and given attention discretely to students with challenges which will help them smoothly progress in class. Rather, emphasis should be placed on teacher professional development to increase regular classroom teachers' knowledge of educating exceptional students. This will help teachers fashion out ways to deal with or handle students with all types of situation.

7. Finally, the use of technology should be promoted to allow subject matter to be accessible in a variety of formats. Be sure to provide captions for audio presentations, provide educationally relevant descriptions for images and graphical layouts and videos. If possible, teachers are to put important topics online then permit and encourage the use of adaptive technology (word processors, special keyboards, voice input devices, speech software, websites and networked systems, Braille printers and translation software. Select textbook and other materials that support and include students who have a wide range of abilities to see, hear, speak and read.

Summary

Based on the headings being discussed above, we can conclude that inclusive education if nurtured in the classroom properly can not only benefit students with disabilities and those with disorders but can also benefit the teacher in organizing and preparing ahead for class teaching and planning of instruction.

Inclusive education involves a human activity whereby the teachers learn to accommodate a diversity of learners in the classroom. The assistance to a learner is planned in a systematic and purposeful way, giving room for learners to actualize his or her full potentials.

Barriers to learning that might exist must be addressed in order to enable the learners benefit optimally from the teaching situation. Inclusive education entails meeting the diversified needs of learners which gives learners an enriching learning experience. Discrimination of learners based on their diversities, prevents them from experiencing life fully. When learners are given ample opportunity to share in the beliefs, ideas and values of other learners within the inclusive classroom, this may enable them to acquire alternative insights and understanding through a mutual learning experience with other learners. Learners begin to see the basic needs of other learners which enable them obtain a much broader basic frame of reference. In this way a learner can carefully evaluate his or her existing knowledge with newly acquired knowledge and insights.

Suggestions

From the foregoing discussions, we can suggest that teachers should allow students of different categories to mingle and learn from each other. All students should be given equal treatment irrespective of their situations.

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EFFECTS OF MANIPULATIVE MATERIALS ON SENIOR SECONDARY ONE STUDENTS' INTEREST AND ACHIEVEMENT IN GEOMETRY IN JOS METROPOLIS, PLATEAU STATE, NIGERIA

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Abstract

The study investigated the effects of manipulative materials on senior secondary one students' interest and achievement in geometry in Jos metropolis, plateau state, Nigeria. A non-randomized pre-test post-test quasi-experimental control group research design was adopted for the study. The population for the study comprised of 4,892 senior secondary one students in 22 public secondary schools in the study area. In the study, a school was purposively sampled from the 22 schools and a sample of 58 senior secondary one students participated in the study. Four research questions were raised to guide the study and four null hypotheses were formulated and tested at 0.05 level of significance. Two instruments namely: Geometry Interest Questionnaire (GIQ) and Geometry Achievement Test (GAT) were used to collect data for the study. The treatment lasted for three weeks. Data collected were analyzed using mean, standard deviation, and ANCOVA through statistical packages for the social sciences (SPSS) version 20.0. Findings of the study showed that there was a significant difference between the interest scale mean scores of the experimental and control groups in favour of the experimental group. Also, there was a significant difference between the achievement mean scores of the experimental and control groups in favour of the experimental group. Again, it was revealed that, there was no significant difference between male and female participants interest mean scores and achievement mean scores in geometry. One of the recommendations was that, Mathematics teachers should use manipulative materials in teaching geometry to enable students participate actively in the learning process for better achievement.

Key words: Manipulative materials, Interest and Achievement in Geometry.

Introduction

In Nigeria, several educational reforms have targeted students' achievement in Science, Technology and Engineering with Mathematics as the pivot. Some of these reforms date back to pre-independence era with the introduction of western education into Nigeria, foreign reforms movement and the impact on Nigeria, reforms in Africa Mathematics Programme (AMP) where Nigeria played a very active role. Other reforms include the reform by the Nigerian Educational Research Council (NERC) now called Nigerian Educational Research and Development Council (NERDC) which was saddled with the responsibility of modernizing the school curriculum including that of Mathematics, the Benin conference of January 1977 and the emergence of New School Mathematics (NSM). These unprecedented measures were largely motivated by evidences pointing towards pedagogical issues, inadequate instructional materials, poor teaching methodology, manpower shortage with its attendant effect on students' interest and achievement in Mathematics. Hence, the need to fashion out measures that will help arouse students' interest thereby improving their achievement in Mathematics.

Mathematics as a subject is globally recognized as an important discipline that can be applied in the field of science, medicine, law, social sciences, languages, engineering, technology, transportation and telecommunication among others to better the quality of life of the people. Kurumeh, Abarakpo, Odoh and Ikyereve (2016) describe Mathematics as a fundamental support for all scientific investigations and activities of human development. Mathematics in its dynamism is integrated into all other disciplines. It is the science that develops explicitly other kinds of sciences such as Physics, Chemistry, Biology, Economics, Sociology, Psychology and Astronomy. This has been established by scholars from diverse fields of studies because of the unlimited opportunities it provides (Kapasa, Bobby & Mulendema, 2015). For instance, in the field of physical sciences, mathematical knowledge and skills are required for experiments and practical works in the laboratories and technological workshops. Similarly in Economics, mathematical knowledge and skills are used in building of models to eliminate or bound recessions and inflations, select portfolio of stocks, investigate economic and population growth (Lassa, 2012). It is for this reason that the Nigerian government made the study of Mathematics compulsory in the school curricula both at the primary and secondary levels of education.

Mathematics occupies a very crucial position in the school curricula because its study helps to build in students solid foundation for everyday living and to develop computational skills in them (Attah, 2016). It helps to foster the desire and ability in students to be accurate in solving problems to the degree relevant to the task at hand. The study of Mathematics also helps to develop in students the ability to recognize problems and solve them with related mathematical knowledge. Mathematics helps to develop precise, logical and abstract thinking ability in students. It provides necessary mathematical background for further education and to stimulate and encourage creativity in students (Lassa, 2012). Therefore, for any nation to survive and develop, serious attention has to be accorded to the teaching and learning of Mathematics at the pre-tertiary levels of education.

Geometry is one of the components of Mathematics that plays very crucial role in schools. The study of geometry helps students to develop skills of critical thinking, problem solving ability and deductive reasoning skills. The study of geometry helps students to understand and know how to apply the relationship between shapes and sizes and by so doing provides them with the opportunity to use such knowledge in their daily lives (Bender & Beller, 2012). The study of geometry also helps to enhance students' creativity. This implies that, it helps students to construct and make their creative thinking come to life. For instance, students who desire to make career in fields such as, architecture, building engineering, civil engineering, mechanical engineering and surveying among others require the knowledge of geometry to enable them design structures, buildings, roads, bridges, flyovers and sky crappers with interesting and fascinating shapes and sizes.

In spite of the importance of Mathematics, the achievement of students in the subject both at national and international examinations have not been impressive, especially geometry (Abakpa & Igwue, 2013).For instance, the West African Examinations Council (WAEC) chief examiners' reports of May/June from 2011- 2020 identified geometry as one of the components of Mathematics in which students have not been achieving satisfactorily. The WAEC chief examiners' report further revealed that, problems involving geometry were either poorly attempted or completely avoided by students due to lack of understanding of the concept. Fabiyi (2017) asserted that the greatest challenge of students in learning geometry include: lack of knowledge of proof by students, lack of background knowledge, poor reasoning skills in geometry, geometric language comprehension, lack of visualizing abilities, teachers' method of instruction, as well as inadequate supply of manipulative materials.

Manipulative materials are materials designed to provide concrete experiences that can help students make the link between mathematical concepts and the real world. Manipulative materials are concrete models that incorporate mathematical concepts, appeal to several senses of the human and can be touched and moved around by students (Moore, 2013). They are objects that can be handled by an individual in a sensory manner during which conscious and unconscious mathematical thinking can be fostered. Iji, Abakpa & Takor (2015), viewed manipulative materials as any material designed for teaching and learning that can actively engage students in Mathematics learning process to foster critical thinking ability. Manipulative materials are concrete learning objects that allow students to comprehend abstract concepts through concretizing them and help to establish relationships between the manipulative materials and abstract mathematical concepts (Hakki, 2016). Furner and Worrell (2017), defined manipulative materials as physical objects that are designed to represent explicitly and concretely mathematical ideas that are abstract. They are materials that facilitate teaching and learning and provide positive contributions to conceptualization and interpretation processes in students. Thus, manipulative materials do not only contribute to the cognitive aspect of the learner, they also enhance the development of psychomotor skills (Cope, 2015). This, it does by addressing several senses of the learner such as sight, touch or hearing within and outside the classroom (Hakki, 2016). The question now is how adequate and effective are these materials?

The problem of inadequate and ineffective usage of manipulative materials seem to hinder students from understanding the basic mathematical principles, computations or the underlying processes that gave rise to the mathematical facts in geometry. It also creates in the students the inability to understand what the question demands, lack the knowledge of what to do, and how to proceed in finding solutions to geometric problems. This problem is attributed to the teachers' inability to use appropriate teaching approach to teach geometry which results in lack of interest and poor achievement of students in Mathematics (Okigbo & Okeke;2011). Students' lack of interest in geometry in secondary schools has not just been a matter of concern to mathematics educators (Telima, 2011), but it has been pointed out by many researchers as one of the factors responsible for poor achievement of students in Mathematics (Iji, Ogbole, & Uka, 2014).

Studies by Musa and Dauda (2014) showed that in West African Senior School Certificate Examinations (WASSCE) General Mathematics, questions involving geometry have an average mark of 41% with 15% of the marks from 15 objective test questions while 26% of the marks are from five essay questions which sum up to 41%. It is evident here that when a student does not perform well in geometry related problems, the tendency is that such a student may not be able to obtain credit pass in Mathematics. Thus, such a student on completion of secondary education may not be able to gain admission into higher educational institutions where skilled, versatile, quality and resourceful labour force are trained for the economic and socio-political development of a nation (Musa & Dauda, 2014). When students after completion of secondary education fail to obtain admission into higher institutions due to their inability to obtain credit pass in Mathematics at WASSCE, the tendency is that, the society may be left with young men and women who are supposed to be in school but are now roaming about the streets thereby constituting serious menace to the society. Most of these young men and women may resort to stealing, involvement in drug related crimes, prostitution, rape perpetrators and victims, kidnapping, banditry, internet fraudsters, and militancy among others. Again, some of these idle young men and women may be recruited by crisis merchants or entrepreneurs to be used to cause problems in the society such as those recruited to become members of Boko Haram, suicide bombers, armed robbers as well as those who may be deployed by politicians to serve as political thugs. Thus, the study hopes to come up with interventions through the use of manipulative materials that might help to reduce the apathy, fears and abstractness of Mathematics to students, thereby possibly generating and sustaining students' interest in Mathematics for improved achievement.

Okigbo and Okeke (2011) identified factors responsible for poor achievement of students in geometry to include, lack of teachers' knowledge of the content area in geometry, poor teaching methodology, absence of interest on the part of the learners, perception that geometrical proofs are difficult to comprehend, teachers' quality and quantity, large class size and inadequate instructional materials in schools. The annual reports of the West African Examinations Council of 2018show an unimpressive picture of students' achievement in Mathematics at the senior school certificate examinations. For instance, students' achievement in Mathematics at the Senior School Certificate Examinations (SSCE) in the years 2011-2020 show a very unstable and worrisome achievement of students in Mathematics. Thus, the percentage pass at credit level in Mathematics for 2011-2015 ranged from 39.57-38.68. The trend between 2011-2015 shows a percentage pass of less than 50 in Mathematics which is quite disheartening for a country like Nigeria that is aspiring to be the educational giant of Africa and that of the world. However, there was an improvement between 2016 and 2017 with percentage pass of 52.97 and 59.22 respectively, which needs to be sustained. In 2018, there was a reoccurrence of the down ward trend where the percentage pass in Mathematics was 49.98. This is not encouraging and as such there is the need to put in conscious efforts to address the problem.

Gender difference in achievement between male and female students in the subject has also become a global point of debate that has dominated most Mathematics education researches. Literature on students' achievement in Mathematics with respect to gender has continued to be of interest and remain inconclusive (Stoet & Geary, 2013). Ali and Bhagawati (2014) observed that male achieved better than their female counterparts in Mathematics. The greatest differential in achievement between male and female is exhibited in geometry. This is because male students were observed to display greater confidence and ability in solving geometric problems, which is a strong predictor of Mathematics achievement (Timayi, Ibrahim & Sirajo , 2016). Studies by Linderberg, Hyde, Petersen and Linn (2010) ascertained that gender differentials among male and femalestudents were converging, indicating that the gap is reducing. This view was upheld by Alex and Mammen (2014) who found no significant difference between the achievement of male and female students in Mathematics. However, gender differentials in Mathematics and Science continue to exist in most countries of the world, Nigeria inclusive (Zeigler, Stoeger, Harder, Park, Portesowa & Parath, 2014). It becomes necessary therefore to look for interventions that could be used to arouse and sustain students' interest in geometry irrespective of gender so as to improve their achievement in Mathematics generally.

Statement of the Problem

Reports from researches and data from the West African Examinations Council (WAEC) showed students' low interest in geometry and poor achievement in WASSCE General Mathematics in Nigeria. Although attempts have been made through researches by scholars and other organized bodies, such as the Mathematical Association of Nigeria (MAN), Science Teachers Association of Nigeria (STAN), National Mathematical Centre (NMC) through workshops, seminars, symposia and conferences geared towards improving students' achievement in Mathematics, such efforts do not appear to have yielded the desired results. Okigbo and Okeke (2011) identified geometry as one of the components of Mathematics in which students have low interest and achieve poorly. This problem is attributed to teachers' inability to employ appropriate instructional approaches in teaching geometry which results to lack of interest and low achievement in Mathematics, particularly geometry (Nwoke, 2017). According to WAEC chief examiners' reports (2018), the percentage pass at credit level in Mathematics between 2011-2018 ranged between (39.57-59.22), which portrays an unstable and worrisome achievement in Mathematics for a country like Nigeria, which is aspiring to engender quality education to its citizenry as enshrine in agenda 4 of the Sustainable Development Goals (2015).

If this frequent low achievement in Mathematics by students remains unchecked, the tendency is that the country may not be able to produce skilled, versatile, quality and resourceful manpower needed for the economic and socio-political development of Nigeria. This is consequent upon the fact that, without credit pass in Mathematics, students on completion of their secondary education cannot proceed to higher educational institutions where highly skilled workforce in Science, Technology, and Engineering needed for today's global economy are produced. In response to this, the study seeks to explore how the use of manipulative materials affects senior secondary one students' interest and achievement in geometry.

Aim and Objectives of the Study

The aim of the study is to investigate the effects of manipulative materials on senior secondary one (SSI) students' interest and achievement in geometry in Jos Metropolis, Plateau State, Nigeria. Specifically, the study seeks to:

1. Find out the post-test interest scale mean scores of SSI students in geometry in the experimental and control groups.
2. Examine the post-test achievement mean scores of SSI students in geometry in the experimental and control groups.
3. Determine the difference between the post-test interest scale mean scores of SSI male and female students in geometry in the experimental group.
4. Find out the difference between the post-test achievement mean scores of SSI male and female students in geometry in

the experimental group.

Research Questions

The following research questions were answered in the study:

1. What are the post-test interest scale mean scores of SSI students in geometry in the experimental and control groups?
2. What are the post-test achievement mean scores of SSI students in geometry in the experimental and control groups?
3. To what extent does the interest scale mean scores of SSI male and female students in geometry in the experimental group differ after treatment?
4. To what extent does the post-test achievement mean scores of SSI male and female students in geometry in the experimental group differ?

Hypotheses

The following null hypotheses were formulated and were tested at 0.05 level of significance:

1. There is no significant difference between the post-test interest scale mean scores of SSI students in geometry in the experimental and control groups.
2. There is no significant difference between the post-test achievement mean scores of SSI students in geometry in the experimental and control groups.
3. There is no significant difference between the post-test interest scale mean scores of SSI male and female students in geometry in the experimental group.
4. There is no significant difference between the post-test achievement mean scores of SSI male and female students in geometry in the experimental group.

Methodology

The study used the non-randomized pre-test post-test quasi-experimental control group design. The population of the study was 4,892 SSI students in 22 public schools in Jos Metropolis, Plateau state, Nigeria. It comprises of 2,510 male and 2,382 female students in SS1 in the study area. The justification for the choice of senior secondary one (SS1) for the study is that, it is at this level that students are exposed to senior secondary school Mathematics syllabus preparatory to Senior School Certificate Examinations (SSCE). It is equally at the senior secondary school level that geometry is taught to students to enable them have the understanding of how to organize and control variables mentally in a systematic manner. The knowledge of geometry at the senior secondary school level also helps students to apply the idea in solving daily life problems such as; having a deeper understanding of the structure of their physical environment as well as exposing them to the fundamental development of the measuring processes. A sample of 58 SS1 students was selected from Government Secondary School Township, Jos using purposive sampling technique. The sample comprised of 28 male and 30 female students from two arms of SS1 class in the school for the experiment. The choice of purposive sampling technique for the study was because the school selected possess characteristics the researcher seeks to study and the participants were assessable. Other characteristics of interest to the research include: the school has two arms of SSI, and the school is co-educational in nature.

Two instruments were used to collect data for the study namely; Geometry Interest Questionnaire (GIQ) and Geometry Achievement Test (GAT). GIQ consisted of two sections; section A and Section B. The section A GIQ sought for information on gender of the participants while Section B consisted of 30 items which elicited information on interest of students in geometry. GAT on the other hand consisted of 50 multiple choice items with options A-E covering both lower and higher order questions. The lower order questions covered knowledge and comprehension of the cognitive domain while questions involving higher thinking processes covered application and analysis. The instruments were validated content and construct wise by experts. Also, the reliability of each of the instruments was obtained. Crombach Alpha method was used to establish the reliability of GIQ which is 0.835 while Kuder Richardson-20 ($KR\text{-}_{20}$) was used to obtain the reliability of GAT which is 0.890 and both instruments were found to be reliable. Data collected were analysed using mean, standard deviation, and Analysis of Covariance (ANCOVA) using the Statistical Package for Social Sciences (SPPS) version 20.0.

Results

Research Question One

What are the post-test interest scale mean scores of SSI students in geometry in the experimental and control groups?

Table 1
Post-Test Interest Mean Scores and Standard Deviation Scores of the Experimental and Control Groups

Group	Number	Mean	Standard Deviation	Mean Difference
Experimental	33	73.0000	5.3561	5.3200
Control	25	67.6800	4.8453	

Table 1 shows that in the post-test, the experimental group had interest mean score of 73.0000 with standard deviation score of 5.3561 while the control group had interest mean score of 67.6800 with standard deviation score of 4.8453. The mean difference between the groups is 5.3200 in favour of the experimental group. This implies that, the experimental group developed more interest in the learning process when taught using manipulative materials compare to their counterparts in the control group who were taught without manipulative materials.

Research Question Two

What are the post-test achievement mean scores of SSI students in geometry in the experimental and control groups?

Table 2
Post-Test Achievement Mean Scores and Standard Deviation Scores of the Experimental and Control Groups

Group	Number	Mean	Standard Deviation	Mean Difference
Experimental	33	30.6061	8.1007	6.3661
Control	25	24.2400	6.3066	

Table 2 indicates that in the prost-test, the experimental group had achievement mean score of 30.6061 with standard deviation score of 8.1007 while the control group had achievement mean score of 24.2400 with standard deviation score of 6.3066. The mean difference between the groups is 6.3661 in favour of the experimental group. This implies that, the experimental group did better in the achievement test because of their exposure to the use of manipulative materials during the learning process compare to their counterparts in the control group who were taught without manipulative materials.

Research Question Three

To what extent does the interest scale mean scores of SSI male and female students in geometry in the experimental group differ after treatment?

Table 3
Post-Test Interest Mean Scores and Standard Deviation Scores of the Experimental Group Based on Gender

Gender	Number	Mean	Standard Deviation	Mean Difference
Male	14	73.6154	6.6900	1.6154
Female	19	72.6000	4.4296	

Table 3 shows that in the post-test of the experimental group, male students had interest mean score of 73.6154 with standard deviation score of 6.6900 while female students had interest mean score of 72.6000 with standard deviation score of 4.4296. The mean difference in terms of gender is 1.6154 in favour of the male students. This implies that, male students had more interest in learning geometry when taught using manipulative materials compare to the female students.

Research Question Four

To what extent does the post-test achievement mean scores of SSI male and female students in geometry in the experimental group differ?

Table 4
Post-Test Achievement Mean Scores and Standard Deviation Scores of the Experimental Group Based on Gender

Gender	N	Mean	Standard Deviation	Mean Difference
Male	14	29.5385	5.3012	1.7615
Female	19	31.3000	9.5647	

Table 4 indicates that in the post-test of the experimental group, male students had achievement mean score of 29.5385 with standard deviation score of 5.3012 while female students had achievement mean score of 31.3000 with standard deviation score of 9.5647. The mean difference in terms of gender is 1.7615 in favour of the female students. This implies that, female students in the experimental group achieved better in geometry when instructed using manipulative materials compare to their male counterparts.

Hypothesis One

There is no significant difference between the post-test interest scale mean scores of SSI students in geometry in the experimental and control groups.

Table 5
ANCOVA Analysis of the Post -Test Interest Mean Scores of Students in Geometry in the Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1023.796[a]	2	511.898	32.729	.000
Intercept	1482.140	1	1482.140	94.764	.000
Pre-GIQ	621.219	1	621.219	39.719	.000
Group	332.767	1	332.767	21.276	.000
Error	860.221	55	15.640		
Total	291853.000	58			
Corrected Total	1884.017	57			

a. R Squared = .543 (Adjusted R Squared = .527)

Table 5 reveals that the F-value of 21.276 and associated P-value of .000 were obtained. Since the P-value of 0.000 is less than 0.05. This shows that there was a significant difference between the post-test interest scale mean scores of students in geometry in the experimental and control groups in favour of the former. This means that, students in the experimental group who are exposed to learning geometry using manipulative materials had more interest in the learning process than their counterparts in the control group who were instructed without manipulative materials.

Hypothesis Two

There is no significant difference between the post-test achievement mean scores of SSI students in geometry in the experimental and control groups.

Table 6

ANCOVA Analysis of the Post -Test Achievement Mean Scores of Students in Geometry in the Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	814.726[a]	2	407.363	7.956	.001
Intercept	3760.426	1	3760.426	73.441	.000
Pre-GAT	238.268	1	238.268	4.653	.035
Group	633.788	1	633.788	12.378	.001
Error	2816.171	55	51.203		
Total	48656.000	58			
Corrected Total	3630.897	57			

a. R Squared = .224 (Adjusted R Squared = .196)

Table 6 reveals that the F-value of 12.378 and associated P-value of .001 were obtained. Since the P-value of 0.001 is less than 0.05. This shows that there was significant differences between the post-test achievement mean scores of students in geometry in the experimental and control groups. This implies that, students in the experimental group who were taught geometry using manipulative materials achieved better than their counterparts in the control group who were taught without manipulative materials.

Hypothesis Three

There is no significant difference between the post-test interest scale mean scores of SSI male and female students in geometry in the experimental group.

Table 7

ANCOVA Analysis of the Post -Test Interest Mean Scores the Experimental Group Based on Gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	733.511[a]	2	366.756	59.639	.000
Intercept	508.792	1	508.792	82.736	.000
Pre-GIQ	725.388	1	725.388	117.957	.000
Gender	.581	1	.581	.094	.761
Error	184.489	30	6.150		
Total	176775.000	33			
Corrected Total	918.000	32			

a. R Squared = .799 (Adjusted R Squared = .786)

Table 7 reveals that the F-value of .094 and associated P-value of .761 were obtained. Since the P-value of .761 is greater than 0.05. This shows that there was no significant difference between the post-test interest scale mean scores of male and female students in geometry in the experimental group. This entails that, the use of manipulative materials was gender friendly as both male and female students had positive interest in learning geometry.

Hypothesis Four

There is no significant difference between the post-test achievement mean scores of SSI male and female students in geometry in the experimental group.

Table 8
ANCOVA Analysis of the Post -Test Achievement Mean Scores the Experimental Group Based on Gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	506.540[a]	2	253.270	4.769	.016
Intercept	1015.100	1	1015.100	19.113	.000
Pre-GAT	482.092	1	482.092	9.077	.005
Gender	83.496	1	83.496	1.572	.220
Error	1593.339	30	53.111		
Total	33012.000	33			
Corrected Total	2099.879	32			

a. R Squared = .241 (Adjusted R Squared = .191)

Table 8 reveals that the F-value of 1.572 and associated P-value of .220 were obtained. Since the P-value of .220 is greater than 0.05. This shows that there was no significant difference between the post-test achievement mean scores of male and female students in geometry in the experimental group. This means that, the use of manipulative materials was gender friendly as both male and female students achieved better when instructed using manipulative materials.

Discussion of Results

As a result of the benefits of mathematics to Science, Technology, Economy and Socio-political development of the society, the subject should therefore be taught to students in an active, thought provoking and meaningful manner that will enable students grasp concepts taught to them. The study was therefore carried out to investigate the effects of manipulative materials on senior secondary one students' interest and achievement in geometry in Jos Metropolis, plateau state, Nigeria. To achieve this aim, students in the experimental group were taught geometry using manipulative materials while those in the control group were taught the same concept without the use of manipulative materials.

Findings from the study revealed that participants who were taught using manipulative materials had positive interest in geometry than those taught with lecture method. This was evident in the mean difference of 5.3200 in favour of the experimental group. This implies that, the experimental group developed more interest in the learning process compare to their counterparts in the control group after treatment. The revelation is related to the findings by Sutton, 2012; Iji, Abakpa, and Takor 2015 who found out that, the use of manipulative materials during mathematics instruction increases and sustains students interest in mathematics. Also, in terms of achievement between students in the experimental and control groups, there was a mean difference of 6.3661 in favour of the experimental group. This implies that, the experimental group did better in the achievement test than their counterparts in the control group. The finding is related to Larbi and Mavis, 2016 who found out that the use of manipulative materials have positive effect on students' achievement which aids in the cognitive development by allowing students to observe, model, construct and internalize mathematical ideas and concepts for improved achievement. Also in terms of gender, there was a mean difference of 1.7615 in favour of the female participants of the experimental group in geometry achievement test (GAT). This means that, the female participants did better in GAT when compared to their male counterparts but it was not significant.

Similarly, in the experimental group in table 5, it was revealed that F(21.276) = P = 0.000, P > 0.05 which shows that null hypothesis of no significant difference was rejected. This implies that, there was a significant difference of the post-test interest scale mean scores of students in geometry in favour of students in the experimental group. Also, in the experimental group in table 6, it was revealed that F(12.378) = 0.001, P < 0.05 which shows that null hypothesis of no significant difference was rejected. This shows that there was a significant difference between the post-test achievement mean scores of students in geometry in favour of students in the experimental group. Again, in the experimental group in table 8, it was revealed that F(I.572) = P = 0.220, P > 0.05 which shows that the null hypothesis of no significant difference was retained . This implies that, the use of manipulative materials is gender friendly in terms of achievement. The finding is consistent with the study conducted by Shafiq (2013) on the effects of gender performance in algebra, geometry, and trigonometry and found no gender difference in the overall students' performance. Research evidence like that of Mutai (2016) and Tiamiyu, Ibrahim and Sirajo (2016) also ascertained that there is no gender difference in students' performance in mathematics. This position is contrary to the findings from the study conducted by Rababh, Veloo and Perumal (2014) who concluded that female students performed better than their male counterparts in problem solving in mathematics.

Conclusion

Based on the findings of this study, it is concluded that SSI students taught geometry using manipulative materials developed positive interest and achieved better than their counterparts taught same concept using lecture method. Also, the interest and achievement of male and female students is not different when exposed to learning using manipulative materials which implies that the strategy is gender friendly in terms of interest and achievement.

Recommendations

In the study, some recommendations were made based on the findings. They are as follows:

1. Mathematics teachers should use manipulative materials in teaching geometry to enable SSI students participate actively in the learning process for improved achievement.
2. Mathematics teachers should also use manipulative materials in teaching other components of Senior School Mathematics where students exhibit weakness.

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TEACHER'S COMMUNICATION SKILLS AND CLASSROOM INTERACTIONS TOWARDS SCIENCE AND MATHEMATICS CONTENT DELIVERY IN LAGOS STATE, NIGERIA

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Abstract

This study was designed to investigate teachers' communication skills and classroom interactions towards Science and Mathematics content delivery in Lagos State, Nigeria. The study adopted a descriptive survey research. The study sample consists of sixty respondents randomly drawn across all the six Education Districts. The instrument used for data collection was 19-item Teachers Communication Skills and Content Delivery Questionnaire developed by the researchers and the respondents were able to access the Online Google form via the link created. It was duly validated and the reliability index gave 0.77 using Cronbach Alpha formula. Three research questions were raised and three research hypotheses were generated which were tested at 0.05 level of significance using Analysis of Variance (ANOVA). The respondents comprise 35 male and 25 female teachers. The results of the study revealed that there was no significant difference between male and female teachers' communications skills and their level of classroom interactions. However, this study favored the male teachers than their female counterparts in terms of Science and Mathematics Content delivery. It was therefore recommended that teachers should embrace excellent communication skills and best classroom interaction practices towards effective Science and Mathematics content delivery.

Key words: Classroom Interactions, Communication, Mathematics, Science

Introduction

Communication is a broad term which have been interpreted by different researchers depending on the context of usage. In recent times, the term is used in the Information Technology circle to connote Information Communication Technology (I.C.T) skills which every digital teacher needs to know how to use, adopt and adapt for teaching and learning in a face-to-face setting, virtual learning platforms or a hybrid classroom setting in the 21st century and beyond. Dharmendra (2017) noted that Carl Friedrich Gauss referred to Mathematics, as the queen of science but unfortunately students fear from this queen. Although, the subject is very essential to the growth of many other disciplines. The science of Mathematics depends on the mental ability. It is the means to develop the thinking power and reasoning intelligence which shares the mind and makes it creative. The development of human beings and their culture depend on the development of Mathematics. This is why it is known as the base of human civilization. It is also the language of all material science and the center of all Engineering branches which revolve around it. Rohid, Suryaman and Rusmawati (2019) revealed that Mathematics is generally identical to the calculation of figures and formulas; giving rise to the notion that communication skills cannot be built on learning Mathematics. Communication skills are very important in the learning of Mathematics. Mathematical Communication is one of the standard processes in Mathematics learning proposed by the National Council of Teachers of Mathematics (NCTM, 2000). Mathematical Communication Skills (MCS) refer to the student's ability to:

(i) arrange and link their Mathematics thinking through communications.

(ii) communicate their logical and clear Mathematical thinking to their friends, teachers and others.

(iii) analyze and assess Mathematical thinking and strategies used by others; and

(iv) use Mathematical language to express Mathematical ideas correctly (NCTM, 2000).

In contemporary terms, Science is a system of acquiring knowledge based on the scientific process or method in order to organize a body of knowledge gained through research. Science is a continuing effort to discover and increase knowledge through research. Scientists make observations, record measurable data related their observations and analyze the information at hand to construct theoretical explanations of the phenomenon involved (Extracts from www.explorable.com dated 18th April, 2022).

Sng Bee (2012) opined that effective communication skills are important for a teacher in transmitting of education, classroom management and interaction with the students in the class. Teacher must teach the students who have different thinking approaches. To teach in accordance with the ability and capability of the students, a teacher needs to adopt such skills of communication which motivate the students toward their learning process. Arikewuyo (2010) identified that one of the characteristics of a good teacher is effective communication. The teacher should be able to communicate effectively with the learners. The National Policy on Education stressed the importance of language as a means of promoting social interaction and national cohesion; and preserving cultures (FRN, 2004).

Singh (2019) revealed that effective teaching depends on numerous factors e.g. the teacher's ability to communicate well. Communication is the art of transmission of information, ideas and attitudes from one person to another. Communication and its advancement are vital to modern civilization. Communication can be verbal or non-verbal forms. Verbal communication involves the use of symbols that have universal meaning for all those who are taking part in the process. Verbal communication may be spoken or written. These spoken or written verbal symbols square measure called Language. Also, verbal communication is highly structured and uses formal rules of grammar. Non-verbal Communication include all human communication that is neither spoken nor written. Non-verbal behaviour is expressed either consciously or unconsciously through signs, actions, object, language, symbols, or gestures.

Ogbu (2011) noted that the predominant way in which classroom interaction occurs is called interaction pattern. Interaction pattern is a way in which messages are transmitted successfully between teachers and students to achieve instructional objective in the classroom. The four major classification of classroom interaction patterns according to Ogbu (2011) are as follows:

(i) Teacher-student interaction pattern: an interaction between the teacher and individual students or group of students.

(ii) Students-students interaction pattern: that is where students react to each other actions, attitude, and opinions during class session; it is further classified as co-operative, competitive and individualistic interaction pattern.

(iii) Teacher-material interaction pattern: that is when the teacher is manipulating instructional materials, machines, and equipment for the purpose of skill learning or in other to stress a point or clarify some issues for the students.

(iv) Student-material interaction pattern: when students look on instructional materials, machines and equipment solve practical problems or experiment with specimen or models.

Classroom interaction pattern is an instructional strategy whereby the teacher ensures that teacher ensures that the above interaction patterns are effectively applied in each lesson delivery (Nnorom and Erhabor (2019).

Strategies for promoting Classroom Interaction

Jia (2013) itemized five strategies for promoting classroom interaction. They are as follows:

1. Improving Questionnaire strategies – The attention of the teacher to the learners can activate the teacher-learner interaction. The teacher should ask the question that can be answered by the learners then the teacher adapt his questions to the levels or abilities of the learners.
2. Attending to Learners linguistic level – The activities should offer different language level to different learners. The used material reflects the unique needs of those learners at the level they have reached.
3. Implementing Cooperative learning – Working cooperatively can helps development of learner's social skills. Cooperative learning means that every member of the group is included and differences among group member are resolved by the group members.
4. Building Positive Teacher-Learner Rapport – Mutual respect between teacher and learners is essential part of education. The dynamic qualities of classroom learning need is the responsibility of the teacher and learner.
5. Reducing Classroom Anxiety – The teacher helps the learners to boost their self-esteem and self-confidence and create comfortable and non-threating environment.

Benefits of Teacher Communication Skills and Classroom Interactions

It is worth to note that through education, individuals acquire knowledge, skills and attitudes that are necessary for effective living. However, to facilitate the process of knowledge sharing, teachers and students must communicates appropriately in the classroom using interactive techniques that best suit specific objectives and expected academic outcomes (Chrisantus, 2019; Atuboinoma and Amadi, 2021). Communications skills and classroom interactions are part of the 21st century core skills. It promotes active participation; enhance learning and retention. It motivates the learners to learn independently.

Statement of the Problem

Science and Mathematics teaching requires teachers who are fundamentally grounded in the content areas of the subject matter. This is important so that the teachers can be able to effectively demystify the abstract nature of the topics to be taught in Science and Mathematics and make learners appreciate the real application to their everyday life activity. Teachers' inability to effectively communicate and utilize classroom interactive technique can adversely affect their content delivery. This culminates to students' dislike of studying Science and Mathematics related courses. Therefore, this study tends to address this issue by offering ways and strategies for better teacher communication skills and classroom interactions towards Science and Mathematics content delivery.

Aim and Objectives of the Study

This study is aimed at investigating teachers' communication skills and classroom interactions towards Science and Mathematics content delivery in Lagos State, Nigeria. Specifically, the objectives of this study are:

(1) to find out if there is any significant difference between the communication skills of Male and Female teachers.

(2) to determine whether there is any significant difference between the level of classroom interactions of Male and Female teachers.

(3) to find out if there is any significant difference between Science and Mathematics content delivery by Male and Female teachers.

Research Questions

The research questions that were raised for this study are:

(1) To what extent do Male teachers' communication skills differ from their Female counterparts?

(2) Do Male teachers have better classroom interactions than their Female counterparts?

(3) Are Science and Mathematics content better delivered by Male or Female teachers?

Research Hypotheses

The null research hypotheses that were generated for this study are:

(1) There is no significant difference between the communication skills of Male and Female teachers.

(2) There is no significant difference between the level of classroom interactions of Male and Female teachers.

(3) There is no significant difference between Science and Mathematics content delivery by Male and Female teachers.

Research Method

The instrument adopted for data collection was 19-item Teachers Communication Skills and Content Delivery Questionnaire developed by the researchers and the respondents were able to access the Online Google form using the link. The Google link used for data collection was forwarded to the respondents via the WhatsApp platform created so that they can respond to the items:

https://docs.google.com/forms/d/10ajmr5RFagBzu0S4Ysm5Lki_1EcCuzI8OrvfZOtELxs.

The respondents filled the questionnaire online. The items contained in the questionnaire are as follows:

SECTION 1: COMMUNICATION SKILLS

1. Use of good interpersonal communication skills can foster learning in Mathematics and Science related subjects
2. Learners can be properly engaged by their teacher who is endowed with excellent communication skills.
3. Teachers communication skills express self confidence in content delivery.
4. Communication skills foster learners' learning in groups.
5. Effective use of teaching strategies is an indication of the teacher's communication skills.
6. Good communication skills lead to active participation of learners.
7. Communication Skills promote effective classroom management.

SECTION 2: CLASSROOM INTERACTIONS

8. Difficulties in Mathematics and Science related subjects can be tackled with peer-to-teacher classroom interaction.
9. Prompt use of positive reinforcement and feedback mechanisms guarantee effective learning.
10. Appropriate use of probing and open-ended questions builds communication and collaboration among learners.
11. The learning outcomes can be realized when there is effective communication in the classroom.
12. Learning resources can be locally sourced or improvised during instruction and can be effectively utilized when the teacher is able to communicate the learning materials effectively.
13. Mathematical and Scientific formula can be learnt easily when the steps involved are carefully explained.
14. Good communication enhances effective information dissemination to learners.

SECTION 3: MATHEMATICS AND CONTENT DELIVERY

15. Mathematics and Science related brainstorming activities can be achievable through effective use of language.
16. Social Interaction is gained through communication and transfer of learning.
17. Teacher's communication skills can be improved upon through micro-teaching sessions and paper presentation at conferences.
18. Teachers with good communication skills are better time-managers.
19. Periodic changes in Mathematics and Science curriculum can be communicated to the teacher through the relevant bodies.

It was duly validated, and the reliability index gave 0.77 using Cronbach Alpha formula. It adopted a 4-point Likert scale of Strongly Agree (4); Agree (3); Disagree (2) and Strongly Disagree (1). This study adopted a descriptive survey research. The study sample consists of sixty respondents randomly drawn across all the six Education Districts in Lagos State, Nigeria. Three research questions were raised, and three research hypotheses were generated which were tested at 0.05 level of significance using Analysis of Variance (ANOVA). The respondents comprise 35 Male and 25 Female teachers.

Data Analysis and Result

Research Question 1

To what extent do Male teachers' communication skills differ from their Female counterparts?

Table I – Mean and Standard Deviation based on Communication Skills

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Male	35	3.6122	.31101	.05257	3.5054	3.7191	2.71	4.00
Female	25	3.5314	.31004	.06201	3.4035	3.6594	3.00	4.00
Total	60	3.5786	.31057	.04009	3.4983	3.6588	2.71	4.00

Table I showed that the mean and standard deviation values of the Male teachers' communication skills is 3.6122 and 0.31101 while the mean and standard deviation values of the Female teachers' communication skills is 3.5314 and 0.31004 respectively. This clearly shows that the mean difference between the Male and Female teachers communication skills is 0.0808. It can thus be deduced that the male teachers had a higher mean value than the female teachers though the gap in their standard deviation values is not significant.

Research Question 2

Do Male teachers have better classroom interactions than their Female counterparts?

Table II – Mean and Standard Deviation based on Classroom Interactions

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Male	35	3.5469	.31658	.05351	3.4382	3.6557	2.71	4.00
Female	25	3.4857	.36187	.07237	3.3363	3.6351	2.71	4.00
Total	60	3.5214	.33459	.04320	3.4350	3.6079	2.71	4.00

Table II showed that the mean and standard deviation values of the Male teachers' classroom interactions is 3.5469 and 0.31658 while the mean and standard deviation values of the Female teachers' classroom interactions is 3.4857 and 0.36187 respectively. This clearly shows that the mean difference between the Male and Female teachers classroom interactions is 0.0612. It can thus be deduced that the male teachers had a higher mean value than the female teachers though the female teachers' classroom interactions standard deviation value is slightly higher than their male counterparts but not significant.

Research Question 3

Are Science and Mathematics content better delivered by Male or Female teachers?

Table III – Mean and Standard Deviation based on Content delivery

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Male	35	3.4286	.38545	.06515	3.2962	3.5610	2.60	4.00
Female	25	3.1920	.41425	.08285	3.0210	3.3630	2.60	4.00
Total	60	3.3300	.41141	.05311	3.2237	3.4363	2.60	4.00

Table III – showed that the mean and standard deviation values of the Male teachers' content delivery is 3.4286 and 0.38545 while the mean and standard deviation values of the Female teachers' content delivery is 3.1920 and 0.41425 respectively. This clearly shows that the mean difference between the Male and Female teachers content delivery is 0.2366. It can thus be deduced that the male teachers had a higher mean value than the female teachers though the female teachers' content delivery standard deviation value is slightly higher than their male counterparts.

Testing of Research Hypotheses

The hypotheses were tested at 0.05 level of significance using Analysis of Variance (ANOVA). The results are displayed in tables IV, V and VI below.

Hypotheses 1 – There is no significant difference between the communication skills of Male and Female teachers.

Table IV – Analysis of Variance on Male and Female Teachers Communication Skills

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.095	1	.095	.987	.325
Within Groups	5.596	58	.096		
Total	5.691	59			

Table IV showed clearly that the f-value as 0.987 and was significant at 0.325. Since, 0.325 was greater than 0.05, this meant that at 0.05 significant level, the f-value was not significant. Hence, hypotheses 1 was accepted as stated. Thus, the study concluded that there was no significant difference between the communication skills of Male and Female teachers.

Hypotheses 2 – There is no significant difference between the level of classroom interactions of Male and Female teachers.

Table V – Analysis of Variance on Male and Female Teachers Classroom Interactions

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.055	1	.055	.484	.489
Within Groups	6.550	58	.113		
Total	6.605	59			

Table V showed clearly that the f-value as 0.484 and was significant at 0.489. Since, 0.489 was greater than 0.05, this meant that at 0.05 significant level, the f-value was not significant. Hence, hypotheses 2 was accepted as stated. Thus, the study concluded that there was no significant difference between the level of classroom interactions of Male and Female teachers.

Hypotheses 3 – There is no significant difference between Science and Mathematics content delivery by Male and Female teachers.

Table VI – Analysis of Variance (ANOVA) on Male and Female Teachers Content Delivery

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.816	1	.816	5.162	.027
Within Groups	9.170	58	.158		
Total	9.986	59			

Table VI showed clearly that the f-value as 5.162 and was significant at 0.027. Since, 0.027 was less than 0.05, this meant that at 0.05 significant level, the f-value was significant. Hence, hypotheses 3 was not accepted as stated. Thus, the study concluded that there was a significant difference between Science and Mathematics content delivery by Male and Female teachers.

Summary of Findings

1. There was no significant difference between the Male and Female teachers' communication skills.
2. There was no significant difference between the Male and Female teachers' classroom interactions.
3. There was a significant difference between Science and Mathematics content delivery by Male and Female teachers.

Discussion of Findings

The results collated from Table I revealed that the mean value of Male teachers' communication skills was higher than that of the Female teacher communication skills, but their standard deviation values difference was not significant. In Table II, the mean value of Male teachers' classroom interaction was higher than that of the Female teacher, but the standard deviation value of the female teachers' classroom interaction was slightly higher than their male counterparts. Also, in Table III, the mean value of Male teachers' content delivery was higher than that of the Female teacher, but the standard deviation value of the female teachers' content delivery

was slightly higher than their male counterparts.
Tables IV, V and VI was used to test the three null research hypotheses for this study. It can be deduced from Table IV and Table V that there was no significant difference between the Male and Female teachers' communication skills and their classroom interactions because the F-values derived are 0.987 and 0.484. These F-values were significant at 0.325 and 0.489 respectively. Since 0.325 and 0.489 are greater than 0.05, this meant that at 0.05 significant level, the two f-values are not significant. Hence, the first two stated null research hypotheses for this study were accepted. Hence, effective teaching and best classroom practices should be the priority of teachers as supported by the research findings of researchers like Singh (2019); Vahey, Jackie and Knudsen (2020).
In Table VI, there was a significant difference between Science and Mathematics Content delivery by Male and Female teachers because the F-value derived is 5.162 and it was significant at 0.027. Since 0.027 was less than 0.05, this meant that at 0.05 significant level, the f-value was significant. Hence, the stated null research hypotheses three was not accepted as stated.

Conclusion

This study concluded that there was a significant difference between Science and Mathematics content delivery by Male and Female teachers' i.e., male teachers performed significantly better than their female counterparts in delivering Science and Mathematics content. This can be attributed to the effective use of language; social interactions with learners and being dynamic to periodic changes in Science and Mathematics curriculum etc. This view is in line with the research findings of Zarrinabadi (2014) which revealed that teacher's attitude, involvement (the quality of teacher-student relationship), immediacy and teaching styles influence the learners' participation and their willingness to communicate. To corroborate this assertion, Sidenvall (2019) opined that Mathematical competence must be sustained.

Recommendations

1. Teachers should embrace excellent communication skills through continuous practice and constructive dialogue.
2. Best classroom interaction practices should be encouraged between the teacher and the learners.
3. Seminars/Workshops centered on the 21st century core skills like communication should be organized for in-service Science and Mathematics teachers.
4. Government should empower the necessary ministries and agencies to review the curriculum in use periodically.

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THE USE OF DIGITAL TECHNOLOGY IN MATHEMATICS EDUCATION DURING COVID-19 PANDAMIC

Abstract

Once the Corona Virus Disease 2019 (*COVID-19) crisis is over, will everything return to normal, or will we instead witness an ongoing boom in online learning? A time of crisis is an opportunity for all education systems to look to the future; there is enormous potential for digital technology in mathematics education, regardless of the impact of COVID-19. In this paper, the researchers focus on answering two research questions: The study also provided a discussion on the implications that such digital technologies could have on research into the fled of mathematics education and practice in addition to suggestions for future research directions on this topic. Interviews were chosen as techniques for the purpose of this research, which were undertaken with 120 mathematics teachers from different secondary schools in Kano, Nigeria. The researchers found that 98% of participants believed that COVID-19 is the gateway for digital learning in mathematics education. In addition, 97% claimed that the use of online education by schools had expanded greatly following the corona virus outbreak. This has resulted in various forms of software being used to facilitate communications between teachers and students included mobile technologies, touch screens and pen tablets, digital library and designing learning objects in mathematics education, Massive Open Online Courses (MOOCs) in mathematics, and computer algebra systems (CAS) such as Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima.*

Keywords: COVID-19, The use of digital technology, Mathematics education

Introduction

The response of educational organizations across the globe to travel bans and quarantines has resulted in a shift towards learning online. This could lead to an upsurge in education – and better prepare us to deal with subsequent emergencies. The nature of global digital education is such that COVID-19 may fuel the development of strong capabilities in areas where there is sufficient connectivity, infrastructure, and resources.

In Nigeria, for example the use of online education by universities and schools had expanded considerably because of the corona virus outbreak. Currently, there is a dearth of research conducted on the use of digital platforms for learning mathematics (Mulenga &Marbán, 2020; Perienen, 2020, Niess, 2006). It is not yet known exactly "is COVID-19 the gateway for digital learning in mathematics education?" "What type of digital technology is being used in mathematics education during the COVID-19 closure period?" As they will be required to learn remotely in their respective homes. It is against this gap of knowledge that this study wishes to narrower. For example, Lagos state government has come up with online learning management system accessible at (ecosuccesscloud.com), some radio programmes for teaching secondary schools' students in Kano state and the likes.

The study also provides a discussion on the implications that such digital technologies could have on research into the fled of mathematics education and practice in addition to suggestions for future research directions on this topic. This will help the reader to understand how recent developments in this area of research have evolved in the last few years.

Research importance

1- Providing useful insights regarding the positive side-effects of COVID-19.

2- The research keeps pace with global and local trends that advocate the need to benefit from the use of digital technology in mathematics education.

3- Enriching educational libraries with a modern topic on COVID-19 and the use of digital technology in mathematics education.

4- Instructing teachers to use of digital technology in mathematics education.

5- Providing useful insights regarding the use or application of digital technology in mathematics education to those developing curricula in the Ministry of Education in the world.

6- Contributing to opening new prospects for further research in order to keep pace with technology and exploit its positive role in mathematics education.

Research questions

(1) Is COVID-19 the gateway for digital learning in mathematics education?

(2) What type of digital technology is being used in mathematics education during the COVID-19 pandemic?

Literature review

Theoretical framework

The theoretical framework adopted to undertake this research include Technology Acceptance Model (TAM) (Davis et al., 1989) is the lenses used to guide the data analysis and data interpretation to investigate the components that influence secondary students' interests in online interactions through digital technology.

Davis'(1993) Technology Acceptance Model (TAM) underpins this study as a theoretical framework. The TAM represents a good fit within a constructivist meta-theoretical paradigm, as it presents individual attitudes and subjective choice for using (or not using) ICT for teaching and learning. Two distinct attitude constructs namely, 'perceived usefulness' (PU) and 'perceived ease of use' (PEU) are used to frame the attitude of the academic towards engagement or indifference to the use of technology. These two behavioural constructs namely PU and PEU also directly influence whether actual engagement with the technology will occur.

Deployment of ICT innovations in mathematics education

The integration of technology within education is a highly complex process involving multiple factors and like all other innovative concepts, it is essential that it is not incorporated prior to testing the various different elements (Haddad &Draxler, 2002). It is important to substantiate innovations in terms of the level to which they are appropriate and suitable, their applicability in classrooms, their impact on the learning process and cost-effectiveness. regarding mathematics education, numerous innovative concepts have been proposed, developed, piloted and implemented for usage with various different consequences,particular fields in which they have verified to be successful are educational approaches based on ICT, application of open and distance learning (ODL), virtual educational platforms, distribution of open educational resources (OERs) and the propagation of research conclusions (Iji&Abah, 2018).

Educational approaches based on ICT are teaching and learning methods in which ICT instruments are actively utilized to enhance the student learning (Agbo-Egwuet al., 2018). Schools around the world are already using a wide variety of extant digital technologies for mathematics teaching. According to Clark-Wilson et al. (2011), existing tools that are based on innovation include dynamic graphing tools, dynamic geometry tools, algorithmic programming languages, spreadsheets, data loggers (motion detectors and GPS), and computer algebra systems (CAS). Further-more, CASs like Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima can facilitate active learning approaches, which enable students to become active participants in the process of discovering and consolidating their personal knowledge, thereby enhancing their theoretical and geometrical comprehension and providing a more on-depth learning strategy (Kumar &Kumaresan, 2008). Based on the observations of Abari (2014), student interest was maintained, and their achievement levels increased subsequent to the enhancement of teaching in a higher-level secondary school mathematics class through GeoGebra. The use of dynamic geometry systems (DGS) such as Cabri and Geometers Sketchpad (GSP), among others, appear to offer new perspectives on geometry in the school setting, in addition to more advanced levels by clearly facilitating the experimentation and exploration of geometrical formations and linkages (Ijiet al., 2018). In addition to the ability to actively enhance teaching, new aspects of ICT innovations have emerged in mathematics education including the Class Learning Interactions – Observation (CLIO) tools, which allow all interactions that occur within the classroom to be systematically observed and monitored (Manny-Ikan et al., 2013).

An area of particular significance in terms of the implementation of ICT innovations within the fled of mathematics teaching is Open and Distance Learning (ODL). The first usage of the name Massive Open Online Course was in relation to the 2008 version of the Connectivism and Connective Knowledge' Course (Kady& Vadeboncoeur, 2013). Massive Open Online Courses (MOOCs) are considered to be the leading type of such courses. The design of MOOCs courses allows multiple learners to participate simultaneously, they provide students the ability to access courses at any time and from any location provided they are connected to the Internet, are publicly accessible with no entry criteria, and offer comprehensive course experiences via the Internet at no charge (Azevedo & Marques, 2017). Additionally, Open University frameworks offered in numerous countries are powered by a robust collection of technologies, providing high-quality competencies necessary for those who wish to be employed in long-tenured careers in the fled of mathematics. ODL schemes are frequently developed for the purpose of establishing a social, cognitive, and teaching presence through the Internet (Hanover Research Council, 2009).

In this respect, synchronous online classrooms can even be more effective for educating younger children compared to conventional types of teaching as they allow visual, auditory, and kinaesthetic processes to be integrated at the same time (Hastie et al., 2007). Likewise, crowd-based design approaches have been developed as a means of facilitating mathematical interactions between students and teachers in virtual environments (Hui et al., 2014).

Online teaching platforms are frequently used for augmenting discussion and cooperation among mathematicians. As suggested by Holzl (1999), the different tools utilized within virtual learning environments can include electronic mail, online forums, computer conferencing and chat groups. The development of different innovative technologies has enabled the replication of mathematical experiences based on technology both within and external to the classroom (Hofmann, 2014). Elluminate.Com represents an effective example of an online classroom as it offers a basic user interface as well as a powerful participant window that displays the names of all session participants, along with a collection of interactivity tools including the ability to raise a hand when requesting to contribute to the debate. Messaging between users and the mathematics teacher is facilitated by the instant messaging functionality, while the whiteboard can be used by the teacher for projecting slides or by the students for writing or drawing with the text and drawing applications. Different examples of frequently utilized online learning platforms include Blackboard and Moodle (Iji et al., 2018).

A different fled in which ICT innovations have been deployed in mathematics teaching is mobile technologies. After the emergence of mobile technologies, one of the areas in which the fastest growth has been observed is educational applications, and it is anticipated that the expansion of these apps along with mobile technologies will continue going forward (Cherner et al., 2016). Hence, the following section will explain to readers how mobile technologies are used for mathematics teaching.

Use of Mobile Technologies in Mathematics Teaching and Learning

There has been increased focus among educational scholars and practitioners on the utilization of mobile technologies (e.g., tablets and tablets) by teachers and learners in the fled of mathematics. The attributes of mobile devices including the fact that they are portable, available, allow users to access the Internet, and are widely embraced by members of the younger generation and others mean that they are considered an emerging medium with the capability to expand the boundaries of mathematics teaching and learning outside the traditional classroom environment. White and Martin (2014, p. 64) contended that the specific features of mobile devices (like the ability to capture and collect data, communicate, and collaborate with different users, consume, and critique media, build and generate individual forms of expression and representation) can be easily translated into the scientific, mathematical and engineering practices emphasised within the Common Core Math and Next Generation Standards (NGSS Lead States, 2013).

Researchers are increasingly focusing on the potential areas of application and possibilities of mobile technologies; however, this remains an under-researched subject regarding mathematics education. Nonetheless, some studies have been conducted (e.g., Crompton & Traxler, 2015; Larkin & Calder, 2015) that have addressed the manner in which way this type of technology could be utilized for mathematics teaching and learning.

The first studies into the application of mobile learning in mathematics can be traced back to the end of the 2000s (e.g., Franklin & Peng, 2008), and since that time, there has been considerable expansion in this kind of research in terms of both international conferences and sector-specific journals. Most studies analyzed within this research can be categorised into three main groups: (a) research into the possible areas of application of mobile devices for mathematics teaching and learning; (b) affective studies on the utilization of mobile devices; and (c) the utilization of mobile devices for educating mathematics teachers.

Various researchers have concentrated on taking advantage of the features of mobile devices, including the benefits of being portable, mobile, and the ability to photograph and video actual phenomena that can subsequently be examined and discussed from a mathematical perspective. One such study was conducted by Wijerset al. (2010), who employed a game based on location named MobileMath for mobile devices with GPS technology that facilitated the creation and exploration of quadrilateral equations along with their properties in a real environment in an external location.

Other studies have concentrated on investigating the opinions and feelings experienced by mathematics teachers and students when teaching or studying mathematics via mobile devices. For instance, Holubz (2015) gathered feedback from teachers and students regarding a programme titled “Bring Your Own Device” (BYOD), which encouraged the utilization of the Internet and mobile equipment when studying mathematics.

Lastly, it can be observed the design of inquiry tasks in mobile environments for preservice and in-service that several studies have analysed the usage of mobile devices for educating mathematics teachers. For example, Yerushalmy and Botzer (2011) presented a discussion on the theoretical aspects in addition to the problems and potential benefits underpinning teachers.

The study conducted by Crompton (2015) exemplifies the manner in which mobile devices can be utilized for promoting mathematical concept learning. As part of her work, Crompton proposed a research study based on design whereby iPads were utilized as a medium for supporting the learning of the notion of angles in primary school children. Within this learning environment, mobile devices were employed by the children for the purpose of identifying and photographing forms that resembled angles that existed naturally in their environment (e.g., tree stumps, shoe patterns, or table corners). Subsequently, the photographed shapes were analysed by the students through dynamic geometry apps installed on their mobile devices. Consequently, this enabled the students to examine whether the naturally formed angles they observed in their physical surroundings in fact corresponded to the mathematic characteristics of an angle.

The usage of mobile technologies in the context of mathematics learning and teaching is a developing fled of research that continues to enlarge at an exponential rate. Hence, the following part of this paper will provide an explanation on how touch screens and pen tablets are used for Mathematics Teaching and Learning.

Use of touch screens and pen tablets in mathematics teaching and learning

Researchers have contended that the attention spans of individuals could be impacted by the input devices utilized when performing activities or tasks supported by computers (Chen et al., 2017; Evans et al., 2011; Mangen, 2008; McLaugh-linet al., 2009). For example, Chen et al. (2017) conducted a study in which they attempted to investigate and make a comparison between student's attention span regarding the time spent on a task and the amount of distractions when utilising touch screens and pen tablets for problem solving tasks in the fled of mathematics with virtual manipulatives. The findings revealed that those students who used touch screens when performing the task had an increased attention span, meaning that the time spent on the task increased and they had less distractions compared to those who used pen tablets. Mangen (2008) argued that the action of clicking a mouse could distract the user from the information they are reading on the computer screen. Technologies that have emerged recently such as touch screens, which offer intuitive and shared interfaces, introduce new methods of incorporating technology into educational practice, including the use of virtual manipulatives on touch screen gadgets for supporting the learning of mathematics (e.g., Moyer-Packenham et al., 2016; Watts et al., 2016). Studies have indicated that when using touch screens, there is a stronger association between the hand gestures of the user and the on-screen results compared with use of a mouse or physical keyboard (Romeo et al., 2003).

Additionally, recent studies have shown that various teachers have tried to utilise pen-based technologies to promote student learning, specifically in the context of mathematics teaching (e.g., Cantu et al., 2008; Huang et al., 2017; Koile& Rubin, 2015), since such technologies enable students to learn how to write equations or draw mathematical representations.

Digital library and designing learning objects in mathematics education

According to the definition provided by the Digital Library Manifesto (Candela et al., 2007), a digital library is a virtual entity that engages in a process of collecting, managing, and preserving rich digital content of all types for the benefit of users. Clearly, such libraries require some form of digital storage. In the fled of education, digital repositories utilise learning objects for the purpose of organising their content, which differentiates their organisational approach from those used for printed documents.

Learning objects (LO) suggested by IEEE Learning Technology Standards Committee (2002) are components of a novel kind of e-learning based on an object-focused approach in computer science. According to the definition, an LO is a digital object that one can use, reuse, and tag with metadata targeted at promoting learning.

The primary characteristics of learning objects are that they are accessible, inter-operable and reusable (Polsani, 2003). Accessibility denotes the ability to tag learning objects with metadata, while interoperability is the technique via which learning objects are shared with other technology systems without the requirement to modify the objects, and reusability denotes the utilization of learning objects in various learning settings.

Widely used learning resources in virtual repositories include MERLOT (Multimedia Educational Resources for Learning and Online Teaching), Wisc-Online, DRI, Khan Academy, and EBA (Digital Repository of Turkey) (Borba et al., 2017).

In 1997, the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) (https:// www. merlot. org/) was established. A resource developed by California State University, it has wide usage around the world. Users are not charged to use MERLOT and it is largely financed by higher education establishments in different countries.

The Khan Academy (https:// www. Khanacademy.org) is an individualised learning resource that caters to learners from different age groups; it provides practice tasks, educational videos and a tailored learning dashboard that allows learners to work at their own speed both within and out of the classroom environment. The mathematics missions provide guidance for early learners through to those studying calculus by using the latest adaptive technology, which can identify the learners' strengths and learning deficiencies (Borba et al., 2017). Murphy et al. (2014) also found a connection between Khan Academy exercises and improved scores on basic mathematics.

What Will You Do In Math Today? (http:// researchideas.ca) is an open repository of resources accessible on the Internet for teaching mathematics that was developed by George Gadanidis at Western University, Canada. This platform receives support from different organizations and incorporates a research-based mathematics text in which learning objects are categorised as numbers, patterns and algebra, measurements, geometry, data, and probabilities (Borba et al., 2017).

Existing research into learning objects has largely focused on measures of quality, individualisation and mobile learning. Gadanidis et al. (2004) examined the pedagogy and the design of interfaces used in interactively visualising mathematical investigations. They reached the conclusion that a large proportion of interactive visualisations have poor designs in terms of both pedagogy and interface design. Research has demonstrated that an important aspect of the ability to predict the effectiveness of repositories is quality assurance of the LORs (Clements et al., 2015).

Similarities between the literature and this research

1- This research is consistent with (White & Martin, 2014; NGSS Lead States, 2013) who explored the effect of mobile technologies in mathematics teaching and learning. It is also consistent with (Chen et al., 2017; Evans et al., 2011; Mangen, 2008; McLaughlin et al., 2009), who found the positive effect in touch screens and pen tablets in mathematics teaching and learning. It is also consistent with (Polsani, 2003; Borba et al., 2017), who determine the effectiveness of using digital library and designing learning objects in mathematics education. This research is consistent with (Kumar &Kumaresan, 2008), who believe that emergence of such mathematical tools and its ability to deal with most of the secondary school cannot be ignored by mathematics educators. It is also consistent with (Azevedo & Marques, 2017), who found the advantage of using Massive Open Online Courses (MOOCs) in mathematics education. However, this research differs from all literature reviews in terms of handling the COVID-19 variable.

2- The previous studies were implemented in non-Arab countries. This also represents the first study on this subject within Kano.

3- The researchers used semi-structured interviews (see Appendix 1) to collect their data, but the tools used in previous studies varied due to differences in their objectives.

4- The current study extended the recommendations of previous studies, such as that of Mulenga and Marbán (2020), the findings of his study motivate new areas of research. Other researchers could carry out studies on the effects of COVID-19 on Education. Others could investigate on some useful digital resources for students during the COVID-19 crisis and lockdown. It may also interest other researchers to examine if digital learning will eventually replace physical classroom in future. While digital learning is a life-long process for many students caught in the consequences of the spread of the deadly virus but may also be a way of coping with home confinement for all.

5- At the time of data collection for this current study, schools were closed and there were confirmed cases of COVID-19 in Nigeria. Health intervention measures had been put in place to restrict movements. The researchers interviewed the participants via Microsoft Teams or Zoom. Thus, this was very helpful to answer my research questions. In contrast to other studies, who during the time of data collection, schools were not yet closed and there were no confirmed cases of COVID-19. Health intervention measures had not yet been put in place to restrict movements. Thus, delivery mode was face-to-face in classroom settings and in the presence of the researchers.

What distinguishes this research from the existing literature

The researchers contend that this research is distinct because it is the only study to have explored COVID-19 and the use of digital technology in mathematics education in Kano Nigeria.

Aspects drawn from the literature reviews:

Drawing on the pedagogical literature, literature reviews, and adopted scientific methodology to form the theoretical framework used in this research.

Identification of the research methodology and tools appropriate for this research.

Reviewing the statistical methods employed and adopting them as appropriate for this research.

Methodology

In this study, the researchers used a semi-structured interview, and the questions included in the interviews were discussed with ten academic faculty members of mathematics in Kano state universities, Nigeria to determine the face validity and appropriateness of the content. Pilot interviews were then conducted to

determine the relevance of the interview questions, as well as to assess the duration of the interview and to evaluate the ability to perform the task. The interview rehearsal was administered to two mathematics teachers.
The sample was selected randomly and consisted of 120 mathematics teachers whose teach in secondary schools, in the third, 2019-2020. These 120 teachers have various academic backgrounds. Some have between 3 to 10 years' teaching experience and others between 11 and 25 years.

Sampling procedures

Emails and WhatsApp inviting teachers who were specializing in mathematics and other related areas to participate in the study. A reminder email was sent two weeks after the initial invitation to encourage participation. The message included an introductory letter and consent form that was requested be sent back to the researchers to indicate willingness to participate (the research's principal topic, invitation paragraph, purpose of the study, why have I been chosen? Do I have to take part? Who will have the access to the research information (data)? Who do I speak to if problems arise? What will happen to the results of the research project? Ethical review of the study and contact for further information). Finally, the participants were thanked in advance for their participation. The researchers chose the first 120 participants that returned the letter to them to be part of the research since they were subject to time restrictions. The researchers interviewed the participants via Microsoft Teams or Zoom. Before the interview, in order to ensure a smooth interview process, the researchers copied the invitation and send it out to the participant. A 9 min inter-view was planned for each interviewee.

Data analysis

Thematic analysis, which is one of the tools of grounded theory was utilized in to analyze the interview data. Initially, every interview was recorded and subsequently transcribed and the data were then read and re-read. The next stage involved the application of thematic coding (underlining the text in various colors) and then the data were matched to separate categories, thereby enabling reduction and synthesis of the large amount of data. After this, every recognized commonality was divided into topics. It was necessary to supply the following three categories of the most significant with ethical issues. In the first category, all participants were informed that they were volunteers in this study and had the right to ask for any of the responses they had given previously to be removed. In the second category, the confidentiality of participants' identities and personal details was guaranteed, meaning that their names would not be included during the translation procedure. The third category involved providing the participants comprehensive details regarding the purposes of the research.

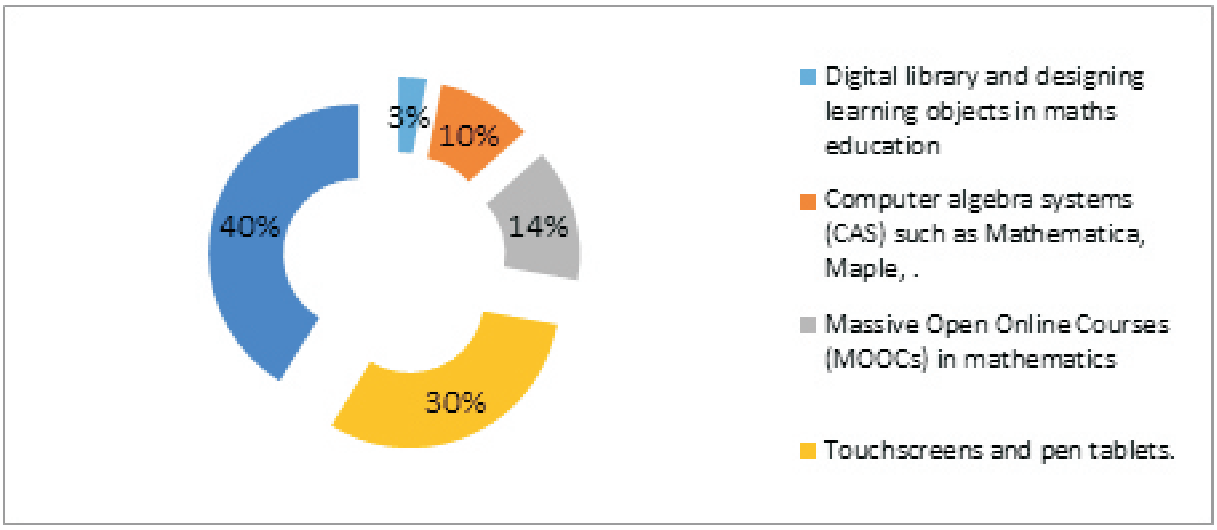
Results

Interviews were chosen as techniques for the purpose of this research; therefore, the researchers would discuss the findings concluded from answers to the interview questions and the literature review according to the research questions see Table 1 and Fig. 1.

Table 1. Summary of the answers to the research questions

The research questions	The answers	No. of Participants	Percentage
(1) Is COVID -19 the gateway for digital learning in mathematics Education?	COVID-19 is the gateway for digital Learning in mathematics education.	118	98%
	The use of online education by schools had expanded greatly following the corona virus outbreak. In line with extreme changes worldwide, schools and universities have closed and thus interactions with colleagues and teaching through traditional lectures have transformed into an online, virtual experience. This has resulted in various forms of software being used to facilitate communicate between teachers and students.	116	97%
(2) What type of digital technology is being used in mathematics education during the COVID-19 pandemic?	Mobile technologies	48	40%
	Touch screens and pen tablets.	36	30%
	Massive Open Online Courses (MOOCs) in mathematics	17	14%
	Computer algebra systems (CAS) such as Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima.	12	10%
	Digital library and designing learning objects in mathematics education	4	3%

Fig. 1 The type of digital technology is being used in mathematics education during the COVID-19 pandemic?



The above table shows that 98% of participants believed that COVID-19 is the gateway for digital learning in mathematics education. 97% claimed that the use of online education by schools had expanded greatly following the corona virus outbreak. In line with extreme changes worldwide, schools and universities have closed and thus interactions with colleagues and teaching through traditional lectures have transformed into an online, virtual experience. This has resulted in various forms of software being used to facilitate communicate between teachers and students. In the teaching and learning of mathematics, 40% of these used mobile technologies, whereas 30% used touch screens and pen tablets please see Fig. 1.

Furthermore, 3% concentrated on using digital library and designing learning objects in

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mathematics education, while 10% used computer algebra systems (CAS) such as Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima. Additionally, 14% used Massive Open Online Courses (MOOCs) in mathematics education as follows:

One participant stated that: "Following the corona virus outbreak, the nature of education may, in some ways, have fundamentally changed, potentially for the better." He provided the following example to illustrate this:"Once the corona virus outbreak has passed, the adoption of online education by schools will have expanded substantially." He also said: "My students found many advantages when using mobile devices such as: cooperation and communication with various users, the capability of capturing and gathering data, constructing and generating individual types of representation and expression, and consuming and evaluating media."

Another participant also contended that: "Yes, COVID-19 is the gateway to digital learning in mathematical education. Students' opinions of online learning may have become more positive because of the outbreak. Having previously viewed distance education as "very second rate." He added: "I noticed that students' attention spans were positively affected when touch screens and pen tablets were used for problem-solving tasks in the fled of mathematics. Therefore, as I have already mentioned, the opinions and attitudes of students towards online learning may have become more positive because of the outbreak."

Another participant noted that: "I think that COVID-19 is the gateway to digital learning in mathematical education. I did not use digital learning previously, but when COVID-19 arrived, I did use it, and I will continue to do so even after this pandemic is over." He added: "I tried to use pen-based technologies to promote and support student learning of mathematics, such as using virtual manipulatives on touch screen gadgets. However, I can say that such technologies enable students to learn how to draw mathematical representations easily."

Similarly, another participant stated: "I think that COVID-19 is the gateway to digital learning in mathematics education, as it solved the many problems that students face in the classroom. For example, several students who were previously reluctant to participate are now putting themselves forward. This is because quieter, more introverted students feel able to participate as they are not on display in front of their peers."

Another participant also noted that: "Teachers can see what every single student is doing, which is not how things usually work in the standard classroom."

However, another contended that: "Working online, it is difficult to establish whether a student is fully engaged and has sufficient understanding, a basic issue that has yet to be solved by technology."

Another participant stated: "Yes, prior to COVID-19, I did not encourage my students to use digital library in mathematics education, because I thought that digital technology is not easy to use. . .However, I do try to use it now, and have found it to be an individualised learning resource which is accessible, interoperable and reusable."

Furthermore, another participant noted that: "Yes, I think that the positive side effects of COVID-19 enable me and my students to see the advantage of using digital library in mathematics education, such as MERLOT (Multimedia Educational Resources for Learning and Online Teaching), Wisc-Online, DRI, Khan Academy, and EBA (Digital Repository of Turkey)." He added: "It is worthy of mention that I noticed that those students who used touchscreens when thinking about their real needs and values developed an increased attention span, compared with those who did not use them. In fact, before COVID-19 arrived in this country, I did not try to use touch screens and pen tablets for problem-solving tasks in the fled of mathematics, because I thought that digital technology is complicated and difficult to operate and use. However, I will now use them to support my students in mathematics."

Another participant noted: "Many students readily confess to a dislike of some basic mathematical concepts and have misapprehensions about mathematics. These have a strong impact on their capacity to learn and understand mathematics and often cause a considerable amount of confusion. The most frequent misconceptions relate to the use of fractions. For instance, students may erroneously believe that 1/12 is smaller than 1/13 because 12 is less than 13." He then went on to add: "For instance, when students were asked to multiply fractions by a whole number, some multiplied the numerator and denominator. This is a misconception as it shows students do not understand why you only multiply the numerator by a whole number. We should work to eradicate such misunderstandings as it is vital to apply knowledge about fractions to the real-world problems students encounter and must try and understand. Regarding health statistics, misunderstanding the size of numbers can have negative outcomes such as underestimating the risks of COVID-19."

Other participants sent a message to teachers who specialize in mathematics and other related areas across the world: "All teachers are being provided with a unique opportunity to exploit students' natural curiosity about the virus, the science underlying the mechanism of viral infections, and the mathematics elucidating pandemics." He continued: "I do not think that we would have done this as teachers in the traditional classroom setting, but COVID-19 gave us an opportunity to use Massive Open Online Courses (MOOCs). This gave the students the ability to access courses at any time and enabled multiple students to participate simultaneously. Increased access to digital technology for mathematics allows for a more customised learning experience. Because no two learners are exactly alike, technology can provide individual students with content and supports that are particularly helpful to their individual needs."

Another participant noted: "During the pandemic, I used computer algebra systems (CAS) such as Mathematica, Maple, MuPAD, MathCAD, and I think that this digital technology facilitated active learning methods. It also gave the students an opportunity of becoming active participants in the process of discovering and consolidating their personal knowledge

He added: "I think that when teachers' anticipations towards the digital technology in mathematics education benefits are confirmed, these tools will enhance their satisfaction which ultimately achieves the perceived objectives."

Discussion of results

The responses of the participants varied on the research questions. 98% contended that the use of digital technology in mathematics by schools had expanded considerably because of the corona virus outbreak, and this was a positive aspect of the pandemic. The researchers think that due to Corona Virus Disease 2019 (COVID-19) crisis, e-learning has become a very urgent need and an imperative of education necessities in most countries all over the world. Its great importance manifested in solving the problem of quarantined students, reduce the effects of the corona-virus epidemics. According to the interviewees, teachers will perceive the digital technology as easy to use because these tools have become mandatory for all educational institutions all over the world. Another possible explanation for these findings is the fact that when teachers' anticipations towards the digital technology in mathematics education benefits are confirmed, these tools will enhance their satisfaction and acceptance which ultimately achieves the perceived objectives. These findings could be explained by the reason that if teachers think or perceive that it is uncomplicated and simple to use the digital technology, then they are willing and intent to spend more effort and time to learn how to do so, which would undoubtedly improve their performance. In contrast, if the digital technology is complicated and difficult to operate and use, then teachers would be unwilling to try to use it.

Teachers are becoming familiar with its 'ease of use', and then found pedagogical purpose or 'perceived usefulness' (Davis, 1993). In this study, teachers' 'turn' towards digital technology seemed to satisfy both TAM constructs of 'ease of use' and 'perceived usefulness' (Davis, 1993).Teachers' beliefs and attitudes also changed with their practice as they experienced 'ease of use' and appreciated the 'perceived usefulness' of digital technology in mathematics education (Davis, 1993).

However, the question that arises is whether such a boom in online learning represents an enduring solution or a tool with which to respond to a crisis. The teachers' responses indicated to the researchers that they will continue to use digital technology in mathematical education, because they have learned that technology can make mathematics easy. They provided the type of digital technology used in mathematics education during the COVID-19 pandemic? In addition, they gave us examples to show that digital technology in mathematics education encourages students to learn more than in a traditional classroom environment.

40% of them used mobile technologies in mathematics teaching and learning, one of them mentioned that “my students found many advantages when using mobile devices such as the ability to capture and collect data, communicate and collaborate with different users, consume and critique media, build and generate individual forms of expression and representation, and this can be easily translated into the scientific and mathematical”. This is consistent with other researchers' findings, such as (White & Martin, 2014; NGSS Lead States, 2013, Alabdulaziz M.S. 2021), The participants mentioned that when the student finds it difficult to solve the task in mathematics, he can access to the mobile technologies and open the videos see the solutions, which allow students to learn at their own pace and in their own learning style. The researchers think that students and teachers are given new experiences through the application of mobile devices as instruments in mathematical education. Since the way in which we teach and learn is being quickly transformed by technology,

With respect to the utilization of mobile technologies for teaching and learning mathematics, most of learners have already determined that mobile phones constitute large parts of their lives both within and out of the classroom.

30% of participants used touch screens and pen tablets in mathematics teaching and learning, one of them stated that “it is worth to mention that I noticed that those students who used touch screens when thinking about what they really need and what they really value had an increased attention span, compared to those who did not use touch screens. Actually, before COVID-19 come to this country I did not try to use touch screens and pen tablets for problem solving tasks in the fled of mathematics, but now I will use them to support my students in mathematics”. This is consistent with (Chen et al., 2017; Evans et al., 2011; Mangen, 2008; McLaughlin et al., 2009).

3% of them concentrated on using digital library and designing learning objects in mathematics education, one of them mentioned that “yes, because before the COVID-19 I did not encourage my students to use Digital library in mathematics education, and now I tried to use it and I found that an individualised learning resource that they are accessible, interoperable and reusable.” This is consistent with (Polsani, 2003). Another participant also noted that: “yes, I think that the positive side-effects of COVID-19 that make me and my students to see the advantage of using Digital library in mathematics education such as MERLOT (Multimedia Educational Resources for Learning and Online Teaching), Wisc-Online, DRI, Khan Academy, and EBA (Digital Repository of Turkey)". This is consistent with (Borba et al., 2017). For example, Khan Academy enabled students to move at a pace that is more appropriate to their learning needs. This is consistent with Murphy et al., 2014 who found a connection between Khan Academy exercises and improved scores on basic mathematics.

A point worth mentioning is that there are useful insights regarding the positive side-effects of COVID-19. According to the participants, their opinion of digital technology in mathematics education has grown more positive because of the increased usage of it during the corona virus school building closures. In addition, they plan to continue using those newfound skills even when school buildings reopen.

10% of the participants used computer algebra systems (CAS) such as Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima, one of them stated that "to help my students with their misconceptions in mathematics, I tried to use Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima, and I noticed that they provided a more on depth learning strategy." This is consistent with (Kumar &Kumaresan, 2008; Alabdulaziz M.S. 2021), The researchers believe that emergence of such mathematical tools and its ability to deal with most of the secondary school cannot be ignored by mathematics educators. Because what the researchers understanding from the participants that using a computer algebra system (CAS) during the pandemic crisis provided many opportunities for improving student learning.

14% of them used Massive Open Online Courses (MOOCs) in mathematics education, one of the participants noted that "I do not think we can do this as teachers in traditional classroom, but COVID-19 gave us the opportunity to use Massive Open Online Courses (MOOCs), which gave the students the ability to access courses at any time, and allows multiple students to participate simultaneously". This is consistent with (Azevedo & Marques, 2017; Alabdulaziz M.S. 2021).

To sum up, as we see from above that 40% of participants used mobile technologies in mathematics teaching and learning, and this is considered as high percentage compared with other digital technologies used. The main feature of mobile technologies that distinguishes it from other learning technologies is its mobility. The researchers think that mobile technologies are highly popular amongst secondary students due to their being easily carried, wireless, containing many apps making it easy for the student to do multiple tasks at one stand. As a result, commercial competitive industry has compelled manufacturers to present new creative features of competitive traits. In addition, it is only understandable why mobile phone companies have worked hard to develop the 5th generation mobile phones that enabled users not only to talk but do almost everything they now do with their PC. This means that all other application or digital technologies ran in mobile technology at any environment, regardless of the OS, the Net, or the type of cellular. Users can download any applications from many websites, whenever they want. They can run the application without being connected to the net. In addition, the mobile technologies are also Mobile phones are available and are part of the daily culture of almost every student. The researchers do not want to forget that corona virus pandemic is a chance to see all these types and benefits of digital technologies in mathematics education, because 98% of participants above believed that COVID-19 is the gateway for digital learning in mathematics education. In addition,

97% claimed that the use of online education by schools, teachers and students had expanded greatly following the corona virus outbreak.

Summary

Results show different types of digital

technology used in mathematics education included (mobile technologies, touch screens and pen tablets, digital library and designing learning objects in mathematics education, Massive Open Online Courses (MOOCs) in mathematics, and computer algebra systems (CAS) such as Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima.), and the effects varied by the type of educational technology used. However, in view of the COVID-19 school closure period, it is apparent that digital learning in mathematics education is the instant positive response.

Implications for further studies

This study has showed that the adoption of digital learning as a response to COVID-19 stimulates the growth of digital learning in mathematics education in Kano Nigeria. The priviledge of the current situation for students engaged in digital learning is to position this transformation not just as a quick response but as a way of combating the spread of COVID-19 and the next transferable disease. The findings of this study motivate new areas of research. Other researchers could carry out studies on the effects of COVID-19 on other areas of the education field. Others could investigate on other useful digital resources for mathematics students during the COVID-19 crisis. It may also interest other researchers to answer the following questions: Will digital learning replace classroom education anytime soon? What the future holds for digitised education post-Covid-19. How will Covid-19 affect the future of digital mathematics education? While some believe that the unplanned and rapid move to digital technology – with no training, insufficient bandwidth, and little preparation will result in a poor user experience that is unconducive to sustained growth, others believe that a new hybrid model of education will emerge, with significant benefits. The researchers believed that a time of crisis is also an opportunity for all education systems to look into the future, adjust to possible threats, and build their capacity. Major world events are often an infection point for rapid innovation – while we have yet to see whether this will apply to digital technology post-COVID-19. Finally, the researchers think that digital learning system designers and developers should pay further attention to these two essential factors (perceived usefulness and perceived ease of use).

Limitations of the study

Although this study was carefully prepared, it still faced several limitations:

1- This study focused only on government secondary schools in Kano Nigeria. However, the researchers believes that this city was a good place to conduct this study, because it has a big population which is drawn from different parts Nigeria.

2- The study sample focused on teachers only, because they are the first people who play a key role in educating students in the classroom. However, the study could have included students if there were no restrictions of time.

Recommendations

In view of the findings, the researchers recommend the following:

1- These digital technologies must be included in mathematics curricula at various stages of education.

2- The stakeholders should take advantage of the findings of this study to encourage teachers to continue using these technologies in mathematics education.

3- Further research is needed to answer the questions that arose in the discussion section.

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AN INVESTIGATION INTO THE IMPACT OF JAPANESE MULTIPLICATION PEDAGOGICAL APPROACH ON SECONDARY SCHOOL STUDENTS' INTEREST AND PERFORMANCE IN QUADRATIC EXPANSION IN MAKURDI METROPOLIS

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Abstract

The study focused on investigation into the impact of Japanese multiplication pedagogical approach on secondary school students' interest and performance in quadratic expansion in Makurdi Metropolis. The study used a quasi-experimental design. A sample of 15 students was used for the purpose of the study. The experimental group were expose to the Japanese Multiplication Pedagogical Approach (JMPA) while the control group were taught using the traditional approach. The instrument used for data collection were Expansion Performance Test (EPT) with a reliability coefficient of 0.81 using the Kuder Richardson Formula 20 and Mathematics Interest Inventory (MII) with a reliability coefficient of 0.75 using Cronbach Alpha. Four research questions and four research hypotheses were raised for the study. The research questions were answered using the descriptive statistics of mean and standard deviation while the Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. Result from the study revealed that the students that were taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those that were taught using the traditional approach had the same level of performance, however, those in the JMPA demonstrated a higher level of interest in learning mathematics. The study also revealed that there is no significant difference in the mean performance score and interest rating of male and female students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach. The study recommends that teachers should implement strategies that build a student's interest in learning mathematics as student's interest in a topic carry so much ability.

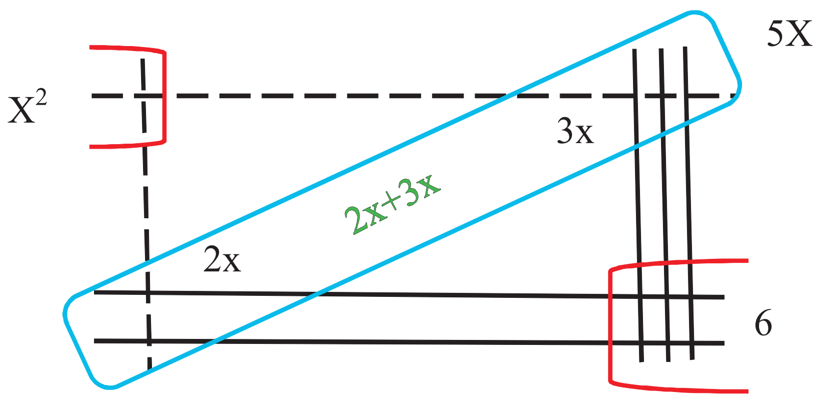
Keywords: Japanese Multiplication, Quadratic Expansion, Students' Interest and Performance

INTRODUCTION

Mathematics first start from the mind; how ready and how positioned the mind is to assimilate mathematical concepts. In the learning of any concept in Mathematics, the mind of the learner must have been familiar with some related attributes of the concept which are in connection to real life situations. Over the years, mathematics has been mistaken by many to be a totally abstract, difficult, unimportant and one that lacks connection to real life situations. However, mathematics is a fundamental part of human thought and logic, and integral to attempt at understanding the world around us. Mathematics provides an effective way of building mental discipline and encourages logical reasoning and mental rigor (Kyungmee, Aarnout, Joana & Lynn, 2008). Mathematics has become the companion of man and his helper since the beginning of human existence on earth. When man first wanted to answer questions such as "How many?" he invented mathematics (Harrison, 2018). Thus, mathematics is the pillar of organized life for the present day. Without mathematical evidence, resolving of issues in our daily lives will be impossible. Mathematics is a study of measurement, numbers and space which is one of the first sciences that humans work to develop, because of its great importance and benefits. It is a vital tool that helps to develop the ability to think, develop wisdom, increases the speed of intuition, and it also helps to explain how things work (Harrison, 2018). The importance of mathematics to our daily lives is one that cannot be over-flogged. The advancement in architectural, technological, and business world are all at the mercy of mathematical knowledge and input. Mathematics is one of the key subjects offered in primary and secondary schools and even studied at the higher institutions. Arithmetic, geometry, calculus, algebra are the branches of mathematics.

Algebra is one of the various branches of mathematics. It deals with symbols and variables. Algebra includes several forms of mathematical representations, such as real numbers, complex numbers, vectors, matrices and so on. Quadratic expression are algebraic expressions where the highest exponent of the independent variable is 2. Expansion of quadratic expression simply means removing the parentheses or brackets from an expression. This is done by multiplying each component of one bracket by the other bracket. For an expression of the form (a + b) (c + d), the expanded version is a(c+d)+b(c+d)= ac+ad+bc+bd. Quadratic expressions are expanded usually using the FOIL (First, Outside, Inside, Last) method and also the Punnet square method. Alternatively, the Japanese method of multiplication has been considered as an interesting and fascinating method for quadratic expansion.

The Japanese method of multiplication works the same way the place value multiplication algorithm works, except that each digit is represented in unary. The Japanese multiplication method is an algorithm for multiplying two large numbers by representing both numbers by a group of lines that form a diagonal pattern. The number of points of intersection near each vertex of a diamond are then counted in a certain order to obtain the solution (Vreken, 2017; Garain & Kumar, 2018). In the Japanese multiplication method, a student can complete a multiplication problem of two large numbers by merely drawing a few lines and counting the points of intersection (Abari & Tyovenda, 2022). It is also referred by many as the stick multiplication method, line multiplication method and many other names. Suppose we want to expand (x+2) (x+3) using the Japanese multiplication method. We will have to consider (x+2) as a component and represent it with horizontal lines (i.e dotted line will be drawn to represent the x, then, we would leave a space and draw two lines to represent the 2) and (x+3) will be considered as another component to be represented with the vertical lines (i.e dotted line will be drawn to represent the x which will intersect with the horizontal lines of x and 2, then we will leave a space and draw another three lines to represent the 3 which will also intersect the horizontal lines). The points at which the lines intersect are then counted to give the answer.



That is, $(x+2)(x+3) = x^2+5x+6$. According to Abari and Tyovenda, (2022), the Japanese multiplication method can facilitate students' visualization of mathematics. This implies that Japanese Multiplication pedagogical approach is capable of stimulating Students Interest in Mathematics.

Interest is the psychological state of engaging or having the tendency to reengage in a particular context in the course of time (Hidi & Renninger, 2006). According to Terna and Eraikhuemen (2017), interest is the state of wanting to know or learn about something or somebody. Udegbe (2009) described interest as a disposition, attitude and feeling of an individual towards an activity, which shows behaviourally, the extent at which the person likes to participate in the activity. Interest plays a significant role in teaching and learning. Before knowledge in any form can affect character, there must be interest. The mind must get absorbed in the facts with which it has to deal and make them its own. It is crystal clear that interest is closely associated with learning as it allows improving and complementing the introduction of an object, to guide meaningful learning, to improve the long-term memory as well as a source of knowledge and orientation of motivation for further learning (Azmidar, Darhim & Jarnawi, 2017). Students tend to engage themselves in deeper learning on a particular subject when they have an interest in it. Interest towards mathematics learning could be considered as a predictor for mathematics performance (Heinze, **Reiss, & Franziska**, 2005).

Performance is the measure of what the students have accomplished or done. It can be accessed through test, assignment, or examination results (Abari & Tyovenda, 2021). A high-performance result comes from appropriate behaviour and the effective use of required knowledge, skills, and competencies. A performance assessment is a way to evaluate, that allows students to demonstrate their knowledge of a particular concept through application. Using performance assessment for mathematics is a great way to help students develop high-level thinking skills and apply what they know. There is a large body of international research on gender differences in academic performance in mathematics. Education has been considered among the basic rights of human beings. From the learning perspective, the gender has seemed to play a significant role. It plays an essential role in motivation, attitudes, and achievement of students (Mousa, 2017).

Gender refers to the social attributes and opportunities associated with being male and female. Adigun, Onihunwa, Sada, and Adesina (2015) affirms that gender is the range of physical, biological, mental, and behavioural characteristics pertaining to and differentiating between the feminine and masculine (female and male) population. The importance of examining performance in relation to gender is based mainly on the socio-cultural differences between girls and boys (Abari & Andrew, 2021).

Purpose of the Study

Mathematics is key to the realization of a nation's scientific and technological aspirations. Despite its importance, there has been proven evidence of continued low interest and poor performance in the subject by the Nigerian students (Terna & Eraikhuemen, 2017). The importance of mathematics in day-to-day activities is no longer news. However, what remains news is the fact that students' interest and performance in mathematics has not improved significantly despite its importance, not even with the introduction and use of technology in mathematics (Olalekan, 2006). Can the Japanese multiplication in expanding quadratic expression improve students' interest and performance in mathematics? Hence, the main purpose of this study is to investigate into the effect of Japanese multiplication on students' interest and performance in quadratic expansion. Specifically, the study seeks to:

i. determine the difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional Approach.
ii. determine the difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA)

iii. determine the difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional Approach.
iv. determine the difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA).

Research Questions: The following research questions were asked to guide the study:

i. What is the difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method?
ii. What is the difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA)?
iii. What is the difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method?
iv. What is the difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA)?

Research Hypotheses: The following hypotheses were formulated and tested at 0.05 level of significance:

i. There is no significant difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method.
ii. There is no significant difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA).
iii. There is no significant difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method.
iv. There is no significant difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA).

METHODOLOGY

The design adopted for this study was quasi-experimental design. The population for this study is all the junior secondary school one (JSS1) students in the co-education secondary schools in Makurdi Local Government Area of Benue State. The sample of students for this study was 15 students drawn from the selected secondary schools.

For this research work, Expansion Performance Test (EPT) and Mathematics Interest Inventory (MII) were used. The EPT is a test instrument that covers all the areas of algebraic expansion that will be taught regarding this study. The EPT is a ten (10) items multiple choice (with options A – D) instrument prepared for JSS1. The instrument was administered to a few respondents in pre-test exercise. The MII is divided into two sections (Section A and B). Section A contains the Bio-data of each respondent, while section B contains information on the research problem. A Likert-type scale of Strongly Agree, Agree, Disagree and Strongly Disagree was used to determine the Interest of the Students in Quadratic Equation.

The researchers administered the pre-EPT, pre-MII, post-EPT and post-MII to all the JSS1students in the two groups. The pre-EPT, pre-MII, post-EPT and post-MII were administered to the selected groups at different times to avoid interaction effect. Data collected were analyzed using descriptive statistics of mean and standard deviation to answer the research questions while the hypotheses were tested at 5% significance level using the Analysis of Covariance (ANCOVA).

RESULTS

The data is presented according to research questions and hypotheses.

Question 1: What is the difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method?

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Table 1: Mean Performance Scores and Standard Deviation by Groups

Group	Pretest		Posttest		
	⍰	SD	⍰	SD	Mean Difference
JMPA	44.38	10.16	63.13	10.10	18.75
Traditional Approach	44.29	15.12	61.43	25.45	17.14
Total	44.35	12.64	62.28	17.78	1.61

In table 1, the mean pretest score for the JMPA is 44.38 with standard deviation of 10.16 and the mean pretest score for the traditional approach is 44.29 with a standard deviation of 15.12. this implies that before the administration of the test, both the students in the experimental and control group were at the same level of performance. However, the mean of posttest scores for the JMPA is 63.13 with standard deviation of 10.10 while the mean of the posttest score for the traditional approach is 61.43 with standard deviation of 25.45. The mean difference of the experimental and control group is 18.75 and 17.14 respectively. This implies that both groups improve upon their performance in the mathematics taught during this period, however, with the JMPA having a prevailing performance. To ascertain the significant difference of the group performance, hypothesis 1 was tested at 5% level of significance.

Hypothesis 1: There is no significant difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method.

Table 2: Summary of ANCOVA Result of Students Performance in both groups

Source	Type III Sum of squares	df	Mean Square	F	Sig.
Corrected Model	3296.895[a]	2	1648.447	13.676	.001
Intercept	45.085	1	45.085	.374	.552
Pretest	3286.151	1	3286.151	27.263	.000
Group	9.374	1	9.374	.078	.785
Error	1446.438	12	120.537		
Total	63025.000	15			
Corrected Total	4743.333	14			

a. R Squared= .695 (Adjusted R Squared= .644)

From table 2, the p-value for groups is 0.785. Hence p>0.05, the null hypothesis is accepted. This implies that there is no significant difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method. It therefore means that both the students in the experimental and control were at the same level of performance even after the administration of the test.

Question 2: What is the difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA)?

Table 3: Mean Performance Scores and Standard Deviation of Male and Female Students

Group	Pretest		Posttest		
	$\bar{x}$	SD	$\bar{x}$	SD	Mean Difference
Male	46.00	10.84	65.00	14.14	19.00
Female	41.67	10.41	60.00	12.00	18.33
Total	43.84	10.63	62.50	13.07	0.67

In table 3, the mean pretest performance score for male and female students in the experimental group is 46.00 and 41.67 respectively while the mean of posttest scores for the male and female students is 65.00 and 60.00 respectively. However, the mean difference in the performance score for the male and female students is 19.00 and 18.33 respectively. This shows that both the male and female students improved upon their performance in mathematics. However, hypothesis 2 was tested at 0.05 to ascertain the level of significant difference of their performance scores.

Hypothesis 2: There is no significant difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA).

Table 4: Summary of ANCOVA Result of Male and Female Students Performance

Source	Type III Sum of squares	df	Mean Square	F	Sig.
Corrected Model	200.698[a]	2	100.349	.776	.509
Intercept	594.715	1	594.715	4.602	.085
pretest	153.823	1	153.823	1.190	.325
Gender	15.511	1	15.511	.120	.743
Error	646.177	5	129.235		
Total	32725.000	8			
Corrected Total	846.875	7			

a. R Squared= .237 (Adjusted R Squared= -.068)

From table 4, the p-value for gender is 0.743. Hence p>0.05, the null hypothesis is accepted. This implies that there is no significant difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA). Hence both the male and female students that were exposed to the Japanese Multiplication Pedagogical Approach (JMPA) improved equally and greatly on their performance in mathematics.

Question 3: What is the difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method?

Table 5: Mean Interest Rating and Standard Deviation by Groups

Group	Pretest		Posttest		Mean Difference
	$\bar{x}$	SD	$\bar{x}$	SD	
JMPA Approach	72.50	13.89	90.63	10.50	18.13
Traditional Approach	67.86	16.04	75.00	10.00	7.14
Total	70.18	14.97	81.32	10.25	10.99

Results in table 5 shows that the mean interest rating of students taught quadratic expansion with Japanese Multiplication Pedagogical Approach (JMPA) is 90.63 with standard deviation of 10.50 while that of the students taught quadratic expansion using the traditional approach is 75.00 with a standard deviation of 10.00. The mean difference in the JMPA and the traditional approach is 18.13 and 7.14 respectively. It therefore means that the mean interest rating of the students taught quadratic expansion using the JMPA is higher than those taught quadratic expansion with the traditional approach. This implies that the students taught quadratic expansion using the JMPA showed higher interest in learning mathematics than the students taught using the traditional approach. To show if the difference in the mean interest rating of students in the two groups is significant, hypothesis 3 was tested at 0.05 level of significance.

Hypothesis 3: There is no significant difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method.

Table 6: Summary of ANCOVA Result of Students Interest in both groups

Source	Type III Sum of squares	df	Mean Square	F	Sig.
Corrected Model	1320.278[a]	2	660.139	8.226	.006
Intercept	1799.665	1	1799.665	22.424	.000
pretest	408.819	1	408.819	5.094	.043
Group	699.739	1	699.739	8.719	.012
Error	963.056	12	80.255		
Total	106450.000	15			
Corrected Total	2283.333	14			

a.R Squared = .578 (Adjusted R Squared =.508)

From table 6, the p-value for groups is 0.012. Hence $p<0.05$ the null hypothesis is rejected. This implies that there is a significant difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method. It therefore means that the students who were exposed to the JMPA showed higher interest in learning mathematics as compared to the students that were taught using the traditional approach.

Question 4: What is the difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA)?

Table 7: Mean Interest Rating and Standard Deviation of Male and Female Students

Group	Pretest		Posttest		Mean Difference
	?	SD	?	SD	
Male	71.00	16.73	90.00	12.75	19.00
Female	75.00	10.00	91.67	7.64	16.67
Total	73.00	13.37	90.84	10.20	2.33

Results in Table 7 shows that the mean interest rating of the male and female students in the JMPA is 90.00 and 91.67 respectively. The result indicates that there is no much difference between the male and female students' mean interest rating in mathematics. However, hypothesis 4 was tested to determine if the difference in the mean interest rating between male and female students is statistically significant or not.

Hypothesis 4: There is no significant difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA).

Table 8: Summary of ANCOVA Result of Male and Female Students Performance

Source	Type III Sum of squares	df	Mean Square	F	Sig.
Corrected Model	176.136[a]	2	88.068	.739	.523
Intercept	999.546	1	999.546	8.389	.034
pretest	170.928	1	170.928	1.435	.285
Gender	.095	1	0.95	.001	.979
Error	595.739	5	119.148		
Total	66475.000	8			
Corrected Total	771.875	7			

a. R Squared= .228 (Adjusted R Squared= -.081)

From table 8, the p-value for gender is 0.979. Hence p>0.05, the null hypothesis is accepted. This implies that there is no significant difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA). It therefore means that both the male and female students demonstrated similar interest in mathematics.

DISCUSSION

Result from hypothesis 1 shows that there is no significant difference in the mean performance scores of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method. It therefore means that both the students in the experimental and control group were at the same level of performance even after the administration of the test. This result disagrees with the findings of Abari and Tyovenda (2022) who conducted a research on the effect of Japanese multiplication on students' achievement and retention in mathematics and found out that the students in the experimental group achieved higher than those in the control group. However, the finding is in line with that of Zengin and Kutluca (2012) who carried out a study to determine the effect of Geogebra on students' achievement in Trigonometry in Turkey and found that the students taught trigonometry with Geogebra achieved higher than those taught with the traditional method.

Result from hypothesis 2 shows that there is no significant difference in the mean performance scores of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA). Hence both the male and female students that were exposed to the Japanese Multiplication Pedagogical Approach (JMPA) improved equally and greatly on their performance in mathematics. This result agree with the findings of Abari, Gimba, Hassan, Jiya, Chado,Gana and Koroka (2019) who conducted a research on effects of Geogebra Instructional Package on Secondary school students achievement in Geometry in Makurdi Metropolis of Benue State and discovered that Geogebra instructional package is not gender bias in terms of improving students' achievement in geometry. The result is also in agreement with the findings of Gambari, Falode and Adebenro (2014) who carried out a study on the effectiveness of computer animation and geometry instructional model on mathematics achievement and retention on junior secondary school students in Minna, Nigeria and found that, there was no significant difference reported in the post test performance scores of male and female students taught geometry using computer animation and instructional model respectively.

Result from hypothesis 3 shows that there is a significant difference in the mean interest rating of secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA) and those taught using the Traditional method. It therefore means that the students who were exposed to the JMPA showed higher interest in learning mathematics as compared to the students that were taught using the traditional approach. This finding disagrees with the findings of Shu and Luan (2019) who conducted a research to examine Students' interest towards mathematics in technology-enhanced learning context and the results of the descriptive statistical analyses revealed that the students in both groups were relatively interested in mathematics.

Result from hypothesis 4 shows that there is no significant difference in the mean interest rating of male and female secondary school students taught quadratic expansion using the Japanese Multiplication Pedagogical Approach (JMPA). It therefore means that both the male and female students demonstrated similar interest in mathematics. The findings of this result agree with that of Ghasemi & Burley (2015) which carried out a study to investigate gender differences in interest in mathematics and found out that there was almost no gender difference in interest in mathematics between fourth graders.

CONCLUSION

In conclusion, the study used Japanese Multiplication pedagogical approach to teach students quadratic expansion and measured the students' performance and interest and compared the learning outcomes with those of students taught quadratic expansion using the traditional method. While there was no significant difference in the performance of students in quadratic expansion between the experimental and control group, there was significant difference in mean interest rating of students taught quadratic expansion in the experimental and control group. The findings also suggested that there was no significant difference in the interest and performance of students taught quadratic expansion using Japanese Multiplication pedagogical approach.

RECOMMENDATIONS

The following recommendations were made based on the findings of the study:

1. More effort should be made by teachers to ensure that students develop interest in learning mathematics. When the topic is linked to what the students like to do; engagement deepens as they willingly spend time thinking and creating ideas in meaningful ways.
2. The study also recommended that teachers should deploy ethno mathematics teaching strategies that can improve the learning outcome

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EFFECTS OF VAN HIELE PHASE-BASED TEACHING STRATEGY ON HIGH, MEDIUM AND LOW ACADEMIC ACHIEVERS

Abstract

This study was inspired by the consistently poor academic achievement of students at all levels of education in mathematics generally and geometry in particular. The study, consequently, investigated the effectiveness of van Hiele's phase-based teaching strategy on high, medium and low achievers among pre-service mathematics teachers' in Niger State, Nigeria. Two research questions and corresponding hypotheses were formulated to guide the study. The study adopts quasi experimental design. One hundred and forty-nine (149) pre-service mathematics teachers from two colleges of education in Niger state were purposively selected for the study. Geometry Achievement Test (GAT), covering topics in Geometry was the instrument used to collect data for both pre and post achievement test. The reliability coefficient of 0.78 was obtained for the instrument (GAT). The data were analyzed using Analysis of Variance (ANOVA). The hypotheses were tested at 0.05 level of significance. The results of the study indicated that van Hiele's phase-based teaching strategy is more effective than conventional teaching strategy in improving pre-service mathematics teachers' achievement towards geometry ($F(1,147) = 30.331, p < 0.05$). In addition the findings also indicated significant difference in mean achievement scores of students with respect to ability level ($F(2,83) = 97.674, p < 0.05$). It was recommended that van Hiele's phase-based teaching strategy should be adopted in teaching geometry in colleges as it solves problem of the difficulties faced by the learners in the area of geometry concept perceived to be difficult.

Keywords: Academic achievers, Effectiveness, pre-service mathematics teachers, teaching strategy, van Hiele's phase-based,

Introduction

The primary aim of Education at whatever level is to help individuals take advantage of its potentials for best possible self and national development. Education is indeed precondition for meaningful and sustained national economy as such, it can never be of quality without effective teaching. The teaching strategy used by teacher therefore plays a significant role in the attainment of instructional contents for meaningful learning and development of necessary skills (Schneider & Preckel 2017).

Skills in this context are the most specific instructional technique, such van Hiele's geometric model which describes how children learn to reason in geometry, it consists of five levels and five phases of instruction which have been applied in many studies (Falentina, Muchyidin & Nasehudin, 2022; Naufal et al., 2021; Pujawan, Suryawan & Prabawati, 2020; Yalley, Armah & Ansah, 2021) that are related to teaching and learning of geometry. The model was thus developed by two Dutch mathematicians in the 1950s, Pierre van Hiele and his wife Dina van Hiele-Geldof. The five levels according to Van Hiele (1986) are: Recognition, Analysis, Order, Deduction and Rigor.

The levels are attained as a result of experience and instruction rather than age. Consequently, a learner is required to have enough knowledge of (classroom or otherwise) geometric thoughts to move to a higher stage of complexity. That is to say that the feature of the model is hierarchical in nature. Each of the levels (levels 1 - 5) is accompanied by five phased-based instruction strategies. Chew (2009) affirmed that learners must go through the entire five phases to be able to achieve each of van Hiele's level. The point here is, each level of geometry classroom instruction is attained as a result of sequence of phases (van Hiele, 1986). The five phases of instruction are: Information, Guided orientation, Explicitation, Free-orientation and Integration. Hence, when a teacher is able to move up level of geometry instruction process as a result of phase-base instruction, it will help in improving learner's achievement in geometry.

Literature about van Hiele model and academic achievement in mathematics exist with different views and finding. To reinforce the current study, other related works done using van Hiele model were reviewed. Abdullah and Zakaria (2013a) affirmed that the treatment employing the van Hiele phase-based teaching can be employed in classrooms to improve learners' geometric understanding. This is supported by Chew (2009) that learners must go via entire five phases to realize every aspect of the van Hiele's level. In the opinion of Usman, Yew and Saleh (2020), the van Hiele phase-based instruction provides teachers the opportunity of allowing the learners to experience geometry stages associated with the van Hiele model. Several studies such as Abdullah and Zakaria (2013b) Abdullah, Ibrahim, Surif, and Zakaria (2014) Alex and Mammen (2016) Alebous (2016) Atebe and Schäfer (2011) Mostafa, Javad, and Reza (2016) were carried out employing van Hiele's phase-based teaching strategy on academic achievement. In all of these studies, Quasi-experimental design, a pretest posttest control group design was employed. The findings however, revealed a substantial difference between treatment and control group. In contrary, Halat (2008) Patkin and Barkai (2014) Luneta (2015) in theirseparate findings though not directly link to quasi experimental studies indicates that there is no substantial difference on the focus group. For this reason, it became very necessary to investigate in order to reinforce previous findings.

Several studies (Abdullahi & zakari, 2013b; Abu et al., 2012; Alex & Mammen 2016; Chew & Lim, 2013; Falentina, Muchyidin & Nasehudin, 2022; Naufal et al., 2021; Pujawan, Suryawan & Prabawati, 2020; Yalley, Armah & Ansah, 2021) have been carried out, validated and discovered to be effective in teaching and learning of geometry as a result of various studies carried out globally, it was however, established that van Hiele geometry model facilitates learning. However, studies comparing the achievement of high, middle and low achieving students are yet to be fully confirmed. This study therefore attempted to determine the effectiveness of van Hiele's phase-based teaching strategy on achievement of High, medium and low achievers among pre-service mathematics teachers' in Niger State, Nigeria.

Aim and objectives of the study

The aim of this study is to determine the effectiveness of van Hiele's phase-based teaching strategy on achievement of High, medium and low achievers among pre-service mathematics teachers' in Niger State, Nigeria.

Specifically, the research objectives were as follows:

1. Determine the mean achievement score of pre-service mathematics teachers taught using van Hiele's phase-based teaching strategy and conventional (lecture) method.
2. Compare the mean achievement scores of low, medium and high-ability level pre-service mathematics teachers taught van Hiele's phase-based teaching strategy.

Research questions

The following research questions were raised for the study:

1. What are the difference in the mean achievement scores of pre-service mathematics teachers taught using van Hiele phase-based teaching strategy and lecture method?
2. What are the difference in the mean achievement scores among low, Medium and high-ability level pre-service mathematics teachers taught geometry using van Hiele phase-based teaching strategy and lecture method?

Null Hypotheses

Based on the research objectives, the following null hypotheses were formulated to guide the study:

H_{O1} There is no significant difference in the mean achievement scores of pre-service mathematics teachers taught Geometry using van Hiele's phase-based teaching strategy and conventional (lecture) method.

H_{O2} There is no significant difference among the mean achievement scores of low, medium and high-ability level pre-service mathematics teachers taught geometry using van Hiele's phase based teaching strategy and conventional (lecture) method.

Methodology

The study adopted the Quasi-Experimental design. Specifically, the pre-test-post-test non-equivalent control group design; there was no randomization of subjects because intact classes were used. Two instructional methods (van Hiele's phase-based teaching strategy and conventional (lecture) methods) were involved; the experimental group were taught using van Hiele's phase-based teaching strategy and control group were taught using lecture method.

The population for the study is made up of all the 814 pre-service mathematics teachers in the two colleges of education in Niger state, Nigeria (College Department of Mathematics, 2017). The target population was year one (100 level) pre-service mathematics teachers who had registered MAT 122 (coordinate geometry). The reason for choosing 100 level pre-service mathematics teachers is because MAT 122 which is designed to prepare the pre-service mathematics teachers constitutes part of the course to be studied at this level. The sample consisted of 149 pre-service mathematics teachers 86 (62 male and 24 female) in experimental group and 63 (54 male and 9 female) in control group respectively captured from the intact class.

Geometry Achievement Test (GAT), covering topics in Geometry was the instrument used to collect data for both pre and post achievement test. To obtain ability level of students, an average of less than fifty percent (< 50%) in pretest score (experimental group) were classified as low-ability level, those that obtained an average of fifty to sixty nine percent (50% < 69%) were the medium-ability level students while those with an average of seventy percent and above (> 70%) are high-ability level students.

The reliability coefficient of 0.78 was obtained for the instrument (GAT). The data were analyzed using Analysis of Variance (ANOVA).

Results

Table 1: Mean and Standard Deviation of Pretest and Posttest Scores of Eexperimental and Control group

Group	N	Pre-test	SD	Post-test	SD	Mean diff
Exp group	86	29.081	11.9757	57.698	10.8953	28.617
Control Group	63	40.095	16.8175	46.032	14.9698	5.937
Total	149	69.176	28.7932	103.73	25.8651	34.59

Table 1 shows the mean and standard deviation of achievement scores of experimental and control group at pretest and postest. From the table, it can be deduced that the mean and standard deviation scores at pre-test and posttest for experimental group is X= 29.081, SD= 11.9757 and 57.698, SD= 10.8953. This gives the mean gain of 28.617 in favour of postest. Similarly, the mean and standard deviation scores at pre-test and posttest for control group is X= 40.095 and SD= 16.8175 and 46.032, SD= 14.9698 respectively. This gives the mean gain of 5.937 in favour of postest. To determine if the difference is significant, ANOVA was used as presented in table 2.

Table 2: Summary of Analysis of Variance (ANOVA) of Posttest Scores of Experimental Scores

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4948.702	1	4948.702	30.331	.000
Within Groups	23984.076	147	163.157		
Total	28932.779	148			

Table 2 shows the ANOVA result of comparison of posttest scores of students in experimental and control group. An examination of the table revealed $F(1,147) = 30.331$, $p < 0.05$. On the basis of this, hypothesis one was rejected. Therefore, significant difference is in favour of experimental group taught Geometry using van Hiele phase-pased teaching strategy

Table 3: Mean and Standard Deviation of Posttest Scores for Low, Medium and High Ability level

Group	N	Mean	Std. Deviation
High Ability	9	75.889	5.6446
Medium Ability	64	58.719	5.8131
Low Ability	13	40.077	7.2164
Total	86	57.698	10.8953

Table 3 shows the mean and standard deviation of posttest scores for low, medium and high ability level. From the table, it can be deduced that the mean and standard deviation scores for high abilty level X= 75.889, SD= 5.6446, medium ability level X= 58.719, SD= 5.8131 and X= 40.077, SD= 7.2164 respectively.

Table 4: Summary of Analysis of Variance (ANOVA) of High, Medium and Low ability levels of Experimental group

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7081.390	2	3540.695	97.674	.000
Within Groups	3008.749	83	36.250		
Total	10090.140	85			

Table 4 shows the ANOVA result of comparison of High, Medium and low ability levels. An examination of the table revealed $F(2,83) = 97.674$, $p < 0.05$. On the basis of this, hypothesis two was rejected. This implies that significant difference was established among the mean scores of the high, medium and low achiever students.

Discussion

The results in Table 1 show that the mean gain achievement score of experimental group 28.617 (van Hiele's phase-based teaching strategy) higher than the mean gain achievement score of control group 5.937 (conventional teaching strategy). This is further confirmed by ANOVA result in Table 2 which has shown that the achievement of experimental and control groups differs significantly. The result indicated that treatment using van Hiele's phase-based teaching strategy produced significant difference on pre-service mathematics teachers' achievement in geometry. Based on the above results, it was inferred that the significant difference observed may be credited to the uniqueness of van Hiele's phase-based teaching strategy.

The result of this study considering the above therefore is consistent with the results reported by Abdullah and Zakaria (2013b) who investigated the effects of van Hiele's phase-based geometry teaching strategy using the Geometer's Sketchpad (GSP) on learners' stage of geometric thinking. Similarly, the result is also supported by the result of Alex and Mammen (2016) who conducted a study with 359 Grade 10 learners from five purposefully selected schools from Mthatha District in the Eastern Cape Province in South Africa aimed at finding out the influence of van Hiele theory-based instruction in the teaching of geometry. The result of the study showed a statistical substantial difference favoring the experimental group. This is also in consistent with the result of Abdullah, Ibrahim, Surif, and Zakaria (2014) who advocated that the procedure of instructing and learning geometry ought to be executed more efficiently for the reason of its significance in students' day-to-day lives. Their study was thus, intended at developing activities centered on learning geometry by means of van Hiele's phases using Geometer's Sketchpad (GSP) software. In this study as well, ADDIE model was used, and learning kit incorporated called Geo-V. The result indicated a substantial difference in learners' geometric achievement between the experimental and control groups. Hence, it was suggested that implementation of activities of van Hiele's phases of learning geometry might be a point of reference in different approaches to teaching and learning of geometry in a classroom setting.

These results are in line with the report in selected Nigerian and South African high schools by Atebe and Schäfer (2011) who investigated a study aimed at finding out the insight into the means in which geometry is taught. The study employed van Hiele model of geometry instruction to explain how the teaching strategy might offer learners improvement in geometry. The results of the study show that the teaching methods employed in geometry teaching facilitated learner's achievement in learning geometry. Precisely, the students taught geometry using the observed teaching strategy offer better opportunities to learn geometry within the South African subsample, than within the Nigerian subsample. In other words, the study shows that the sample student whose observed teaching experience are arranged in line with van Hiele's phases of learning exhibited an improved understanding of concepts in geometry than those whose geometry instruction is in divergence from van Hiele's phases of instruction.

Also supporting the result of this study is the work of Mostafa, Javad, and Reza (2016) which examined the entire student teachers of Farhangian University of Isfahan Iran with population of 176 allotted randomly to treatment and control group respectively. The study employed quasi-experimental design, a pretest posttest control group design to find out the effect of educational package on pre-service teachers' achievement using van Hiele's theory. A standardized questionnaire of achievement goal was the instrument used for data collection in the study. Descriptive and inferential statistics was employed for analyzing the data collected. The result of the study shows a substantial difference between the treatment and control group scores.

This result is in conformity with correspondent studies incorporating phase-based instruction, namely Chew (2009), and Chew and Lim (2013), Muchyidin and Nasehudin, (2022), Naufal et al., (2021), Pujawan, Suryawan and Prabawati (2020) Yalley, Armah and Ansah (2021) whose studies were respectively meant at finding out the effect of the van Hiele model over conventional teaching strategy. This therefore implies the introduction of van Hiele's phase-based teaching strategy is timely as learners show quite a significant achievement in geometry. In addition, the result has reinforced the need for employing van Hiele's phase-base teaching strategy in the classroom instruction with the view of achieving improved teaching and learning. Also in consonance with the current study is the study by Alex and Mammen (2016) in the Eastern Cape Province in South Africa in which a multiple choice geometry test was administered to the students before and after five weeks of instruction (pre- and post-test design). The result indicated a statistically significant difference in the mean scores in favour of the experimental group.

However, the result of this study contradicts the finding of Halat (2008b). Halat (2008b)*compared reasoning stages in geometry of the pre-service elementary school and secondary mathematics teachers with a total of 281 teachers (125 elementary school teachers and 156 secondary mathematics teachers).The result revealed no statistically significant difference on the reasoning stages between the pre-service elementary school and secondary mathematics teachers.*

Conclusion

The result obtained based on the aforementioned finding of the study indicated that there was significant difference between pre-service mathematics teachers taught using van Hiele's phase-based teaching strategy and those taught using conventional teaching strategy.

The results of the study indicate that van Hiele's phase-based teaching strategy is more effective than conventional teaching strategy in improving pre-service teachers' achievement. Consequently, the use of van Hiele's phase-based teaching strategy could be regarded as one of the veritable strategies for enhancing achievement of pre-service mathematics teacher in Niger state and Nigeria in general.

Based on the results of this study, implications of the study can be drawn on teaching and learning of mathematics and geometry in particular within the context of Nigerian Colleges of

Education.

Firstly, the study provided enough indication to illustrate that van Hiele's phase-based teaching strategy enhanced pre-service mathematics teachers' academic achievement scores. The result revealed a significant difference between the achievements of pre-service mathematics teachers taught using van Hiele's phase-based teaching strategy and those taught using conventional teaching strategy. In other words, learning through van Hiele's phase-based teaching strategy was significantly more effective in improving the geometry achievement of pre-service mathematics teachers. The effectiveness of van Hiele's phase-based teaching strategy could be attributed to the uniqueness of the strategy (phase-based) which aided lecturer to organize a more designed and logical geometry class as pointed out by Abdullah and Zakaria(2013a)andMeng and Idris (2012). Accordingly, the result obviously supports the view that new teaching approach in the study of geometry should be strongly encouraged (NCTM, 2000). As such the teaching strategy is a worthy teaching strategy to be adopted in teaching geometry in colleges of education.

The significant teaching implications for classroom teaching practices is that, the application of van Hiele's phase-based teaching strategy in mathematics classrooms would therefore serve as a stimulus, which possibly will encourage pre-service teachers to come to class and actively participate during mathematics instructions. The strategy certainly permits the learners to learn geometry effectively. In particular, this suggests that the academic achievement of pre-service teachers in mathematics would be greatly improved if pre-service teachers are exposed to van Hiele's phase-based teaching strategy. Therefore, teachers should consider van Hiele's phase-based teaching strategies in teaching learners, as the strategy will solve problem of the difficulties faced by the learners in the area of geometry concept perceived to be abstract. Another implication is that, the teaching strategy (van Hiele's phase-based teaching strategy) when incorporated into Nigerian classrooms specifically at college of education level would assist in producing better academic achievement of pre-service mathematics teachers. This implies that mathematics lecturers now generally have a supplementary inventive teaching strategy that will be employed to fight underachievement and steady low academic achievement which have been recognized as dictated by over dependence on conventional teaching strategy.

Recommendation

van Hiele's phase-based teaching strategy is a worthy teaching strategy as such should be adopted in teaching geometry in colleges as it will solve problem of the difficulties faced by the learners in the area of geometry concept perceived to be abstract.

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EFFECTS OF ELABORATION STRATEGY ON STUDENTS' LEARNING ACHIEVEMENT AT SENIOR SECONDARY SCHOOL MATHEMATICS, LAGOS STATE, NIGERIA

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Abstract

This study examined the effects of elaboration strategy on students' learning achievement at senior secondary school, Lagos State, Nigeria of quasi-experimental design of two non-equivalent groups with sample comprised 113 students from two public secondary schools. Achievement test was used as research instrument with reliability coefficients of 0.77. The data was analysed using both descriptive statistics (mean, standard deviation and bar chart) and inferential statistics (ANCOVA) which were used for research questions and in testing the hypotheses at 0.05 level of significance respectively. The finding revealed positive effect of elaboration strategy on students in treatment group over conventional group; the male students performed better than female students in terms of gender. Furthermore, H_{01} revealed that pretest value of $[F(1,112)=133.170; p<0.05]$ and the posttest value of $[F(1,112)=51.681; p<0.05]$ are both significant at 0.000 and H_{01} therby is rejected; H_{02} revealed that gender value of $[F(1,112)=0.757; p>0.05]$ is not significant at 0.386 and H_{02} is thereby not rejected; and H_{03} revealed that interaction value of $[F(1,112)=6.946; p>0.05]$ is not significant at 0.010 and H_{03} is thereby not rejected. Conclusively elaboration strategy on students has positive effect towards students learning achievement in mathematics classroom.

Key words: Elaboration strategy, Mathematics, Learning Achievement.

Introduction

Mathematics is the backbone to all sciences subjects in school that plays a conspicuous role in the revitalization of nations and peoples, towards the progress, growth and prosperity of civilizations (Farrajallah, 2017).“Mathematics is taught not only to know and understand what is contained in the mathematics itself, but the mathematics is taught aims to train mindset of students to solve the problem with the critical, logical, meticulous and precise ways” (**Salwah, n.d.)**There is no doubtwhyMathematics is among the key subject to pass before being admitted for most courses into tertiary institution in Nigeria education as a result of its importance. “As a matter fact, Mathematics requires a planned learning instruction that would allow students' active participation in Mathematics classroom” (Alabi, 2020). This planned learning instruction must be tailored in a stepwise order, from simple to difficultterms in order to deepen the students' understanding in Mathematics classroom.Meanwhile, the students continue to encounter challenges towards the learning of the concepts. In ameliorating this challenge, several learning strategies had been used by various researcherswhich are classified into Organizational, Delivery, and Management strategies. While among organizational strategy include elaboration strategythat help in solving students' challenges in learning activities through a sequential order.

Besides, in the history of elaboration theory according to Reigeluth, Merrill, Wilson & Spiller (1980) highlighted five course content organisation to include **epitome, analogy, levels**

of elaboration, relating and summarizing. These are details as follows:

- *i.* ***Epitome:*** The comprehensive ideas that can be conceptual, procedural or theoretical of the course content, in addition to illustrative specimens for such ideas in the aids for drilling and practicing.
- *ii.* ***Analogy:*** The process of lesson in the stretched epitomes being related and compared to a topic familiar to learners in order to facilitate the new knowledge and information with the learners' cognitive knowledge.
- *iii.* ***Levels of Elaboration:***The process of presenting course content via gradual elaboration of stretched epitomes from the general or simple or abstract to the specific or complex or concrete respectively depending on the volume of the course content and the learners' ability to understand.
- *iv.* ***Relating:*** At this stage of elaboration theory, inter-relation occurs in period of either to previous or following stage in order to form a wide-ranging theory towards educational task.
- *v.* ***Summarizing:*** This involves wide-ranging summarization of the concepts, principles and procedures with the stretched epitome that comes at the end of course content (Reigeluth et. al., 1980).

It is the desire of the researchers that elaboration theory as itemed by (Reigeluth et. al., 1980) is capable of bringing the required change in students towards their learning achievement as supported by other researchers. “Elaboration strategy is a teaching method that focuses on deliberate sequencing of concepts from simple to complex” (**Guwam&Gwandum**, 2017). The elaboration strategy is seen from abstract to concrete ideas through organization of learning content from the general to the specific topics, as learning starts in brief overview and wide-ranging of the elements of the educational task (Elsayed, 2015). **Thus, many researchers had worked severally on elaboration strategy and reported its effectiveness on students learning achievements. Salwah(n.d.)** conducted study to investigate**the effectiveness of elaboration strategy in improving student's learning achievement. This research was conducted on senior high schools of two classes of experimental and control groups selected randomly using experimental research design.The result indicated that the students' Mathematics learning achievement in elaboration strategy classroom is more effective than students in conventional strategy classroom.In another research study conducted by (**Elsayed, 2015) on effectiveness of using elaboration theory in teaching Mathematics to develop academic achievement and critical thinking for primary students in Oman. *This research study was randomly selected and conducted on 119 students in the fifth grade school in Salalah city of Dhofar Governorate* **of two classes of experimental group** *(60 Students)* **and control group (***59 Students).* The result indicated that there was a significant difference in favour of elaboration strategy classroom over conventional strategy classroom at 0.05 level of significance between the students' academic achievement.

Ezeahurukwe (2010) conducted study to investigate the effects of elaborative interrogation and self-assessment strategies on Mathematics achievement, test anxiety and self-efficacyof low achieving students in Lagos State, Nigeria. The study focused mainly on teachers' methods of teaching Mathematics with little or no consideration given to learning strategies adopted by the students as well as some affective components of the students that could contribute to achievement. This study was a non-equivalent control group quasi-experimental design involving three treatments and one control group with three instruments namely: Mathematics Achievement Test (MATS), Mathematics Test Anxiety Scale (MTAS) and Mathematics Self-Efficacy Scale (MSES) were used for the pre-test and post-test. The study revealed that the mean scores of mathematics low achieving students exposed to elaborative interrogation, self-assessment and a combination of the learning strategies were higher than those in the control groups whoadopted the conventional way of learning Mathematics. The study also revealed that gender has no significant influence on the Mathematics achievement, test anxiety and self-efficacy of low achieving Mathematics students and similarly there is no significant interaction effect of gender and the learning strategies on the Mathematics achievement, test anxiety and self-efficacy of low achieving students.

However, this paper focused on the effectiveness of elaoration strategy on students' learning achievement in sequences and series at Senior Secondary school, Lagos State, Nigeria.Decisively, the success of every nation can easily be traced to the level of education offering to perspectives citizen of that nation. One can as well improve this standard of education via incorporation of desirable learning strategy. Besides, the role and outcomes of learning of Mathematics bring to the society cannot be overestimated. If not critically check from secondary school learning curriculum may hinder the development of the nation. In this vein, to profound solution to improve students' learning become imperative at all level education which form the basis for this research work.

Statement of the problem

The results of students' learning achievements in the Mathematics over this year had been woefully reported from year to year (Eniayeju & Azuka, 2010; Olosunde & Olaleye, 2010; Bot, 2017). This rate of failure in mathematics had been mainly attributed to lack of strategy for teaching and learning in the classroom. As there are many strategies which the teachers can afford, yet students' learning achievement still faced various challenges (Alabi & Sanni, 2021). Thus, among the teaching strategies is elaboration strategy which had been effectively reported over the years for students' learning achievement. The effects of elaboration strategy had been supported with similar or different subject contents research study (**Guwam & Gwandum**, 2017; Elsayed, 2015; **Salwah, n.d.)**. The classroom teachers as well as the educators had also been drawn to paying adequate attention in the Mathematics classroom. Despite all these efforts by various quarters, the yearly WAEC Chief Examiner Report on students' Mathematics achievement still faces various challenges in the Mathematics discourse. *The implication here is that the use of elaboration and other strategy has not been implemented accordingly.*

Purpose of the study

The purpose of the study was to investigate the**effectiveness of elaboration strategy on students' learning achievement at senior secondary school Mathematics, Lagos State,** Nigeria. In explicit terms, the study sought to explore:

- students' learning achievement towards Mathematics in the experimental and control groups.
- gender difference between students' learning achievementin the experimental and control groups.
- the interaction effect of strategy and gender on students' learning achievement in the experimental and control groups.

Research questions

The following research questions guided the study:

1. To what extent is the mean difference of **students' learning achievement** towards

Mathematics in the experimental and control groups?

2. To what extent is the gender difference of students' achievement in the experimental and control groups?

3. Is there no significant interaction effect of strategy and gender on students' learning outcomes in the experimental and control groups?

Null hypotheses

The null hypotheses for this research study were tested at 5% level of significance:

H_{01}: There is no significant difference of students' learning achievement in the experimental and control groups.

H_{02}: There is no significant gender difference of students' learning achievement in the experimental and control groups.

H_{03}: There is no significant interaction effect of strategy and gender on students' learning outcomes in the experimental and control groups.

Methodology

The study employed a quasi-experimental design which involved two non-equivalent groups. The researchers and research assistants undergone all the process of the research study. The sample comprised 113 Senior Secondary Two (SSII) students (57 males & 56 females) from two public secondary schools in Lagos State. The SS II students were adopted because the content taught was under the scheme of work of SS II. There was no randomization of subjects as intact classes were randomly assigned to experimental and control groups. School A comprising of 58 students (28 males & 30 females) served as the experimental group while school B comprising of 55 students (29 males & 26 females) served as the control group. One research instrument was used which include, achievement test. A pre-test is used to measure students' fundamental knowledge in Mathematics and further compared the result with post-test score which were assigned after the treatment. The data were collected using Achievement Test on sequence and series which comprised 20 items. The items were presented in a multiple-choice format with four alternative choices with one correct answer.

The content which is basically on concepts and principles of sequence and series was strengthened in content validity and reliability by three professional mathematics educators. Its reliability was tested on 20 students who did not participate in the study and a Cronbach Reliability Coefficient of 0.77 was obtained. The data collected were analysed in the consideration of the research questions and hypothesis. In analyzing the data, both descriptive statistics (mean, standard deviation and bar chart) and inferential statistics. In testing the hypothesis formulated, the ANCOVA analysis was used and it was tested at 5% level of significance.

Results

Research Question One To what extent is the mean difference of **students' learning achievement** towards mathematics in the experimental and control groups? To deal with this question, the mean scores in both experimental and control groups were computed. Figure I give the summary of these results.

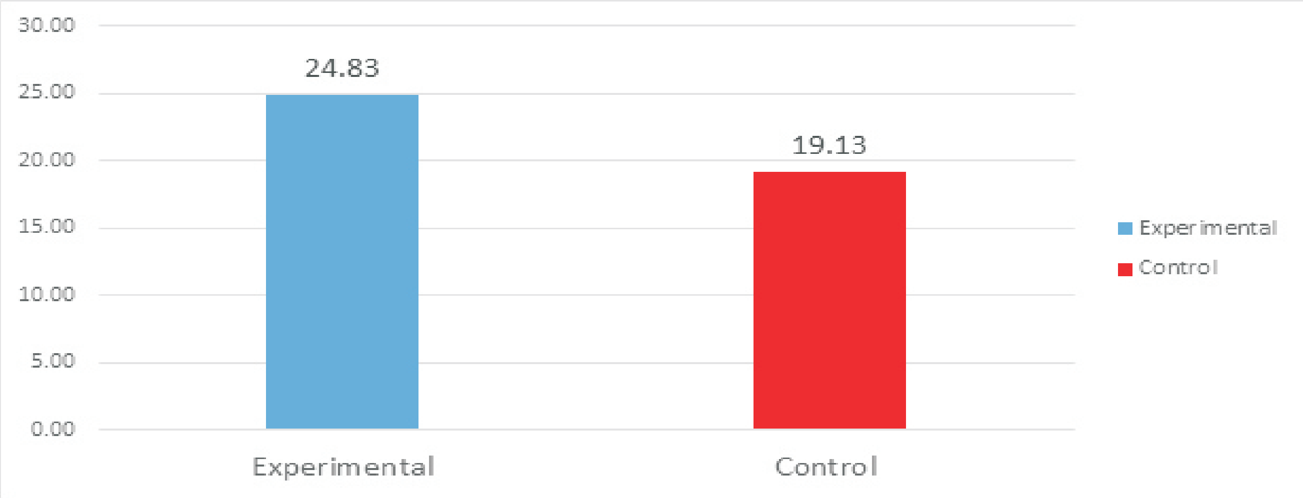

Figure 1: Mean Scores of Students' Learning Achievement

From the results presented in fig. 1, it was shown that the mean scores of students' learning achievement in experimental group is 24.83 while in control group is 19.13. This indicated that students' learning achievement mean score of experimental group is higher than mean score of control group.

Research Question Two: The question asked that to what extent is the gender difference of students' achievement in the experimental and control groups? To deal with this question, the mean scores in terms of gender for both experimental and control groups were computed. Figure II give the summary of these results.

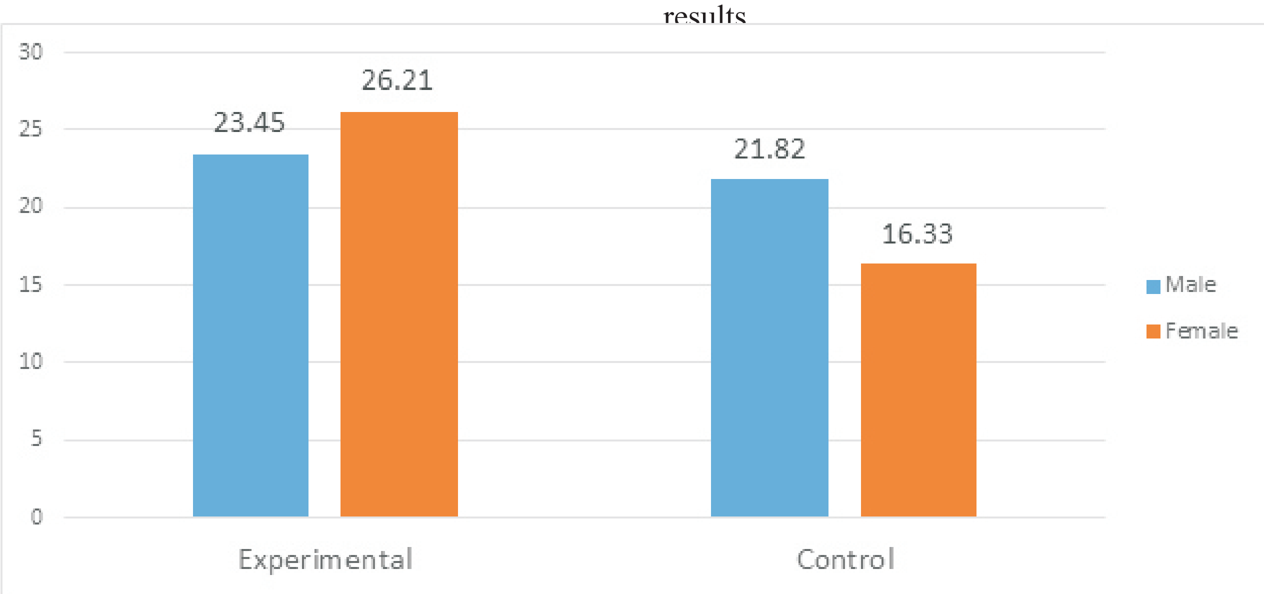

Figure 2: Gender Mean Scores of Students' Learning Achievement

From the results presented in fig. 2, it was shown that the male mean scores of students' learning achievement in experimental group is 23.45 while in control group is 21.82 and female mean scores of students' learning achievement in experimental group is 26.21 while in control group is 16.33. This indicated that male mean scores of students' learning achievement of experimental is higher than male mean score of control group. Similarly, female mean scores of students' learning achievement of experimental is higher than female mean score of control group.

Table 1: Analysis of covariance (ANCOVA) of students' learning achievement in experimental and control groups.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6107.607[a]	4	1526.902	43.579	.000
Intercept	1810.768	1	1810.768	51.681	.000
Pretest	4665.963	1	4665.963	133.170	.000
Gender	26.519	1	26.519	.757	.386
Group	930.595	1	930.595	26.560	.000
Gender * Group	243.382	1	243.382	6.946	.010
Error	3784.075	108	35.038		
Total	64848.000	113			
Corrected Total	9891.681	112			

a. R Squared = .617 (Adjusted R Squared = .603)

Hypothesis One: There is no significant difference of students' learning achievement in the experimental and control groups. The result shows that there is statistical significant difference of students' learning achievement in the experimental and control groups from Table 1with pretest value of [F(1,112)=133.170; p<0.05] is significant at 0.000 while the posttest value [F(1,112)=51.681; p<0.05] is also significant at 0.000. Therefore, H_{01} is rejected.

Hypothesis Two: There is no significant gender difference of students' learning achievement in the experimental and control groups. The result shows that there is no statistical significant gender difference of students' learning achievement in the experimental and control groups from Table 1 with gender value of [F(1,112)=0.757; p>0.05] which is not significant at 0.386. Therefore, H_{02} is not rejected.

Hypothesis Three: There is no significant interaction effect of strategy and gender on students' learning outcomes in the experimental and control groups. The result shows that there is no statistical significant interaction effect of methods and gender on students' learning achievement in the experimental and control groups from Table 1with interaction value of [F(1,112)=6.946; p>0.05] which is not significant at 0.010. Therefore, H_{03} is not rejected.

Discussion of findings

The findings revealed that the mean score of students' learning achievement of experimental group is higher than those in control group and also when considering in terms of gender, the mean scores of male and female students of experimental group are higher than those in control group. This implies that elaboration strategy having a positive impact on students

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learning achievement in senior secondary school education than those using conventional approach. The results further revealed that hypothesis one indicating that there is significant difference of students' learning achievement in the experimental and control groups which is in favour of those taught using elaboration strategy as it was found in the literature (**Guwam & Gwandum**, 2017; Lin & Tai, 2015; Githua&Njubi, 2013).

Hypothesis two indicating that there is no significant gender difference between the students' learning achievement in the experimental and control groups. As a result of this, elaboration strategy can be used to close the gap if exist between the male and female students towards their learning achievements. This is in support to **Guwam&Gwandum**, (2017) findings that there are nosignificant differences between the male and female students when exposed to elaboration strategy towards learning achievement and in similar to Ezeahurukwe, (2010) findings that gender has no significant influence on the Mathematics achievement, test anxiety and self-efficacy of low achieving Mathematics students.

Hypothesis three indicating that there was no significant interaction effect between the method and gender on students' learning achievement in the experimental and control groups.This implies that the interaction between the strategies and gender did not in any way determine the students learning achievements. The implication of the results is that those in experimental group were exposed to elaboration strategywhich had a significant difference in their learning achievement when compare to those in control group. This is in support to Ezeahurukwe (2010) findings that there isno significant interaction effect of gender and the learning strategies on the Mathematics achievement, test anxiety and self-efficacy of low achieving students.

Conclusion

The study was carried out to investigate the effects of elaboration strategy on students' learning achievement in sequence and series mathematics education at senior secondary school, Lagos State, Nigeria. The study widening the existing literature of Elaboration strategy as a very essential strategy for improving the students' learning achievements.

- The result shows that there is statistically significant difference of students' learning achievement in the experimental and control groups. Therefore, H_{01} is rejected.
- The result shows that there is no statistically significant gender difference of students' learning achievement in the experimental and control groups. Therefore, H_{02} is not rejected.
- The result shows that there is no statistically significant interaction effect of methods and gender on students' learning achievement in the experimental and control groups. Therefore, H_{03} is not rejected.

Considering the results of this study, it becomes neccessary to conclude that elaboration strategy on students in mathematics classroom will effect positively their learning achievement.

Recommendations

The following recommendations are made based on the findings:

- Using of elaboration strategy to impact students should be encoraged at senior secondary schools as its implicated to their learning achievement.
- The pre-service teacher should also be trained to understand elaboration strategyas they are future teacher to teach future students.
- Regular seminar and workshop should be organised in order to prepare the mathematics teachers on ultilisationof elaboration strategy towards improving students learning achivement.

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EFFECT OF THINK PAIR SHARE STRATEGY ON ACADEMIC ACHIEVEMENT IN ALGEBRAIC EXPRESSION AMONG SECONDARY SCHOOL STUDENTS IN KANO, NIGERIA

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Abstract

The study investigated the effect of the think-pair-share strategy on students' academic achievement in algebraic expression. The study was guided by two objective, research questions and two corresponding research hypotheses. The study used a quasi-experimental design with pre- and post-test, experimental, and control groups. The population of the study consisted of 9,573 SS II students in the Nassarawa education zone. Four intact classes, which consist of a total of 248 SSII students, were randomly selected from the Nassarawa Education Zone, Kano. The instrument used for data collection was the Algebra Achievement Test (AAT), which was validated by four experts, and the AAT's reliability was determined to be .88 using the Pearson product moment coefficient. AAT was administered to the subjects at the beginning of the study as a pretest. After a treatment period of six weeks, AAT was re-administered to the subjects for the posttest. The mean and standard deviation were used to answer the research questions, and the hypotheses were tested using the Z-test statistical tool at the level of .05 significance. The findings revealed that the achievement of students taught using the Think-Pair-Share strategy was better than that of those taught using conventional methods of teaching, and it was also discovered that there was no significant relationship between the teaching strategy and the students' gender. Therefore, it is concluded that the think-pair-share strategy improved students' academic achievement in algebra. The study recommends teachers embrace the strategy as it improves students' achievement in algebra and mathematics in general.

Keywords: Think-pair share, Algebraic expression, Achievement.

Introduction

The world has come a long way as a result of rapid discovery, innovation, and invention in science and technology through observations and experiments. Modernization in every aspect of life is the greatest example of the implementation of scientific and technological knowledge (Ahmad 2019). Science is the study of the physical and natural worlds through observations and experiments. Abimbola (2020) submitted that innovative and inventive science and technology skill development is dependent on mathematics teaching and learning. Mathematics teaching exposes students to different ways of reasoning that lead to solutions to real-life problems.

Mathematics is a branch of science that helps students at all levels determine their choice of profession. Mathematics is recognized as an essential tool for the development of any society; it's a discipline that deals with data, measurement, and observations from science, with inferences, deductions, and proof (Yadaz, 2019). The application of mathematics cuts across all areas of science, technology, commerce, agriculture, economics, and health.

According to Jayanthi (2019), commercial organizations use mathematics in accounting, inventory management, marketing, sales forecasting, and financial analysis. It teaches the financial formulas, fractions, and measurements used in interest calculation, hiring rates, salary calculation, tax calculation, and other business tasks. Business mathematics, which also includes statistics, analysis, and studies in economics, help explain the interdependent relation between different variables; they try to explain what causes a rise in prices, unemployment, or inflation. Mathematical functions are modes through which real-life phenomena are made more understandable and logical. In addition, certain qualities that are nurtured by mathematics are the power of reasoning, creativity, abstract or spatial thinking, critical thinking, problem-solving ability, and even effective communication skills.

In Nigeria, mathematics is made a compulsory subject due to its impact on national development (FBN, 2004). Despite the importance and application of mathematics across different fields, there has been a continuous outcry over the poor academic achievement of students in mathematics in internal and external examinations (Gagara, Kwari, & Dikop 2019). In the WAEC chief examiner's report for 2020, it was observed that only half of the candidates could attempt elementary algebra and find the missing values successfully. Algebraic concepts are the chief cause of failure in mathematics (Abdullah & Suhairom, 2018; Ogbu, 2020; Ladele, 2013). This is as a result of many factors, such as the use of an inappropriate teaching strategy or continuous dependence on the same teaching method, an overcrowded classroom, a lack of qualified teachers, inactive methods of instruction, and improper assessments of students' performance (Jimoh, Mamman, and Kaseem, 2020). Based on the view above, it shows that poor student-student relationships, poor student-teacher interactions, and self-learning have been normal classroom practices. Knowing what methods are available and what objectives each method is best suited for helps teachers easily select instructional methods that help students develop self-reliance, become motivated to learn, and improve academic achievement. Abdurrahman and Sani's (2022) good teaching strategy encourages students' active participation, promotes academic achievement, and improves their retention rate. Therefore, students need an effective learning strategy such as the Think-Pair-Share (TPS) instructional strategy.

Think-Pair-Share, on the other hand, is a strategy that encourages students to develop individual ideas, share those ideas with others, and reduces competitiveness in the learning environment. It is a questioning technique that promotes students' active participation in the class discussion, provides an opportunity for every student to share an idea and to answer every question posed by the teacher, rather than using the basic recitation method in which a teacher poses a question and one student offers a response (Sampel, 2013). Think-Pair-Share's instructional strategy, if effectively utilized, makes learning and working together a way of life among students and also leads to improvements in academic achievement and retention ability in mathematics (Ginga, Usman, and Mohammed, 2019; Anaduaka, Sunday, and Olaoye, 2018, Ahmed, Mahabad, & Abdul Karim, 2016, and Al-Sultani, 2015).

In view of this, the present study investigated the effects of the Think-Pair-Share (TPS) learning strategy and determined if it improved students' academic achievement in algebraic concepts among senior secondary school students in Nassarawa, Kano.

Statement of the Problem

Reports on mathematics results at both internal and external examinations have shown that students performed poorly due to a variety of factors, even though an improvement has begun to be observed (WAEC report, 2022). It is observed that most of the teaching methods adopted in mathematics class are not socially friendly. This factor of student-student and teacher-student relations can easily affect the student's achievement. Hence, the problem of this study was to determine the effect of the think-pair-share strategy on students' achievement in algebra in Kano State senior secondary schools.

Objectives of the Study

i. Investigate the mean achievements score of students taught algebra using think pair share strategy and those taught with conventional method.

ii. Determine the mean achievement scores of males and females when taught algebra with think pair share co-operative learning strategy.

Research Questions

i. What is the difference between the mean achievement scores of students taught algebra using think pair share strategy and those taught using the conventional method?

ii. Is there any difference in the mean achievement scores of male and female students taught algebra using think pair share learning strategy?

Research Hypotheses

The research hypotheses were set for testing at 0.05 level of significance as follows:

H_{01}: There is no significant difference between the academic achievements mean scores of students taught algebra concepts using think pair share co-operative learning strategy and those taught using conventional method.

H_{02}: There is no significant difference in the academic achievement mean scores of male and female students taught algebra by think pair share co-operative learning strategy.

Methodology

Research Design

The study was quasi-experimental design which adapted the pre-test, post-test control group design. The design contains two experimental and control groups, and pretest (O_1) posttest (O_2) to determine the academic achievement of these groups. The experimental groups were exposed to intervention (treatment) period using Think-Pair-Share strategy and the control groups was taught using guided-discovery method for six weeks.

Population

The population consisted of 9573 SSII students from Nassarawa Educational Zone, Kano. The SSII students were used because SSI students were newly introduced to senior secondary algebraic concepts while SSIII students were busy preparing for the Senior School Certificate Examination (SSCE).

Sample and Sampling Technique

Four schools were selected using Stratified random simple techniques, then one intact class was selected from each school using simple random sampling techniques consisting of 64 and 69 students used for male and female experimental group and 53 and 62 students used for male and female control group respectively. Hence, the sample size was 248 SSII students made up of 117 male and 131 female students.

Instrumentation

The Algebra Achievement Test (AAT) was the instrument used for data collection. The AAT consisted of 30 items from the senior secondary school scheme of work. It was validated by four research experts: one senior lecturer from mathematics education, one specialist in test and measurement, and two secondary school mathematics teachers who have spent more than 15 years teaching in secondary school. The instrument was pilot tested on 30 respondents, which was different from the sample population. Using the Pearson product-moment reliability coefficient technique, the reliability coefficient was determined to be .88.

Treatment

AAT was administered to both experimental and control groups as a pre-test before the commencement of the experiment by the researcher. Two mathematics teachers served as research assistants, one from each of the selected schools for the control group and were also given detailed plan and instruction on the study prior to the treatment. The treatment process lasted for the period of six (6) weeks for both control and experimental groups. At the end, AAT was administered as post-test to both groups to measure the achievement and research questions were answered using descriptive statistics (mean and standard deviation) while the hypotheses were analyzed using inferential statistical tools (**Z**-test statistical tool) at 0.05 level of significant using statistical package for social science (SPSS) version 22.

Results

Research Question One:

What is the difference between the mean achievement scores of students taught algebra using think pair share strategy and those taught using the conventional method?

Table 1 : Mean and Standard deviation of the students' post -test

Group	**N**	$\bar{x}$	**Stand. Deviation**	**MD**	**Stand. Error Mean**
Experimental	133	16.128	4.52	2.571	.39193
Control	115	13.557	4.241		.39547

Result of Table 1 shows that the experimental group had a mean score of 16.128 in AAT with the standard deviation of 4.52 while the control group had a mean score of 13.557 with the standard deviation of 4.241. The mean difference between the groups is 2.571, indicating that there is a positive difference between the two groups in favor of experimental group. Therefore, this suggested that the experimental group got higher mean than the control group.

Research Question Two:

To what extent do the mean achievement scores of males and females differ when taught algebra using think pair share learning strategy?

Table 2: Mean and Standard Deviation of Male and Female Students Post-test

Group	**N**	$\bar{x}$	**Stand. Deviation**	**MD**	**Stand. Error Mean**
Male	64	15.781	4.315	0.396	.5394
Female	69	16.449	4.711		.5671

Table 2 shows that mean achievement score of male students is 15.781 with the standard deviation of 4.315 while the female counterpart mean achievement score is 16.449 with the standard deviation of 4.711 and the difference between the male and female mean achievement score is 0.396, indicating that both the male and female students in the experimental group approximately had the same achievement score when taught algebra using TPS strategy.

Hypotheses

The null hypotheses were tested at 0.05 level of significance as follows:

H_{01}: There is no significant difference between the academic achievements mean scores of students taught algebra concepts using think pair share strategy and those taught using conventional method.

Table 3: Independent Sample Z-test of the experimental and control group

Group	N	$\bar{x}$	SD	DF	Z- value	Sig.	Decision
Experimental	133	15.977	4.391	246	7.991	.000*	Not Supported
Control	115	11.365	3.351				

*P< .05

Table 3 reveals that the calculated z-value is 7.991 and the p-value is .000 which is less than significant level 0.005. The result affirms that there is significant different between the mean achievement score of the students taught algebra using TPS strategy and those taught using conventional method. Therefore, the null hypothesis is rejected. Hence, the experimental group achieved higher than the control group in the posttest mean achievement score.

H_{02}: There is no significant difference in the academic achievement mean scores of male and female students taught algebra by think pair share co-operative learning strategy.

Table 4: Independent Sample Z-test of Male and Female Students Post-test.

Group	N	$\bar{x}$	SD	DF	Z-value	Sig.	Decision
Male	64	15.781	4.3149	131	.851	.396*	Supported
Female	69	16.449	4.7109				

*P> .05

Table 4showed independent sample Z-test of male and female students taught algebra using TPS strategy. The result shows that the z-value is .851 and significant level of .396 which is greater than the p-value .005 (.396 > .005), indicating that the p-value supported null hypothesis (**H_{02}**). This suggested that gender and the method of teaching do not mutually influence students' achievement especially when taught with TPS strategy. Therefore, the hypothesis three is thereby accepted.

Discussions of the findings

From the findings it was revealed that there was a significant effect on the students' academic achievement based on the independent sample Z-test. The result indicated that those taught algebra using TPS strategy outperformed their counterpart taught using conventional method (P

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= 0.00 < 0.05). This finding agreed with the results of Adedeji (2021), Ginga, Usman and Mohammed (2019), Agbede and Ba'aba (2019) and Henry (2018) *who found out that students learning through TPS strategy improve students' learning achievement.* This is also in line with the study conducted by Okafor & Chiagozie (2021) and Isa (2014) who reported from their findings that TPS strategy enhance teacher-students' relationship and student-students' interaction in the teaching and learning mathematics, and it encourages students to search for knowledge rather than teacher controlling the transmission of knowledge to students. Therefore, use of TPS strategy goes a long way in boosting student' confidence in classroom discussion and participation. A student who is exposed to TPS is likely to possess in-depth knowledge of the content area because such student will be able make an effective interaction between peers, while he also compares and evaluate his understanding of the content area with others understanding (Bamiro, 2015). Hence, TPS could arouse the student's interest toward the content area which could leads to better achievement.

It was also found that the mean achievement of the male exposed to TPS strategy is approximately equal to their female counterpart exposed to the same TPS strategy. The difference between the male and female achievement is not statistically significant (0.396). This result is in line with Akanmu (2019) and Yusuf, Owede and Bello (2018) who posited that there is no gender influence in the students' achievement in mathematics when taught using TPS strategy. However, it is also in variance to Haakachima and Lunjebe (2019) as well as Isa (2014) who found out that males benefited more than the girls who were both subjected to cooperative learning. While it contradicts Lawan (2016) who found out that the female students taught using cooperative strategy out-performed their male counterpart. Thus, this result indicated that TPS strategy favoured both male and female in the aspects of algebra and its more effective in enhancing student academic achievement. This shows that employing TPS strategy for teaching and learning mathematics by given the female students equal opportunity to fill the narrow gap in learning mathematics when compare with their male counterpart to actively participate in the learning process, then the female students are capable competing in mathematics.

Conclusion

Based on the findings the following conclusions were made:

1. The use of TPS learning strategy in teaching algebra concepts significantly improves students' academic achievements than traditional method.
2. The TPS strategy is not gender dependent, both the male and female students in the experimental group approximately had the same achievement score when taught algebra using TPS strategy. Therefore, the strategy is gender friendly.

Recommendation

The recommendations from the study are as follow:

1.The mathematics teachers should be trained on how to use the effective instructional method such as TPS strategy in teaching mathematics to improve students' academic and reflective thinking achievement.

2. Mathematics teachers should endeavor to adopt TPS strategy and give equal opportunity to both male and female students in the process of teaching and learning of mathematics for better achievement.

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