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Effectiveness of Differentiated Instruction Method on Geometrical Concepts of Ninth Grade Students

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Abstract
Investigating the effectiveness of tailored instruction on the development of geometry concepts at the ninth-grade level was the aim of this study. This study used a quasi-experimental pretest-posttest nonequivalent control group design to examine how differentiated instruction affected the development of geometric concepts, the dependent variable. The primary objective of the study was to determine how individualized instruction affected the formation of geometry concepts in the ninth grade. The hypothesis was that there is no statistically significant difference between intervention group and the group which was taught through traditional method on concept development of geometry at the ninth-grade level. Students in the ninth grade in boys' high and higher secondary schools in the Sargodha area made up the study's population. Using a multistage sampling method, the sample was selected. Initially, all male schools in Sargodha city that offered ninth-grade science studies were included. Purposive sampling was then used to choose one school. Two complete ninth-grade sections (the scientific group) made up the study's sample. One section was designated as the experimental group and another as the control group using random assignment. Researchers created a pretest as a research tool. Before administering pretest, its reliability and validity was obtained through expert opinion, pilot testing and Kuder Richardson reliability coefficient. Before intervention pretest was conducted to both groups. Using differentiated instruction, the lesson plans for the intervention were developed. The experimental group received differentiated instruction for six weeks, while the control group received traditional instruction. A posttest was administered after the intervention, and the results from both groups were compiled. The paired sample t-test and the independent sample t-test were used to analyze the data. The statistics showed that the performance of the experimental and control groups was significantly different. It was concluded a significant difference between both groups. So, differentiated instruction experience a large effect on students' performance of treatment group. Based on conclusion, it was recommended that the teacher should improve teaching strategies and use differentiated instruction to impart instruction. It was recommended for Punjab Textbook Board to inculcate differentiated instruction-based activities in Mathematics textbook at secondary level. It was also recommended to Punjab education curriculum training assessment authority

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(PECTAA) to impart training to the teachers for better understanding of differentiated instruction.

Key words: Differentiated instruction, concept development, geometry, lesson plans, experimental group, control group.

Introduction

Mathematics is an important subject in elementary and secondary education, equipping students with the basic knowledge and practical skills they need to make sense of the world and manage everyday life (Ariyanti & Santoso, 2020). Students' ability to think logically and solve problems is greatly aided by mathematics. One of the most crucial factors that teachers need to take into consideration in order for students to learn math effectively is their level of self-assurance in their own mathematical abilities. (Azucena et al., 2022; Kunhertanti & Santosa, 2018).

Geometry, a basic branch of mathematics, focuses on the study of points, lines, planes, shapes, and solids. According to Hollebrands and Stohl Lee (2011), geometry has long been a core part of the secondary school math curriculum. Over time, the tools used to explore geometry have advanced—from traditional instruments like compasses and rulers to modern technologies such as computers, graphing calculators, and tablets.

In daily life geometry has many practical applications, including measuring the circumference, area, and volume of objects (Tanton, 2016). Beyond its practical uses, studying geometry also helps students develop spatial awareness, strengthen their logical reasoning, and build problem-solving skills that are useful in real-world situations (Bot, 2017).

According to reports from the West African Examinations Council (WAEC) for the May/June 2015 session, despite its significance, geometry is still one of the mathematical subjects that students find challenging. Many pupils demonstrated a poor grasp of geometry, according to the 2015 WAEC Chief Examiner's assessment. For instance, several candidates had trouble recalling the fundamental formulas for calculating the sum of the interior and exterior angles when asked to solve a problem requiring the ratio of the inner angle to the exterior angle of a regular polygon (provided as 5:2). This suggests that students lack basic geometric concepts comprehension.

Differentiated Instruction (DI) has become a key topic of interest and discussion in the field of education. It is a teaching approach aimed at addressing the individual learning needs of every student in the classroom (Tomlinson, 2017). DI is grounded in the understanding that students differ in their learning styles, abilities, interests, and levels of readiness—and that these differences should be acknowledged and supported in the learning process (Lavrijsen et al., 2021).

The goal of differentiated instruction is to ensure that all students have an equal opportunity to learn and succeed by tailoring teaching to their individual strengths and needs (Paskevicius, 2021). At its core, this approach rejects the idea of "one-size-fits-all" teaching and instead embraces the belief that every learner is unique and deserves personalized support. The effect of differentiated instruction (DI) on student learning has been the subject of several studies in recent years. Ziernwald et al., as well as Peters et al. (2022). The results, however, have been conflicting; while some studies emphasize its advantages,

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others present erratic or even contradicting data. Due to this, some researchers have questioned DI's overall effectiveness as a teaching method. The extent to which DI actually improves student learning outcomes is still up for question, despite the fact that it is receiving increasing attention in the field of education.

The WAEC report also noted that many students struggled to correctly apply circle theorems, further highlighting challenges in understanding geometry. Research by Ubi, Odiong, and Igiri (2018) identified several factors contributing to students' difficulties with geometry. These include ineffective teaching methods, lack of instructional materials, limited time for the subject, gender-related factors, the complexity of the content, and common misconceptions. Telima (2012) also observed that many students leave geometry lessons without grasping key concepts or learning the basic terminology, which hinders their overall understanding.

The goal of this study was to find out how different teaching methods affected well ninth-grade students understood geometric concepts.

Objectives of the Study

- The objectives of the study were:
- To find out the effect of differentiated instruction on students' performance of geometry at ninth grade level.
- To compare the performance of the experimental group, which received differentiated geometry instruction at the ninth grade level, and the control group, which received traditional geometry instruction.

Hypotheses of the Study

- $H_0 1$ There is no statistically significant effect of differentiated instruction on students' performance of geometry at ninth grade level.
- $H_0 2$. In terms of geometry performance at the ninth grade level, there is no statistically significant difference between the experimental group and the control group that received traditional and differentiated teaching, respectively.

Literature Review

What is instruction?

In 15th century initially the word instruction was used (vocabulary .com ,n.d.).It was the time, when word instruction was highlighted and elaborated as "action or method of teaching"(Harper,2020).Instruction explained as "training, lesson, and facts applied to explain a subject "and systematic way to transform learning or developing expertise in recent times(Wright,2011). So it was declared that to increase student learning and communication through teaching in an improving environment is called instruction (Arands&Castle,2002).In continuation of thinking instruction is limited in scope than teaching and it is one aspect of it.

Instructions in Mathematics

Mathematics teacher must apply instruction in a variety of ways, Mathematics abilities largely employed in mathematics modules having link with others key areas and subjects. To decide the method of transforming concept for students understanding, teacher should aware of the subject matter in order to simplify it to the students. Making points, taking short notes and asking questions are the

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knowledge seeking strategies which may lead students to success. It is an easy method to retain information, reproduction and to interact with the students.
An aggregate of methods and strategies has significant impact than a single method (Karp & Voltz 2000, swanson,2001). Tomlinson's differentiation model, which is supported by constructivism (Subban, 2006), readiness, what we know about human learning (Tomlinson, 2017), and active instruction (Department of Education and Training Victoria, 2019), replicates the idea that teachers should improve learning and instruction by assisting students through their zone of proximal development. Subban (2006), Tomlinson (2017), and the Department of Education and Training Victoria, 2019, respectively.

Geometry: A Necessary Component of Mathematics
Geometric concepts are essential for mathematical reasoning. In addition to assisting us in defining and visualizing the objects in our environment, they have an effect on our comprehension of non-observable entities, such as representations of those objects. Additionally, the ability to think geometrically is a powerful indicator of future mathematical performance (Dindyal, 2015). The Philippines' emphasis on geometry in secondary education is reflected in the K–12 curriculum, which begins in grade 3 and progresses in a spiral fashion. Montebon, 2014; Orbe, Espinosa, and Datukan, 2018; Adarlo and Jackson, 2017).

Geometry and Students' Performance
Several students leave the classroom without understanding essential terminology who are unable to grab basic concepts in Geometry (Telima, 2012). Isa, Mammam, Badar, and Bala (2020) argued that students' academic success is strongly connected to teaching methods. Subsequently, the poor performance of students in mathematics has been moderately attached to the lecture method normally employed by some teachers. To report this issue, Obafemi (2022) advocated the use of differentiated instruction as a method of teaching to enhance students' academic performance.

Differentiated Instruction
In 2000, Dr. Carol Ann Tomlinson described differentiated teaching as an approach that suggests all students diverse pathways to engage with learning material effectively. During third year of teaching Tomlinson observed significant differences in her students' knowledge level which turned her to adopt differentiated method of teaching told by her in an interview (2013) with Echo Wu. Some students struggled with basic reading skills, while others were already aware with the material she was teaching. This provoked her to collaborate with colleagues to research how to adapt standard teaching practices to ensure that all students could benefit from the curriculum (Wu, 2013).

Dr. Carol Ann Tomlinson aims various differentiation strategies that teachers can apply in their classrooms. One of the key strategies is working with small groups. Tomlinson claims that in a typical classroom setting, it can be thought-provoking for teachers to determine whether each student has fully understood the material. However, in small groups, teachers can quickly measure student comprehension by asking individual questions related to the topic at hand (Wu, 2013).

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Other important strategies include learning stations and learning contracts. Learning stations allow students to rotate through different areas to focus on specific skills they need help with. Each station provides clear directions on how to complete the tasks and information on how to seek additional assistance, enabling students to work on their individual skill gaps while maximizing classroom time. Learning contracts, on the other hand, enable teachers to create tailored tasks for students based on their readiness or interests, offering greater flexibility and promoting more effective learning (Wu, 2013).

Review of Empirical Studies

The effectiveness of diversified instruction in secondary math classes in the United States was examined by Ariss (2017). The experimental classrooms featured a wide variety of teaching methods. The five instruments used to collect data were interviews, lesson plans, assessment instruments, student comments, and observations. Thirty tenth graders were the subjects of a convergent parallel quantitative and qualitative study. The participants were divided into two groups at random, each consisting of 15 students: the experimental group and the control group. Students were pleased with diverse instruction, particularly tiered exercises and flexible grouping that allowed the teacher to do more than just lecture, according to the findings.

Studies Demonstrating Improved Outcomes in Geometry Understanding

Canque, Trinnidal, and Cortes (2021) looked into how differentiated instruction with tiered activities affected geometry instruction. Their results showed that both the experimental and control groups' performance significantly improved from the pretest to the posttest.

Garba and Muhammad (2015) investigated how well students' geometric achievement was affected by differentiated instruction in senior secondary schools in Kebbi State. Their study included 69,573 students and used a pretest-posttest control group methodology. A sample size of 96 participants was obtained by selecting schools and student levels using a process called random sampling. The Central Limit Theorem states that at least thirty people must participate in experimental research. The sample included 41 female students and 55 male students. A geometric achievement test (GAT) was used to collect the data, and the split-half method produced a Spearman-Brown equal length reliability coefficient of 0.76. The data analysis, which included the mean, standard deviation, and a t-test with a 5% significance level, revealed that differentiated instruction outperformed lectures in assisting students in achieving success in geometry.

Methodology

To measure the effect of independent variable i.e. differentiated instruction on dependent variables i.e. concept development of geometry, the pretest-posttest nonequivalent control group design of quasi-experimental research was applied.

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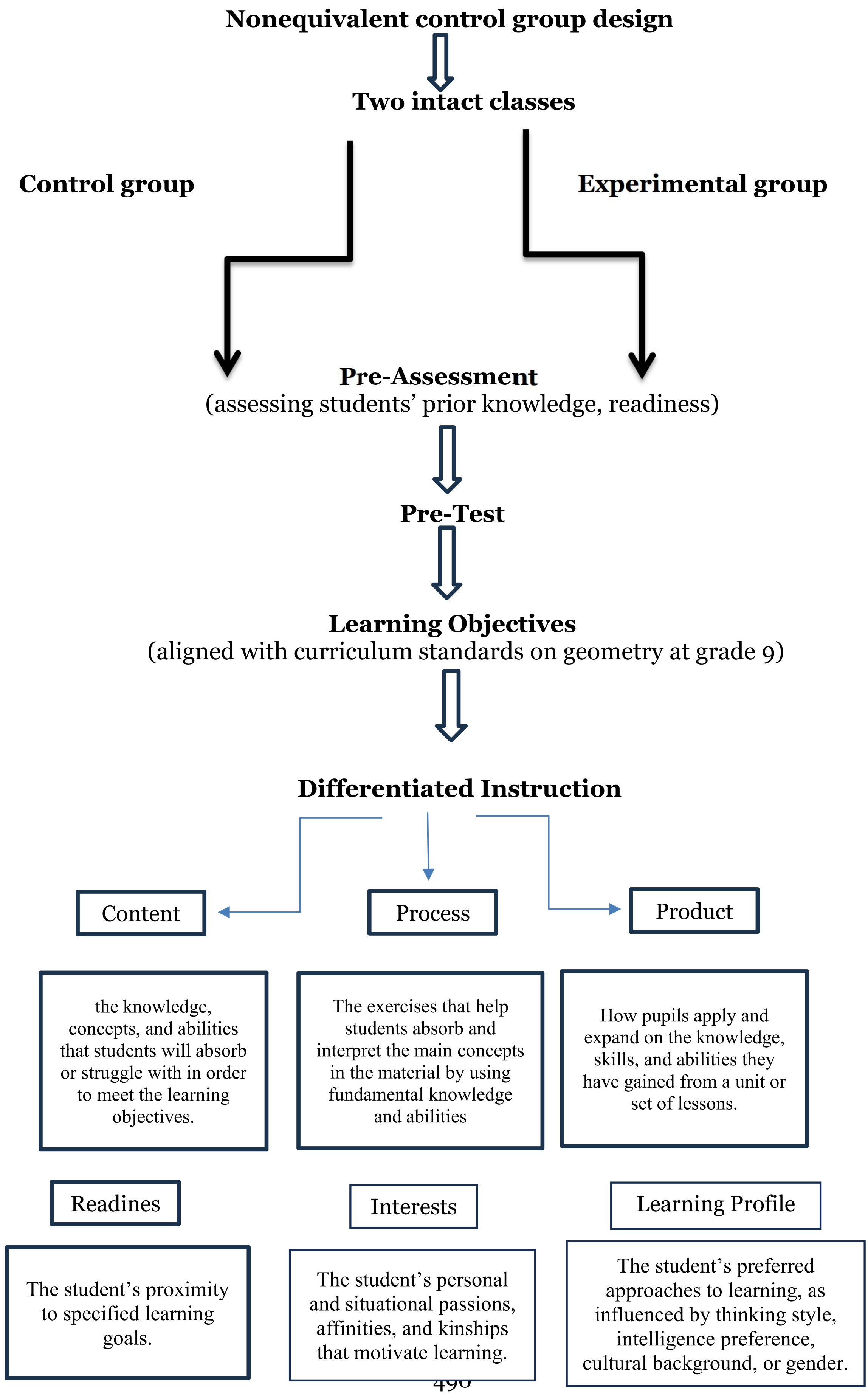

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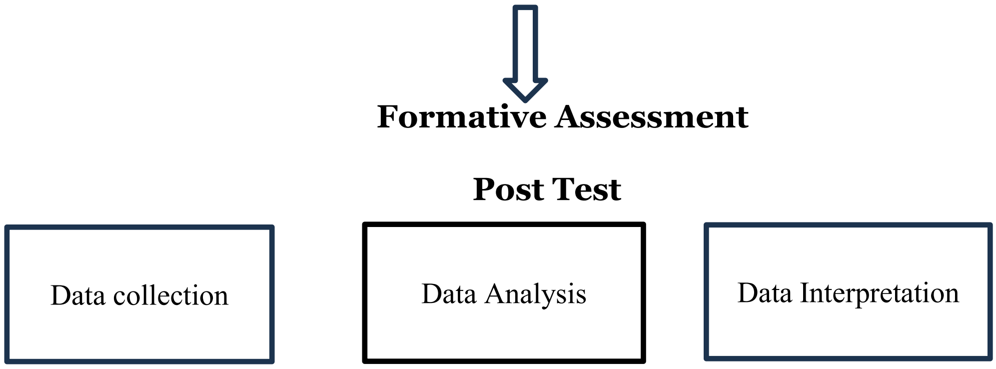

Figure 1: Quasi-experimental pretest, posttest

Population

Population of the study was based on grade 9 students of high and higher secondary schools of district Sargodha.

Sampling Technique

To reach the desired sample it was difficult to use only one sampling technique. So Multistage sampling was used to divide the process into stages to select representative sample of study. These stages were as follows.

1. At first stage, all such schools having availability of science students and having two or more sections of 9^{th} grade were selected based on purposive sampling from Sargodha city with the permission of head teachers.
2. At second stage, from these selected schools, one school (i.e. Government lab model higher secondary school for boys attached with Quaid-e-Azam Academy for educational development Sargodha) was selected based on simple random sampling to fulfil the purpose of experiment.
3. At third stage, two intact sections (science group) of ninth grade were taken as sample of the study.

Research Instrument

1. Lesson plans were developed on content of coordinate geometry and descriptive geometry.
2. A pre-assessment test was developed and administered to check the readiness level of students before intervention, which was the prerequisite of differentiated instruction.
3. A pretest and posttest were developed to measure the effect of differentiated instruction on concept development of geometry at grade 9.
4. Pretest in geometry was developed from content selected for experiment including the first three levels (knowledge, comprehension and application) of Bloom's taxonomy's cognitive domain.
5. Researcher developed the instrument himself because most of the tests available were not compatible with the content of geometry textbook published by Punjab curriculum and textbook board.
6. Three levels of bloom taxonomy were considered because main objectives focus on concept development.

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Validation of Research Instrument

Pretest for geometry at ninth grade level students was got validated as follows:

i. Pretest items were developed and finalized with the consultation of five (5) experts. The experts were highly qualified in Mathematics, one was master's in mathematics, two were PhD in Mathematics and two were expert in mathematics, PhD in education. The content and face validity along with vocabulary and geometry' terms were analyzed. After experts' recommendations the terminology of geometry and some common mistakes were corrected according to their recommendations in English and Urdu language likewise.
ii. After the incorporation of experts' recommendations and instructions the tool was modified and pilot study was conducted for item analysis, discrimination analysis, difficulty analysis and reliability analysis.

Pilot Study of the Test

For pilot testing, a geometry pretest was given to the sample of 100 students. Test reliability, item difficulty, and discrimination index were calculated based on the data gathered from the pilot study.

Item distribution topic wise and allocated percentage of items were based on bloom's taxonomy (Knowledge, Comprehension, and Application) levels. Coordinate plane comprises three knowledge-based items allocated 3 marks and carries 11.5% of the bloom's knowledge level and the content as well. Distance formula and mid-point each carries 2marks along 1item for comprehension and 1 for application level and 8% of the bloom's comprehension, application level and content coverage. Graph of linear equation represents 3 items (Knowledge, Comprehension, Application) carries 3 marks,11.5% content coverage. Interpretation of graph comprises 6 marks with 23% content coverage and 2 items for each level. Right bisector includes 5 marks,3 for knowledge,1 for comprehension,1 for application with 19% of total items, while angle bisector encompasses 5 marks,2 for knowledge,2 for comprehension,1 for application with 19% of total items. These topics were taken from textbook of mathematics for ninth grade level published by Punjab textbook board (2022). The test items were included three levels of cognitive domain (knowledge, comprehension, application). The division of 26 items according to these levels is as follows:

- 11 items (42%) were developed on knowledge level.
- 8 items (31%) were developed on comprehension level.
- 7 items (27%) were developed on application level.

Items were selected based on item difficulty and item discrimination index.

Procedure of the experiment

1. Lessons were developed from 19 student learning outcomes according to differentiated instruction model of Tomlison.
2. Two intact classes of ninth grade level were selected and randomly declared one as experimental group and other as control group.
3. Before to start experiment, pretest was administered to both experimental and control group based on multiple choice items.
4. The pretest was administered and marked, while results were kept confidential to avoid any complex and distress for students.

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5. The treatment was carried out through differentiated instruction for six weeks started from January to mid of February 2025, while instruction was carried out in conventional method to control group, each session was 40-minute duration for both groups.
6. The qualification of researcher and the teacher of control group was same to reduce the effect of teacher.
7. Same content and learning outcomes were delivered to both groups with only difference of
8. Teaching method.
9. Both groups were given posttest which was same as pretest after conducting experiment through differentiation.

Finding and Results

The experimental and control groups' posttest results on concept development are presented in the table below.

$H_0 2$. The idea development of ninth-grade geometry students does not show a statistically significant difference between the experimental and control groups' differentiated teaching.

Table 1: *Independent sample T-test for Posttest of control and experimental group*

Post test result	N	Mean	SD	t-value	df	p-value	Effect size
Control group	25	5.88	2.72	14.5	48	0.000	4.12
Experimental group	25	15.4	1.82				

Since Table 1 demonstrates a significant difference in the geometry posttest results of students in the experimental and control groups, the null hypothesis was rejected with t = 14.5, df = 48, and p = 0.000 <0.05. Hence, the greater mean ($M = 15.4$ & $SD = 1.82$) with greater effect size Cohen's d = 4.12 > 0.8 shows that students of experimental groups taught through differentiated instruction achieved better results as compared to students of control groups ($M = 5.88$& $SD = 2.72$) taught through traditional method.

The results within the experimental and control groups are compared after a comparison of the results from the pre-test and post-test between the experimental and control groups. The outcomes are measured in the following tables:

Table 2: *Paired sample T-test for Pretest and Posttest of control group*

Control group	N	Mean	SD	t-value	Df	p-value
Pretest	25	5.72	2.33	-.241	48	0.812
Posttest	25	5.88	2.72			

Table 2 shows the results of pretest and posttest of control group such that t (48) = -0.241, df = 48 and p = 0.812> 0.05 which is larger than the alpha value so the null hypothesis was accepted. Therefore, there was no discernible difference between the control group's pupils' pretest and posttest scores on the

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development of geometric concepts.

The experimental group's pretest and posttest results are measured after the control group's results are measured. The following table displays the results:

Table 3: ***Paired sample T-test for Pretest and Posttest of Experimental group.***

Experimental group	N	Mean	SD	t-value	Df	p-value	Effect size
Pretest	25	5.80	2.12	19.07	48	0.000	4.87
Posttest	25	15.40	1.82				

Table 3 shows that the null hypothesis was rejected because the pre- and post-test scores of the geometry students in the experimental groups differed significantly, as shown by t = 19.07, df = 48, and p = 0.000 < 0.05. Hence, the greater mean ($M = 15.4$ & $SD = 1.82$) with greater effect size Cohen's d = 4.87 > 0.8 shows that students perform better in posttest as compared to pretest after treatment through differentiated instruction.

Conclusions

In case of pretest of both groups there was no significant difference in results which paved the way of intervention for concept development of geometry.

1. 1. It was determined that there was a substantial difference between the control and experimental groups based on posttest results. So, differentiated instruction experience a large effect on students' performance of treatment group. Students of different ability levels were interested and worked at their own level when the teacher in the experimental group changed the content, the procedure, and the product using differentiated methods. The differentiated instruction instructor made the material simpler to comprehend for the students who performed below average. However, the above-average students did not find the material to be as simple, and the teacher in the experimental group adjusted it similarly for them, so they were not discouraged.
2. According to findings of pretest and posttest within the control group was no significant difference because no treatment was given to them by applying teaching strategies to make the concepts easier to students. In this case the Mean score of pretest and posttest revealed very small difference which was not significant.
3. In pretest and posttest experimental group findings concluded significant effect on students' performance. In this case p-value is less than .05 resulted positive effects of differentiated strategies to enhance the interest, learning profile and learning environment of the class. To impart learning environment through flexible grouping, tiered assignments according to the varied level of students made the concepts easy to understand.

Discussion

The study main objective was to compare the results of differentiated instruction on students' concept development between control and experimental group. The standard deviations of the experimental and control groups decreased from 2.72 to 1.82 on the posttest, indicating an increase in variety. Conversely, the control group's standard deviation increased somewhat from 2.33 on the pre-test to 2.72.

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In this case, the p value was 0.000 and the t value was 14.5, both of which are below the significance level of 0.5. As a result, the experimental and control groups' conceptual growth differs significantly. As a result, the null hypothesis—which claimed that there was no statistically significant difference between the two groups' differentiated instruction—was rejected, and the claim that the control and experimental groups' differentiated instruction on the concept development of geometry at the ninth-grade level differed significantly was accepted. Table 3 displays a significant difference between the groups. Both the t-value of 19.07 and the p-value of 0.000 were below the significance level of.05. This indicated that the experimental group was significantly impacted by differentiated instruction. The effect size was also calculated to determine the difference between the independent variables for each group. Cohen's d formula was used to show the effects of each technique on each group. According to Sullivan and Fienn (2012), a Cohen's d value of 0.2 indicates a moderate impact, a d value of 0.5 indicates a medium effect, and a d value of 0.8 or higher indicates a large effect. The significant size of the effect suggested that the intervention strategy had a significant effect. According to Tables 1 and 3, the treatment with differentiated instruction had a significant effect size of 4.12 and 4.87, respectively. Differentiated instruction developed the concepts of the students because in lesson plans were based on scenario based real life example and adopted content, process and product which are aligned with students' readiness, interest and learning profile. Flexible grouping, pair work and graphic organizer strategies made it possible to improve the performance in geometry. The findings also support the findings of Muthomi & Mbugha (2014) and Obafemi (2022), who found that pupils who receive differentiated education outperform those who receive instruction using a traditional technique. This suggests that one effective method for teaching mathematical ideas is differentiated education.

Recommendations

1. Curriculum experts and textbook developer should encourage to inculcate differentiated instruction as a strategy being an innovative method in curriculum and textbooks.
2. More research should be conducted involving more variables like gender, public &private schools' comparison on differentiated instruction in mathematics and other subjects.
3. It is recommended that assessment organizations, such as the Punjab Examination Commission and the Board of Intermediate and Secondary Education, match the assessment framework to idea development based on Bloom's Taxono

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