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Comparative Analysis of Field-Dependence and Field-Independence as Determinants of Students Achievement in Geometry

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Abstract
The study was aimed at comparing field-dependence and field-independence as determinants of students' achievement in geometry which constitutes a large percentage of the mathematics curriculum for secondary school students in Nigeria. A total of 200 SSII students from two schools in Yakurr Local Government Area of Cross River State, Nigeria, were used for the study. A pre-test comprising 50 multiple choice questions, the group Embedded Figure Test (GEFT) comprising 10 items, and a post-test comprising 50 multiple choice questions were all employed for data collection. Both descriptive and inferential statistics were used for data analysis. The result obtained showed that field-dependence and field-independence were determinants of students' achievement in geometry, however, indicating that significant differences in achievement between field-dependent and field-independent students was determined by the method of treatment used in the study. The results also showed that whereas maximum guidance was very effective for both subsets of students, minimum guidance tended to favour the field-independent students, putting the field-dependent students at a disadvantage. Based on the findings, it was recommended that educators, curriculum planners, teachers and students should all translate the results of this study into viable educational programmes that will enable mathematics students to achieve maximum success in examinations.
Keywords: Cognitive style, field-dependence, field-independence, maximum guidance, minimum guidance.
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Introduction

Because of its perceived role in scientific and technological development, mathematics is a compulsory subject in the secondary school curriculum in Nigeria (FRN, 2004; NPE, 1977). In addition, the concepts and principles of mathematics are regarded as useful and are applied in the study of other subjects such as Economics, Engineering, Biological Sciences. Beside these facts, mathematical knowledge is needed by every individual for intelligent and efficient functioning in his or her world (Anaduaka, 2013). Mathematical knowledge is an integral part of everyone's life and affects virtually every field of human endeavor. Even the most rudimentary knowledge of mathematics is necessary for human survival. For instance, counting, measuring, adding, subtracting etc. are all essential for our daily living. Mathematics is essential for use in the home, school, office, business, industries, farms, decision-making, committees and government agencies. Usman in Anaduaka (2013) noted that in everywhere we go, everything we do or propose to do, either the structure of mathematics or its application plays a vital role and this is why most countries, races and peoples put emphasis in all aspects of studying, developing, and applying mathematics.

As a body of knowledge essential for the attainment of a scientifically and technologically driven society, mathematics sets the demarcation between the developed and the underdeveloped nations (Ale and Lawal in Anaduaka, 2013). The distinguishing evidences in the standards of living among nations is indicated by their ability to embrace mathematics, science and technology (Nosa and Ohenhen in Anaduaka, 2013).

The world today is fast becoming a global village and therefore compels everyone to possess skills of accuracy, logical reasoning, systematic and orderly arrangement of facts, problem solving skills and self-reliance. Such skills can only be acquired through mathematical knowledge. Individuals and corporate bodies utilize mathematics to organize complicated situations or problems into clear, simple and logical steps. In every society today, high-paying jobs often demand someone who possesses the ability to simplify complicated situations and reduce them to the level that everyone can understand. Students with adequate mathematical knowledge have the competitive edge needed to make career choices for such high paying jobs (Anaduaka, 2013).

It is pertinent, therefore that all students receive quality mathematics education. The era of viewing mathematics just a prerequisite for entry into universities and other tertiary institutions should be gone. This is practically so because now, more than ever, every Nigerian child needs mathematical knowledge in order to cope with living, contribute meaningfully to a scientifically and technologically driven society such as ours and to promote justice, fairness, equity and truth in a society where corruption and injustice override good virtues.

Quite unfortunately, in spite of the laudable potentials of mathematics and its relevance to the development of Nigeria, students' achievement in the subject has been discouraging. This is evident in the report of the senior secondary certificate examination (SSCE) organized by the West African Examination Council (WAEC) and the National Examination Council (NECO). Theses examinations are taken by students at the end of their secondary education and are used as measures of knowledge and skills acquired at that level of education (SSCE, WASSCE, 2010-2018, SSCE, NECO, 2010-2018).

Table I: Percentage of students in Nigeria having credit and above (A1-C6) pass and below (D7-F9) in the May/June WASSCE in General Mathematics between 2000 and 2016

Year	% of students	
	A1-C6	D7-F9
2000	32.80	62.20
2001	41.60	58.40
2002	15.00	85.00
2003	45.80	54.20
2004	53.80	46.20
2005	35.55	64.45
2006	39.90	60.06
2007	15.56	84.44
2008	23.00	77.00
2009	31.00	69.00
2010	33.55	66.45
2011	38.93	61.07
2012	49.00	51.00
2013	36.00	64.00
2014	31.30	68.70
2015	34.18	65.82
2016	38.68	61.32
Mean (%)	27.31	72.69

Source: Test Development Division, West African Examination Council (WAEC) Lagos, Nigeria.

The result of this examination is also used as prerequisite for admission into tertiary institutions of learning where students are given opportunities to pursue courses in their areas of interest. In most Nigerian Institutions, a credit pass in mathematics and English Language is a basic requirement for admission in any course whatsoever. Evidence from Table I of results released yearly by the examination bodies continue to reveal a steady trend of mass failure of the students in mathematics, which averages about 72.69% per year. (See Table I).

In an attempt to explore the reasons for the poor achievement in mathematics examinations, a number of reasons have been adduced. For example, while some believe that poor achievement in mathematics is due to lack of adequate professional teachers, which leads to absorption of quacks into the system (Onah, in the Nation online, 2007), others believe it is due to phobia for the subject (Lawal, 2017). There are those who also attribute this poor achievement to lack of passion, lack of reading practices etc. (Lantern Books, 2017). One cannot be absolutely sure whether these reasons are based on research findings or not. But an important point which seems to have eluded the minds of many is the fact that researchers in the field of educational psychology have always suggested that learning a concept depends largely on the cognitive style preferences of the learners. (Witkin, 1993; Chinien and Boutin, 2015; Jonassen and Grabowski, 1993; Ford and Chem, 2000). It is perhaps right to say that certain concepts in mathematics are not taught in the manner that agrees with the cognitive style preferences of mathematics learners, especially at the secondary school level. In Nigeria for example, the secondary school curriculum is hinged largely on geometry. It becomes necessary to ask questions about the manner of cognition of geometrical concepts by learners at this level. Such questions are important because they help us see clearly where we are missing the point.

The desire to bring about improvement in teaching and learning has given rise to various researches on cognitive styles. Different styles have been identified by research experts namely: leveling and sharpening (Martin and Saljo, 1996); Holistic and Servalistic cognitive styles (Pask, 1970); Reflection and impulsivity (Kagan, 1965); Divergence and convergence (Cavilford, 1956); but the one of interests to this study are the field-dependent and field-independent cognitive styles proposed by Witkin, Moore, Goodenough and Cox (1977). To understand cognitive style, a definition of cognition must first be understood. A collection of mental processes that include awareness, perception, reasoning, and judgment is known as cognition (Standard, 2003). The study of cognitive processes has its roots in the Gestalt psychology of Max. Wertheimer, Wolgang Kohler and Kurt Koffka and in the studies of cognitive development in children by Jean Piaget during the 19th century. At the beginning of the 20th century, Carl Jung published a theory of psychological types (1923), where he postulated that personality comprises three facets each with a continuum descriptor. The first facet, attitude, can range from extroversion (those personalities that are outgoing) to introversion (those personalities that are focused inward). The second facet, perception, deals with a persons method of understanding stimuli; an intuitive person is meaning-oriented while a sensory person is detail-oriented. Judgment is the final facets of personality and deals with a persons approach to making decisions, a thinking person tends to be analytical and logical, while a feeling person tends to judge based on values. Jung's Types Indicator (MBTI), is a standard personality test administered today in many cognitive style experiments.

The definition of cognitive style has been a subject of debate among psychologists over the years. Goldstein and Blackman (1978) defined cognitive style as "a hypothetical construct that has been developed to explain the process of mediation between stimuli and responses. The term cognitive style refers to characteristic ways in which individuals conceptually organize the environment". They further added that cognitive style is an information transformation process whereby objective stimuli is interpreted into meaningful schema. Messick in Chinien and Boutin (2015) defined cognitive style as "the information processing habit representing the learners typical mode of remembering". In another definition by Dufresne and Turcotte in Chinien and Boutin (2015), cognitive styles are described as "high-level heuristics that organize and control behavior across a wide variety of situations".

Hermar Witkin (1973), a pioneer in cognitive styles defined cognitive styles in terms of a process. He argued that cognitive styles are concerned with the form rather than the context of the learning activity. According to him, cognitive styles are actually broad personal styles which show typical ways in which we process information. They refer to individual differences in how we perceive, think, solve problems, and learn. Witkin spent a great part of his academic career developing measures of cognitive styles. His work centred mainly on ascertaining the extent to which a person's perception of an item was influenced by the surrounding field in which the item appeared. His aim was to determine if "some people saw the tree, while others saw the forest". He termed those who saw the forest as field-dependent while he called those who saw the tree within the forest field-independent".

Peterson and Rayner (2009) gave a consensus definition of cognitive styles that was provided by many experts in cognitive psychology through a Delphi study. It states, "Cognitive styles are individual differences in processing that are integrally linked to a person's cognitive system". More specifically, they are a person's preferred way of processing (i.e. perceiving, organizing and analyzing) information using cognitive brain-based mechanisms and structures. These styles form very important dimensions of individual differences among students. In an attempt to give an explanation for the cognitive style construct, Cross in Chinien and Boutin (2015) notes: "People see and make sense of the world in different ways. They give their attention; they approach problems with different methods for solution; they construct relationship in distinctive patterns; they process information in ways… style has a broad influence on many aspects of personality and behavior perception, memory, problem-solving, interest, and even social behaviors and self-concepts".

Studies on cognitive styles are quite numerous. In this study, however, Witkin's field-dependent and field-independent cognitive styles are given special attention since they constitute the crux of the study. This is so because these two poles of cognitive styles are by far the most researched and the most influential of all (Learning & Skills Research Centre, 2004). As Messick noted in Chinien and Boutin (2015), most of the promises which do not hold true for other cognitive styles are actually true for field-dependent and field-independent cognitive styles. According to Witkin (1973) an individual who, when presented with a surrounding field, has difficulty in isolating items from the field is termed field-dependent. On the other hand, individuals who, when presented with a field, do not seem to have difficulty in isolating items from the field are termed field-independent. Field-dependent individuals are easily manipulated by the field they encounter, whereas field-independent individuals are not easily manipulated by the field, rather they are able to manipulate the field itself by keeping other variables in the field constant and separating an item or items from it. Thus while field-dependent individuals adopt a global view of a field, their field-independent counterparts adopt a specific view of the field. As Witkin puts it, field-dependent individuals see tree in their specific nature rather than forest in its global or general nature. Witkin was able to distinguish between field-dependents and field-independents by designing tests for his subjects.

The first test he designed was the body adjustment test and the rod and frame test. In these test the subjects were asked to determine their alignment, misalignment with true vertical rods given internal and external stimuli that may differ. It was found that one group of subjects determined their alignment as vertical based solely on the visual cues in the room. Witkin stated that it would be surprising that some could be tilted 35 degrees away, and, if in that position he was aligned to with the room, tilted at the same angle, he would report that he was perfectly straight. These subjects who were unable to determine their vertical alignment owing to a discordant visual field were referred to as field-dependent. Subject who were able to perceive their alignment as separate from the visual surroundings were referred to as field-independent (Witkin *et al,* 1977).

The second test was The Group Embedded – Fiqures Test (GEFT). This test was designed by Witkin to determine field-dependence/field-independence based on the time the subjects take to find a simple figures in a more complex visual field (Witkin *et al,* 1977). Subject who were field-dependent spent more time finding the figure while field-independent subjects found the figure quickly. The importance of this measures of cognitive style to problem-solving as stated by Witkin was thus: "The individual who, in perception, cannot keep an item separate from the surrounding field-in other words, who is relatively field-dependent – is likely to have difficulty with that class of problems… where the solution depends on taking some critical element out of the context in which it is presented and restructuring the problem material so that the item is now used in a different context" (Witkin *et al,* 1977).

Various theories have been deveoped in regards to field-dependent and field-indepenent cognitivr styles. One of the theories is the Cognitive Control Theory (Jonason and Graboski, 1993). According to this theory, field-dependence and field-independence are not cognitive styles but cognitive controls. Cognitive controls are the physchoanalytic entities that regulate perception. Cognitive styles define learners' traits whereas cognitive controls "have the status of intending variables that define principles by which motoric behaviour, perception, memory and other basic quantitative forms of cognitive functioning are organized as an individual coordinate himself with his environment. Cognitive controls defined some level of individual difference falling between mental abilities and cognitive styles. Mental abilities refer to content and level of cognitive activity, whereas styles refer to the manner and form of learning. Abilities specify the competencies, the mental operations, and the kind of information being process, while styles are stated in terms of propensities. Abilities are unipolar measures (less ability vs more ability), whereas styles are bipolar (visual vs verbal). Abilities are value directional (i.e more is necessarily better), while styles are value differentiated (neither pole is necessarily better). Another major difference between ability and styles is that the former are affected by the content domain or nature of the task, while styles are generalizable tendencies regardless of contents. Finally, abilities enable learners to perform tasks and styles control the ways in which the task is performed.

Cogntive control however have characteristics of both abilities and styles. There are like styles, in that there are concern with the manner and form of learning. They refer to propensities and are stated in term of typical behaviour. They also reflect information-processing techniques and are seen as controling rather than enabling. They are like abilities in that they are unipolar and are not value neutral. Controls are also like abilities in that they are affected by content domain and task.

Another very important theory considered in this study is the theory of differentiation proposed by Witkin and Goodenough (1977). In an earlier research by Wilkin and Goodenough, a theory of differentiation was proposed which also saw field-dependence and field-independence cognitive styles as part of heirachical construct placement. This theory holds that differences between field-dependent and field-independent people reflect the higher order construct of self-non-self segregation, in turn is a particular aspect of still higher construct of psychological differentiation.

According to this theory, a more differentiation person shows more self-non-self segregation. As part of a more segregated self are a more articulated body concept and a greated sense of personal identity. Overall, the more segregated the self, the more likely a perosn is to be field-independent, having greater cognitive restructuring skills though fewer interpersonal skills. This view helps us in the understanding and appreciation of how self-non-self segregation influences the cognition of geometrical shapes and forms in mathematics learning. In other words, viewing field-dependence and field-independence as cognitive styles provides information on how self-non-self segregation determines the extent to which learners of mathematics are able to isolate specific geometrical patterns from a surrounding field of a giving geometrical object. Learners who are able to isolate simple geometrical forms from complex figures could be termed mathematically field-independent. Those with extreme difficulty in this task could be termed field-dependent. They could be learner of mathematics, however, who fall in the continuum between the two extremes.

Statement of the problem

The concept of geometry has been an area of interest in mathematics education. Funk and Wagnalls in Daniel (2010) defined geometry as "that branch of mathematics that deals with the properties of space". In its most elementary form, geometry is concerned with metrical problems of determining the areas and diameter of two dimensional figures and surface areas and volumes of solids. In the context of this study, geometry spans from plane to solid shapes and other mathematical concepts such as trigonometry, calculus, etc. that are developed from it. A close look at the WAEC and NECO syllabi reveals that the concept of mensuration, plane, circle and coordinate geometry trigonometry, calculus and even statistics are considered germane to the mathematical needs of students. As Pilant (2009) noted, students in secondary schools study geometry, so as to enable them to make progress to tertiary institutions for higher study of geometry which is a basic requirements for scientific and engineering studies. Hushkowtiz, Bruckhenier and Vinner in Daniel (2010) also noted that a basic knowledge of geometry concepts, their attributes and simple relations is fundamental for children to interact effectively with their environment as well as for them to enter into a formal study of geometry, itself, and other areas like science and engineering. Fey (1991) pointed out too that geometrical instruction is intended to foster intellectual development through logical reasoning techniques adopted in the study of geometry. He further added that the primary objective of geometry studies is to provide learners with an understanding of the space around the environment and to help them develop skills in problem-solving that are necessary for dealing with everyday affairs.

However, Fey noted in Daniel (2010) that despite the obvious importance of geometry to a wide range of important real world problems and the strong traditional belief that geometry is ideal vehicle for teaching logical reasoning, the place off geometry in contemporary schools is neither satisfactory nor settled. In reports of the General Mathematics Paper 2, WASSCE (SC) results from 2010 to 2018 the chief examiner of the West African Examination Council (WAEC) stated repeatedly that the major challenges of students were hinged on geometry and its related topics such as mensuration, bearings, trigonometry, graphs, inequalities, vectors and statistics, which constitute about sixty percent (60%) of the entire mathematics syllabus for students at that level. The implication of these reports is that students score less than the expected pass mark in the WAEC General Mathematics largely because their proficiency in geometry and its related topics is wanting. It suffices, therefore, to think that exploring information on how best geometry and its related concepts can be taught will help enhance achievement in mathematics.

The problem under consideration in this study therefore is, “How can students’ achievement in geometry be enhanced?” “Will comparative analysis of field-dependence and field-independence be effective in facilitating students’ achievement in geometry and its related concepts?” This study considers this problem to be worthy of attention and it is therefore geared towards seeking for its solution. The research seeks to answer the question, which learning style, field-dependence and field-independence, will influence students’ achievement in geometry and its related concepts.

Purpose of the study

The objective of this study is to investigate the effect of field-dependent and field-independent cognitive styles on the achievement of students in geometry. In particular, the study will focus on:

1. Determining the differences between the geometry achievement of field-dependent and field-independent learners
2. Determining the effects of maximum or minimum guidance in geometry lessons on the achievement of field-dependent and field-independent a learners, and

Research questions

The research questions under consideration in this study are:

1. Is there any difference between the geometry achievements of field-dependent and field-independent learners?
2. What is the effect of maximum or minimum guidance in geometry lessons on the achievement of field-dependent and field-independent learners.

Research hypotheses

The null hypotheses related to the main variables are hereby expressed as follows:

H_{01}: There is no significant difference between the mean geometry achievement of field-dependent and field-independent students in both the experimental group (given maximum guidance) and the control group (given minimum guidance).

H_{02}: There is no significant difference between the mean achievement of field-dependent and field-independent learners who received maximum or minimum guidance in geometry lessons both within and between the two groups.

Research methods

Research design

This employed the quasi-experimental pre-test-post-test control group design. This allowed the extent of group similarity to be checked. The pre-test provided some appreciable level of statistical control. The subjects were divided into two groups. Each of these two groups was further divided into two subgroups (one subgroup was made of the field-dependent students while the other comprised the field-independent students). Thus there were two major groups and four subgroups, two of which constituted the major groups. The first major group served as the experimental group. It was treated with maximum guidance using the guided discovery teaching and learning method. The second group served as the control group. It was treated with minimum guidance using minimally assisted discovery teaching and learning method. The two major groups were kept in isolation to avoid contact while their subgroups remained together. Each major group was taken from a separate school that lied remote from the other. To take care of the non-equivalence of the two groups, the pre-test was used to provide statistical control for initial differences between them.

Area of the study

This study was conducted in Yakurr Local Government Area of Cross River State, Nigeria. The settlements in this area include Ugep, Ekori, Idomi, Nko, Mkpani, Agoi, Asiga and Nyima.

Population of the study

The population of the study was made up of all senior secondary II (SSII) students in schools around Yakurr Local Government Area of Cross River State, Nigeria. It comprised 2400 students. This class was selected for this study following the fact that the curriculum for mathematics at that level lays emphasis on geometry topics that are taught anew.

Sample and sampling technique

The sampling technique adopted in this study were the simple random sampling and the stratified random sampling. Two communities were selected from the eight communities in the area of study using stratified random sampling technique, which allowed for remoteness. The names of the communities were listed, then the selection was done by counting two strata of 4 steps each. After the selection of the two communities, two schools were selected from each community by simple random sampling technique. The names of the schools were written out in pieces of paper, wrapped and put in a bowl. The bowl was then shaken thoroughly to ensure that every school was given a fair chance of being selected. The selection was done by picking one school at a time and with the eyes closed. After the first selection, the bowl was shaken thoroughly again before the next selection was made. From the selected schools the list of SSII students was collated and their names were written out in pieces of paper, wrapped and put in the bowl. The bowl was then shaken again to give a fair chance of selection to every student. 100 different selections were made for each school so that the total number of selections made for the two schools was 200.

Instrumentation and validation

The test instruments developed for this study include the following

Mathematics Achievement Test I (MAT I Pretest): This test consisted of 50 multiple choice questions on basic mathematics topics that are in geometry. The topics were taken from the SSI and SSII syllabi. The test was administered for 1 hour.

Group Embedded Figure Test (GEFT): This was a non-verbal speed test published by Witkin and Goodenough (1971). It was a test of students' ability to find a single form where it was hidden within a complex pattern. The GEFT questions used in this study were similar to those of Witkin. It was used to differentiate the field-dependent subjects from their field-independent counterparts. The GEFT questions comprised 12 item, 2 items were used as examples which were properly illustrated, while the 10 items were used for the assessment. The test was administered for 20 minutes.

Mathematics Achievement Test II (MAT II, Posttest): This test also comprised 50 multiple choice questions from the same topics as is the case with the pretest. It was administered for 1 hour.

Lesson notes: They were prepared along with practice exercises on topics such as plane geometry, solid geometry, circle geometry, mensuration, and trigonometry. The notes were given to the subjects to study for the period of treatment.

The content validity of the instruments was verified and certified by two uninvolved experts contacted from the mathematics and educational test and measurement departments of a different tertiary institution. The instruments were tested for their scope, clarity or ambiguity. They were also analyzed item by item to ascertain their difficulty level as well as their discriminating indices. The treatment instrument were also analyzed to ascertain its scope, simplicity of presentation of facts, proves and examples as well as exercises. The exercises were analyzed for clarity and ambiguity. The test instrument were also tested for inter-rater reliability by calculating the correlation of its scores with those obtained from a distant school within the state, using the split half method. This gave r=0.67, showing that they were reliable. The GEFT instrument had been tested by the designers and had forms reliability estimate of 0.88 and a high validity owing to its positive correlation with other measures of perceptual differentiation.

Research procedure
A total sample of 200 SSII subjects selected from two schools in Yakurr Local Government Area of Cross River State, Nigeria, were invited to take the Mathematics Achievement Test I (MAT I) which served as the pre-test. Then the Group Embedded Figures Test (GEFT) was administered as soon as the pretest had been taken. The GEFT was a test of psychological differentiation which enabled the researcher(s) to distinguish the field-dependent from the field-independent subjects. Then the subjects were given notes along with a scheme that was prepared from geometry/mensuration and trigonometry. The experimental group was treated with maximum guidance through repeated classroom interactions that employed the guided discovery teaching and learning method. The control group was on the other hand treated with minimum guidance through sparing classroom interactions that employed the minimally assisted discovery teaching and learning method. After the treatment classes which lasted for about two (2) months, the subjects where given two (2) additional weeks to prepare for the posttest which was finally administered at another date scheduled between the researchers and the students.

Data collection
The Group Embedded Figures Test (GEFT) was awarded 1 mark each, so that the obtainable score was 10 marks for all the items. To determine a student's field-dependence or field-independence, the ages of the students were arrange in order of magnitude. The mean score (x) of a particular age was determined. A student whose score was below the mean score of his/her age was classified as field-dependent while a student whose score was above the mean score of his/her age was termed field-independent. The Mathematics Achievement Test (MAT I and MAT II) were each allotted 2 marks per item, so that the obtainable score for the 50 items in each test became 100. The scores for the two tests were recorded as pretest and posttest.

Method of data analysis
The data collected were analyzed using both descriptive and inferential statistics. Analysis of variance. (ANOVA) was employed in data analysis. All hypotheses were tested at 0.05 level of significance

Results and discussion
The three research questions were answered using the mean and standard deviation of the FI and FD students in both the experimental and control groups.

Table I shows the GEFT mean scores of the 200 subjects that were used for the study. The experimental group, EXP. (i.e. the group treated with maximum guidance), had 25 students that were 15 years of age. These students had a mean score of 5.56 in the GEFT. 13 of them score either less than or equal to this mean score and were classified as field-dependent (FD), while the remaining 12 students scored above this mean score and were termed field-independent (FI). 45 students in this group were 16 years of age and their GEFT mean score was 5.61 of which 22 scored less than or equal to this value and were classified as FD, while 23 scored above this mean mark and were termed FI. 23 students of this same group were 17 years of age and had a mean score of 6.61 of which 12 were termed FD and 11 were termed FI by the same argument. 7 students in this group were aged 18 years and had a mean score of 6.19m of which 4 became FD and 3 became FI. The total numbers of FD and FI students in the experimental group were 51 and 49 respectively.

Table I: GEFT mean scores by age for FD/FI

Group	Age (Yrs)	N	GEFT mean score	Subgroup FD	FI
EXP.	15	25	5.56	13	12
	16	45	5.61	22	23
	17	23	6.61	12	11
	18	7	6.19	4	3
Total		**100**		**51**	**49**
CTRL	15	13	5.31	8	5
	16	22	5.71	8	14
	17	29	6.07	19	10
	18	36	6.08	23	13
Total		**100**		**58**	**42**

In the control group, CTRL (i.e. the group treated with minimum guidance), 13 students were aged 15 and had a mean GEFT score of 5.31. 8 students out of this number scored less than or equal to the mean and were classified as FD, which 5 of them had a score about their mean and were termed FI. 22 students aged 16 years had a mean score of 5.71 of which 8 scored below or equal to this mean and were termed FD, while it scored above this value and were termed FI. 29 students aged 17 years had a mean score of 6.07 of which 19 were FD and 10 were FI by similar argument. 36 students aged 18 years had a mean score of 6.08 of which 23 the total numbers of FD and FI subjects for the control group were 58 and 42 respectively.

RQ_1: Is there any difference between the geometry achievement of field-dependent and field-independent learners?

Table 2 provides a summary of the achievement of the subjects by giving the pretest and posttest mean scores and standard deviations of the FD and FI students in both groups (i.e. the experimental and the control groups).

Table 2: Pretest and posttest mean scores and standard deviations of FD and FI students

Group	Subgroup	N	$\bar{x}$	SD	Mean diff
			Pretest		
EXP	FD	51	44.4586	5.5938	
	FI	49	51.5510	6.9073	7.0924
CTRL	FD	58	45.6207	5.6625	
	FI	42	53.7143	6.1931	8.0936
			Posttest		
EXP	FD	51	62.2745	70.6884	
	FI	49	70.7347	12.1840	8.4602
CTRL	FD	58	55.5172	6.8268	
	FI	42	69.4762	9.9320	13.9590

From Table 2, it can be seen that differences (7.084, 8.0936, 8.4602 and 13.9590) actually exist. The differences are all in favor of the FI students. This shows that field-independence accounts for better achievement in geometry test.

RQ_2 What are the effects of maximum and minimum guidance in geometry lessons on the achievements of field-dependent and field-independent learners?

This research question can be answered in two ways. First, we have to compare the FD and the FI posttest mean achievements within the groups. Secondly, we have to compare FD between the groups and the FI between the groups.

Within the groups, notice from Table I that the mean difference of the posttest achievements of the experimental group (8.4602) is less than that of control group (13.9590). Recall that the experimental group received maximum guidance while the control group received minimum guidance. This indicates that whereas maximum guidance reduces the difference in mean achievements, minimum guidance increases the difference in mean achievements. This is so because maximum guidance favors both learners while minimum guidance favors the FI students much more than it does favor the FD students.

Between the groups, the same research question can be answered by observing Table 3 below.

Table 3: Pretest and posttest mean scores and standard deviations of FD and FI students Between the groups

Group	Subgroup	N	$\bar{x}$	SD	Mean diff
			Pretest		
EXP	FD	51	44.4586	5.5938	
	FI	58	45.6210	5.6625	1.1700
CTRL	FD	49	53.4760	6.2419	
	FI	42	51.5510	6.9073	1.9250
			Posttest		
EXP	FD	51	62.2745	10.6884	
	FI	58	55.5172	6.8268	6.7573
CTRL	FD	49	70.7347	9.7122	
	FI	42	69.4962	9.9370	1.2385

From Table 3, it can be observed that the posttest mean difference between the FD students of the experimental and control groups (6.7573) is greater than the mean difference between the FI students of the experimental and control groups (1.2385). This clearly shows that maximum guidance increases the achievement of the FD students whereas minimum guidance reduces the achievement of the FD students. It also shows that the FI students are favored by both situations. They can achieve just as much when guided maximally or minimally.

Testing of research hypotheses

HO_1: There is no significant difference between the mean geometry achievements of field-dependent and field-independent students in both the experimental, EXP, and the control CTRL, group.

Table 4: ANOVA of the mean in pretest and posttest scores of FD and DI students within the groups

Group	Subgroup	N	$\bar{x}$	SD	df	f	$P_{(2tons)}$
				Pretest			
EXP	FD	51	44.4586	5.5938	50		
	FI	49	51.5510	6.9073	48	1.5247	0.1423
CTRL	FD	58	42.6207	5.6625	57		
	FI	42	53.7143	6.1931	41	1.1962	0.5262
				Posttest			
EXP.	FD	51	62.2745	10.6884	50		
	FI	49	70.7147	12.1840		1.2994	0.3611
CTRL	FD	58	55.5172	6.8268	57		
	FI	42	69.4762	9.9370	41	2.1187	0.0088

ANOVA of the pretest mean scores of the FD and the FI students in the EXP group yields F=1.5247 with a probability value P=0.1423. Testing, H_{O1} at α=0.05 it can be seen that P>α, thus showing that the difference between the two means is NOT significant. Therefore, H_{O1} is accepted for the EXP group. The same analysis applied on the pretest result of the control, CTRL, group yields F=1.1962 with P=0.5262. Testing H_{O1} at α=0.05, It is seen that P>α, thus showing that the difference between the means of the FD and FI students in the CTRL group is NOT significant. Therefore, H_{O1} also accepted for the CTRL group (see Table 4).

Again, ANOVA of the posttest score of the EXP group shows that F-1.2994 and P=0.3611. Testing H_{O1} at α=0.05, it can be seen that P>α, thus showing that there is no significant difference between the FD and the FI students after the treatment. Similar analysis applied on the posttest results of the control group shows that F=2.1187 and P=-.0088. Testing H_{O1} at α=0.05, it is found that P<α, thus showing that there is a significant difference between the mean scores of the FD and the FI students within that group. Therefore, H_{O1} is accepted for the EXP group but rejected for the CTRL group (Table 4).

H_{02}: There is no significant difference between the mean achievement of field-dependent and field-independent learners who received maximum or minimum guidance in geometry lessons both within and between the two groups.

This hypothesis is also tested both within the groups and between the groups

Within group analysis

Recall that from Table 3 ANOVA of the pretest means scores of FD and FI within the EXP group yielded F=1.5247 and P=0.1423. Testing H_{O2} on this, it is found that P>0.05, thus showing that the difference between the two mean scores of the FD and FI within the EXP is NOT significant (Table 4). ANOVA of the mean pretest scores of the FD and FI in the CTRL group also shows that F=1.1962 and P=0.5262. Since P>0.05, it follows that the difference between the mean pretest scores of the FD and the FI within the CTRL group is NOT significant. Therefore, H_{O2} is accepted for both groups in the pretest scores (Table 4).

Recall also from Table 4 that ANOVA of the posttest mean scores of the EXP group yields F=1.2994 and P=0.3611. Testing H_{O2}, it can be seen that P>0.05, showing that the difference within the group is NOT significant. Again ANOVA of the posttest mean scores of the CTRL group yields F=2.1187 and P=0.008. Clearly, P<α=0.05 showing that the difference in this case is significant. Therefore, H_{O2} is accepted for the EXP group but H_{O2} is rejected for the CTRL group.

Between group analysis

Table 5: ANOVA of the pretest and posttest mean scores of FD and FI students between the groups

Group	Subgroup	Guid.	N	$\bar{x}$	SD	df	f	$P_{(2tails)}$
					Pretest			
EXP	FD		51	44.4510	5.5938	50		
CTRL	FD		58	45.6210	5.6625	57	1.0247	0.9341
EXP	FI		49	53.4760	6.2419	48		
CTRL	FI		42	51.5510	6.9073	41	1.2439	0.4771
					Posttest			
EXP.	FD	MAX	51	62.2745	10.6884	50		
CTRL	FD	MIN	58	55.5122	6.8268	57	1.2207	0.0012
EXP	FI	MAX	49	70.7347	9.7122	48		
CTRL	FI	MIN	42	69.4762	9.9370	41	1.5037	0.1840

ANOVA of the pretest scores between the FD students of the EXP group and the FD students of the CTRL group yields F.1.0247 and P=0.9341 (Table 5). Testing H_{O2}, on these values at α=0.05, it is found that P>α, thus showing that the difference in the mean scores between the FD students of the two groups is NOT significant. Similar analysis applied on the pretest mean scores of the FI students in the CTRL group yields F=1.2439 with P=0.4771. Testing H_{O2}, on these values at α=0.05, it can be seen that P>0.05, pointing that the difference between the two means is NOT significant. Therefore, H_{O2} is accepted for both subgroup in the pretest.

ANOVA of the posttest mean scores of the FD students between the EXP and the CTRL groups shows that F=2.2207 and P=0.0012. Testing H_{O2}, it can be seen that $P<\alpha=0.05$, showing that the difference between the mean scores of FD students both groups is significant. Similar analysis applied again on the posttest mean scores of FI students between the EXP and the CTRL groups shows that F=1.5037 with P=0.1840. Testing $H_{O2,}$ on these values at $\alpha=0.05$, it can be seen that $P>\alpha=0.05$, pointing that there is no significant difference between the two means in this case. Therefore, H_{O2} is rejected for the FD students between the EXP and the CTRL groups in the posttest, while it is accepted for the FI students between the two groups in the posttest.

Discussion of findings

The first purpose of the study was to determine the difference between the achievements in geometry of field-dependent (FD) and field-independent (FI) learners of mathematics. Analysis of the pretest scores of the FD and the FI learners in both the experimental (EXP), and the control (CTRL) groups showed that there was no significant initial differences between the achievements of the two subgroups (FD and FI). In fact, from the pretest analysis, although

$$\overline{X_{FD}} < \overline{X_{FI}}$$

In both groups, this difference could have come by chance and it is, therefore, not sufficient for any conclusion. Analysis of the posttest mean scores of the FD and the FI learners in the EXP group showed that there was no significant difference in their mean achievements. In the CTRL group, however, analysis showed that the difference in the posttest mean achievement was significant. In effect, this means that cognitive style was not the only factor determining the difference. There could be some external factor arising from the way the subjects in both groups were treated. However, it just suffices to conclude that field-dependency has little but not a significant effect on the geometry achievement. The effect becomes significant when factor emanating the manner of treatment play in this finding agrees with those of Pecklaj, 2003; Boodao and Rowley, 1991; Ranil and Reid, 2006; Tat and Fook, 2005; Mancy and Reid, 20004; Astunniyah, *et al*, 2017; and Suderman *et al*.,2016. However, it also differs slightly from their findings in the respect that it identifies another factor as being more salient. According to this finding, if treatment is handled properly, the difference between the FD and the FI will not be so significant. However, poor treatment will bring about a significant difference.

The second purpose of the study was to determine the effect of maximum guidance on the mean geometry achievement of FD and FI students both within and between the two groups (i.e. EXP and CTRL). Within group analysis of posttest mean scores showed that they was no significant difference in the EXP group, both the FD and FI students did almost equivalently well. Between group analysis of the posttest mean scores showed that the difference between the FD students in the EXP group and the FD students in the CTRL group was significant. In fact, the FD students in the EXP clearly outdid the FD counterparts in the CTRL group.

i.e. $\overline{X_{FD,\ EXP}} < \overline{X_{FD,\ CTRL}}$

The FI students in the EXP group did not achieve significantly better than the FI counterparts in the CTRL group.

i.e. $\overline{X_{FI,\ EXP}} < \overline{X_{FI,\ CTRL}}$

Initial differences in pretest scores did not prove significant in both cases. Therefore, this reveals the fact that maximum guidance during classroom interaction enables both field-dependent and field-independent to make better achievement in geometry. This findings also agrees with those of Saiad *et al,* (2014); Blazer and Hill (2016); Crossfield and Bourne (2017); Cheryan *et al.* (2014), and NCEE (2013). Thus by this finding, it can be said that maximum guidance helps the FD learners to measure up with FI learners in terms of achievement. Thus the assertion that field-independent students achieve significantly better in test of mathematics achievement than their field-dependent counterparts could be as a result of the manner of treatment given to them during classroom interactions.

The third purpose of the study was to determine the effect of minimum guidance on the mean achievement of the FD and the FI learners both within and between the groups (i.e. EXP and CTRL). Within group analysis of the posttest mean achievements of FD and FI students in the CTRL group showed that there was a significant difference. In fact, the FI students achieved significantly better than the FD students in the CTRL group.

i.e. $\overline{X_{FI,\ CTRL}} < \overline{X_{FI,\ CTRL}}$

Between group analysis of the FD students in the EXP and the CTRL groups showed already that there was a significant difference. However, the case with the FI students in the EXP and CTRL group did not show any significant difference. This showed that the FI students in the EXP group did not outdo the FI students in the CTRL group. This findings therefore revealed that minimum guidance did not favour the FD students as much as it favour the FI students. This again agreed with finding of Mayer (2004) who proposed that minimum guidance does not help learners discover problem-solving rules, conservation strategies or programming concepts. However, Mayer failed to recognize that the group of learners affected by his proposition is the field-dependent learners. The findings also agree with Herdiana *et al*. (2017) who also suggested that minimum guidance is only helpful to a tiny fraction of learners. However, the fraction affected in this study cannot be regarded as tiny.

Conclusion

Following the findings of this study, the conclusions of the study are hereby stated as follows:

1. Field-dependent and field-independent cognitive styles affect students' achievement in geometry which constitutes a large percentage of the mathematics curriculum for secondary school students. However, field-dependency itself is in turn affected by the treatment method adopted by mathematics teachers during classroom interactions. Therefore, the principal determinant of students achievement in geometry (mathematics) is the method of teaching adopted by the teacher rather than just field-dependency.
2. When both field-dependent and field-independent learners are given maximum guidance following the guided discovery teaching method, which adopts a numbers of positive strategies to help learners make the most of their learning, they will both achieve better results in geometry (mathematics) and any difference which may arise in the achievement could be insignificant and does not necessarily indicate that one subgroup is better than the other.
3. When both field-dependent and field-independent learners are given minimum guidance, which emphasis the discovery learning method that allows learners to try to make sense of what they learn by themselves, the field-dependent learners will be most disadvantaged at this point and as such the field-independent learners will achieve significantly better result in any test of geometry in mathematics. This indicates that any learning situation in mathematics classes whereby teachers fail to provide adequate guidance to the learners will not favour the field-dependent learners and this will result in poor achievement.

Recommendations

The following recommendations are provided:

1. **Educators:** In has indeed, become imperative upon Nigerian educators, if necessary steps must be taken to revamp our education system, to translate the findings off research on field-dependent and field-independent cognitive styles into educational practice. Learners in various categories of the education system should be tested for field-dependence and field-independence and grouped appropriately. Necessary steps should be taken to modify the educational programmes of schools for the maximum benefit of learners in these two categories. Learning programmes that promote maximum guidance should be encouraged and adopted to help the field-dependent learners. Steps should be taken to train teachers of mathematics on how to execute guided discovery teaching methods to boost the achievement of learners in mathematics.
2. **Curriculum planners:** They should capitalize on the gain of these findings by adjusting the mathematics curriculum to suit the cognitive style preferences of the learners. The curriculum should be modified in such a way as to cater to the differences in characteristics between the field-dependent and the field-independent learners, thus offering them opportunity to learn in conditions that best fit them.
3. **Students:** They should be subjected to the field-dependency test the results communicated to them through the school counselors. The students should be advised to seek for mathematics teachers who can provide detailed guidance in their teaching to enable the field-dependent learners uncover hidden facts. The students should also seek for additional teaching time through private extramural. They should also go for textbooks containing details and guided steps towards problem-solving to enable them to understand concepts and figures through the use of colors and illustration.
4. **Teachers:** They should be informed of their students' degrees of field-dependence and field-independence. This will enable them to device lesson plans to cater to the needs of the students. They will be able to match then students' cognitive styles with learning situations that most profit them. Sensitizations and training programme should be organized for them to equip them with necessary skills in the implementation of curricula for mathematics with adjustments bordering on field-dependency.

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