

**The effect that Visual Learning Styles have on the
performance of the first-year Mathematics students when
learning to solve Quadratic Equations**

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Abstract

This study investigated the effect of visual learning styles on the performance of first-year Mathematics students at the University of Namibia when learning to solve quadratic equations. The study was motivated by the persistent poor performance in Basic Mathematics over the years. Basic Mathematics is a first-year course offered by the Faculty of Agriculture, Engineering and Natural Sciences at the University of Namibia (UNAM).

The objective of the study was to determine whether there are statistically significant differences in students' performance when using visual learning styles in solving quadratic equations. The theoretical framework of the study was based on Fleming's VARK model, developed in 1987. A single-group pre-test–post-test design (ABA) with an intervention was employed to collect quantitative data, which were analysed using t-test.

The study population comprised 469 first-year Mathematics students, from which a sample of 119 students was drawn. Participants were selected using a combination of convenience and random sampling techniques and were taught at different times using varied instructional strategies.

The main findings of the study revealed statistically significant differences between pre-test and post-test scores, indicating an improvement in students' performance when visual learning styles were applied. Based on these findings, the study recommends that lecturers adopt teaching approaches aligned with visual learning styles to enhance student performance.

Keywords: *Basic Mathematics, VARK Model, visual learning style*

Background of the Study

Basic Mathematics is a first-year course offered by the Faculty of Agriculture, Engineering and Natural Sciences at the University of Namibia (UNAM). First-year Mathematics is a compulsory course also in the other faculties at the University and most students find it difficult. Due to the poor performance of students in first-year mathematics, the University has introduced two modes of studying first-year Mathematics. The two modes of instruction were the fast stream (one semester) and the slow stream (a year-long course).

The intention was to provide underperforming students with sufficient time to master the required content over an extended period, thereby improving their overall performance in first-year Mathematics (Miranda, Gideon, & Mugochi, 2013).

Felder-Silverman (1988), Dunn and Dunn (1978), and Witkin (1981) identified several factors that account for differences in learning, one of which is the learning styles used by individuals.

Also, Sreenidhi and Tay (2017) and Gokalp (2013) have identified learning styles as a factor that might influence students' performance in Mathematics. "The general definition of learning styles is characteristic cognitive, affective, and psychosocial behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Mac Keracher, 2004, as cited in Syofyan & Siwi, 2018, p.642).

The study used Fleming's VARK model to compare the performance of the visual learning styles during the pre-test and post-test. The model was ideal for this study as it clearly explains that we use our senses to learn (Jaleel & Thomas, 2019). The model classifies individuals as visual,

auditory, reading/writing, and kinaesthetic based on the sensory modalities they use for learning.

Moreover, the study compared the performances of visual learning styles during the pre-test and post-test when solving quadratic equations in first-year mathematics. Visual learning style refers to students who prefer using figures, pictures, and symbolic tools such as graphs, flowcharts, and hierarchies to learn (Othman & Amiruddin, 2010).

Amiruddin, Martisa, and Febrianti (2020, p. 5) argued that “visual learning style is a better choice for improving students’ academic achievement compared to aural and kinaesthetic learning styles.” Therefore, there is a need to compare students’ performance when using visual learning styles in the pre-test and post-test. Such a comparison will help identify groups that require additional learning support and, subsequently, improve the overall performance of first-year Mathematics students.

The first-year Mathematics course syllabus comprises various topics, including algebraic expressions, sets, equations and inequalities, trigonometry, and sequences. The study was conducted at a selected campus of the university located in the northern part of Namibia, which exclusively offers teacher training programmes. At this campus, the programme prepares students to teach across different phases upon successful completion of their studies: lower primary (Grade 0–3), upper primary (Grade 4–7), and secondary (Grade 8–12).

Research Questions and the Hypothesis of the Study

How does the visual learning style affect the performance of the first-year Mathematics students when solving quadratic equations?

Hypothesis

*H*₀: There is no statistically significant difference in the first-year students’ performance using visual learning style during the pre-test and post-test when learning to solve the quadratic equations

*H*₁: There is statistically a significant difference in the first-year students’ performance using visual learning style during the pre-test and post-test when learning to solve the quadratic equations.

Literature review

Definition of Learning Styles

Learning style is generally defined as the characteristic cognitive, affective, and psychosocial behaviours that act as relatively stable indicators of how learners perceive, engage with, and respond to their learning environment (McKerracher, as cited in Syofyan & Siwi, 2018). Various scholars have conceptualized learning style primarily as an expression of individual differences, which may be reflected not only in learners' approaches to learning but also in their broader lifestyles and personality types (Zhang & Sternberg, 2005, as cited in Abidin, Rezaee, Abdullah, & Singh, 2011). These differences may be reflected in individuals' lifestyles and even in their personality types (Zhang & Sternberg, 2005, as cited in Abidin, Rezaee, Abdullah, & Singh, 2011). Learning styles refer to the preferred ways in which individuals approach learning. Unlike intelligence, learning styles are relatively fixed, making it difficult to alter one's habitual mode of learning; for instance, individuals may naturally favour either visual or aural approaches (Sreenidhi & Tay, 2017). Xu (2011) similarly observed that learning styles are stable, as they are closely linked to an individual's learning habits, personality, and cognitive patterns.

In addition to the fore going it should be noted that although most of the studies found that students perform better when teaching instructions are aligned to their learning styles, several other studies (Rohrer & Pashler, 2012 and Rogowsky, Calhoun, & Tallal, 2020) have questioned the methodologies used to support this hypothesis as most did not use experimental designs. "In summary, there is currently no empirical evidence to support the practice of tailoring instruction to students' purportedly different learning styles". (Rohrer, & Pashler, 2012, p.636). This highlights a gap in the literature, indicating the need for a study that can provide empirical evidence to determine whether aligning teaching methods with students' learning styles leads to improved academic performance.

Different Types of Learning Styles/Models

Several models of learning styles have been proposed, including those by Kolb (1984), Felder-Silverman (1988), Dunn and Dunn (1978), Witkin's Field Dependence/Field Independence model (1981), and Fleming's VARK model (1987), among others (Cassidy, 2004). These models suggest that teachers have a range of instructional approaches to choose

from, allowing them to select methods that best suit the nature of the content being delivered.

This study employed Fleming's VARK model. One of the most common and widely used categorizations of the various types of learning styles is Fleming's VARK model (sometimes VAK - an acronym for the Visual (V), Auditory (A), and the Kinaesthetic (K) sensory modalities) which provides the learners with a profile of their learning styles, based on the sensory modalities that are involved in taking in information (Sreenidhi & Tay, 2017). However, there is no evidence whether the VARK model can lead to improved performance in Mathematics; it is therefore for this reason that this study seeks to address this knowledge gap.

Fleming's VARK Model

VARK model was modified from VAK model, to VARK learning style model by Fleming in 2006. The VARK model was later refined by classifying learning styles into four distinct modes, each corresponding to a specific sensory preference: visual, aural, reading/writing, and kinaesthetic. The acronym VARK is derived from the initial letters of these modes (Othman & Amiruddin, 2010). This model is particularly relevant to the present study, as it focuses on the performance of first-year Mathematics students who predominantly employ visual learning styles when solving quadratic equations.

Sreenidhi and Tay (2017) emphasized that one of the most common and widely-used categorizations of the various types of learning styles is Fleming's VARK model (sometimes VAK – an acronym for the Visual (V), Auditory (A), and the Kinaesthetic (K) sensory modalities) which provides the learners with a profile of their learning styles, based on the sensory modalities that are involved in taking in information. Fleming's VARK learning style questionnaire classifies students according to their preferred learning modes, such as visual, aural, reading/writing, or kinaesthetic. This study applies a portion of the VARK model to investigate how visual learning styles affect the academic performance of first-year mathematics students.

Visual Learning Style

Students predisposed to this style are likely to be provided with demonstration and can learn through description. Moreover, visual

learners prefer to use figures, pictures, and symbolic tools such as graphs, flowcharts, hierarchies, models, and arrows to represent information

The Effect of Visual Learning Style on Students' Academic Performance

Most students favour to learn in particular ways with each style of learning contributing to the success in retaining what they have learnt. These facts reveal that each learning style has its own strengths and weaknesses (Abidin et al., 2011). In carrying out this study, the researchers hold the viewpoint that understanding students' learning styles (weaknesses and strengths) is very important when planning lessons, as this will help in improving student's performances.

Khan et al. (2019) found that visual and kinaesthetic learning preference scores had non-significant correlation with academic achievement of college students, while auditory learning preference scores and total learning preference scores had significant correlation with academic achievement of college students. The study investigated the effect of visual learning styles have on students' performances; therefore, these findings appear to give a better insight for the analysis of this study.

Different Views about Learning Styles

There are different views about the learning styles. Yusoff (as cited by Othman and Amiruddin, 2010) states that an individual may have more than one learning style or else known as bimodal. It is an advantage to anyone who has more than one type of learning style, because those individuals possess more flexible views and acceptance of their learning environment. It is important to note that, although the VARK learning style does not involve intelligence or inherent skill, it closely relates to how individuals acquire and process information or new knowledge.

Additionally, the VARK model can be viewed as a personalized method that learners use to gain knowledge, develop skills, and shape attitudes (Othman & Amiruddin, 2010). Several factors also influence learning styles, including personal experiences, personality traits (e.g., extroversion versus introversion), and intelligence levels (Sreenidhi & Tay, 2017). Demographic factors such as age, gender, and subject combinations further affect an individual's learning style (Bosman & Schulze, 2018). In this study, first-year mathematics students form a

diverse group with varying academic backgrounds, ages, and genders. Many students combine mathematics with other subjects, such as biology or physical sciences, which adds further variation to their learning approaches.

Critics have questioned the concept of learning styles, noting the difficulty of measuring learning, particularly in determining the exact moment learning occurs. Simply knowing one's learning style does not automatically improve learning; instead, learners benefit when they reflect on how and when they learn and take deliberate action as part of a metacognitive process (Akka, Mendagudli, Awanti, & Nigudgi, 2017). Since this study focuses on improving first-year mathematics performance, understanding students' learning styles is essential for developing recommendations for both students and lecturers

Implications of Learning Styles for Teaching and Learning

This study also examines the implications of learning styles for teaching and learning processes. Miller (as cited in Khan, Arif, & Yousuf, 2019) argued that educators have a responsibility to understand and address the diversity of students' learning preferences. Research based on Fleming's VARK model has highlighted the need to develop teaching and learning approaches that align with students' preferred learning modes (Wright & Stokes, 2015). Mismatches between an instructor's teaching style and a student's learning approach can create learning obstacles in the classroom and underscore the importance of employing a variety of instructional techniques (Cook, 2005, as cited in Mirza & Khurshid, 2020). Felder (1995) further noted that students learn more effectively when information is presented through multiple approaches rather than a single method. Based on this literature, teachers have a duty to vary instructional methods to optimize student learning outcomes.

Xu (2011) also emphasized that teachers should use diverse teaching strategies in classrooms to accommodate students' varied learning styles. This requires planning different types of classroom activities. However, limited instructional time makes it challenging for teachers to organise lessons and tasks according to the different learning styles present, which may affect students' learning outcomes (Othman & Amiruddin, 2010).

Riding and Cheema (1991) suggested that learning styles can either enhance or impede academic performance. However, research on the relationship between instructional design and learning styles remains limited (Abidin, Rezaee, Abdullah, & Singh, 2011). Students who

understand their preferred learning styles can organise their learning more effectively (Sreenidhi & Tay, 2017). At the study institution, students' learning styles are not typically assessed, and many students may be unaware of their own preferences. This represents a significant research gap that this study seeks to address.

Becker et al. (as cited in Othman & Amiruddin, 2010) highlighted that, while traditional teaching methods such as lectures, textbooks, and discussions remain important, teachers should diversify their instructional approaches to accommodate the varied learning styles of students. Currently, teaching at this university relies heavily on lectures, which may not cater to all learning styles and could contribute to lower performance among first-year mathematics students.

Learning Styles in Namibian Context

The researchers identified one study on learning styles conducted in Namibia. This study, a thesis by Silas (2013), found that mathematics teachers reported both positive and negative effects of learning styles on the teaching and learning of mathematics. Silas conducted the study with Grade 11 learners, using Kolb's experiential learning model and the Kolb learning style questionnaire. The findings of Silas' study are relevant to the present research in several ways; for example, both studies focus on algebra and examine the influence of learning styles. Although Silas employed Kolb's learning style model, there are notable similarities with the VARK model used in this study, as both models classify individuals according to their preferred learning styles.

Overall Performance in Mathematics

A study by Miranda, Gideon & Mugochi (2013) also found that the intervention (two-streams) has a positive impact on the performance of the students on the first-year mathematics but was not confident enough to make such a conclusion because they commented; "It is still very early to confidently conclude that the introduction of the two-mode curriculum in the first-year mathematics at the University of Namibia has had an impact on students' academic performance" (p.673). Undoubtedly, the performance of students in the first-year mathematics did not improve even after the introduction of the two streams, although in some aspects, the difference in performance could be seen.

Students Understanding of Solving Quadratic Equations

Algebra forms the foundation for advanced mathematics at the university level, particularly for secondary students (Hu, Son, & Hodge, 2021). Saglam and Alacaci (2012) noted that quadratic equations play a central role in the curriculum, as they bridge elementary algebra and calculus. At this university, quadratic equations are equally critical, as the module in which they are taught serves as a prerequisite for pre-calculus in the second semester and is essential for tasks such as sketching graphs.

Lopez, Robles, and Martínez-Planell (2016) reported that multiple studies have shown that many secondary and undergraduate students do not fully understand how to solve quadratic equations or the rules underlying their solutions. A similar trend was observed among first-year students at this university, where performance in other topics such as trigonometry, set theory, and sequences was consistently higher than in tests covering quadratic equations.

A quadratic equation is a polynomial of degree two, with at most two possible values for the variable. It is generally expressed as $ax^2 + bx + c = 0$, where, *a*, *b* and *c* are constants, with non-zero values (Hu, Son, & Hodge, 2021). Students typically solve quadratic equations using factorization, completing the square, or the quadratic formula. At the university, first-year mathematics students employ all three methods (Faculty of Science Prospectus, 2021). To enhance understanding and visualization especially for students with visual learning preferences algebraic tiles and graphical representations are used when teaching quadratic equations.

Visual Learning and Solving Quadratic Equations

Research indicates that visual learners tend to perform better in subjects that allow them to see and visualize relationships and patterns (Othman & Amiruddin, 2010). In the context of solving quadratic equations, visual learners benefit from graphical representations, such as plotting parabolas and identifying the roots of equations on a graph. Studies have further shown that incorporating visual aids and visual problem-solving techniques enhances students' comprehension and retention of methods for solving quadratic equations.

Research methodology

The study employed a quantitative research approach and adopted a true experimental research design utilising a single-subject design. The population comprised 469 registered first-year students enrolled in the first-year Mathematics (Basic Mathematics) during the 2022 academic year at the selected campus. A sample of 119 students was selected using a random sampling procedure to ensure that all participants had an equal chance of being selected from the population, as recommended by Gay et al. (2011), who argue that random sampling enhances representativeness.

Data Collection Procedures

Ethical clearance was obtained from UNAM's Decentralised Ethics Committee. The researcher scheduled appointments with the students, after which a pre-test was administered face-to-face. This was followed by the intervention (treatment), and subsequently, a post-test was conducted, also in a face-to-face format.

Given that the study utilised a single-subject design, participants were placed in one group, and both the pre-test and post-test were administered with the intervention occurring between the two tests. The researcher marked both tests, and the scores were recorded accordingly. Both descriptive and inferential statistical analyses were employed to compare student performance in the pre-test and post-test.

Additionally, a focus group discussion was conducted face-to-face by a colleague to minimise potential bias, as the researcher was the lecturer and supervisor of the participants. Students also completed an online questionnaire.

Results and Their Discussions

To address the research question and test the hypothesis, the results are presented and discussed in this section.

Comparing the performance of students during the pre-test and post-test for the visual learning styles

In addition to addressing the research question, this section tests the following null hypothesis:

There is no statistically significant difference in first-year students'

performance when using visual learning strategies between the pre-test and post-test while learning to solve quadratic equations.

The analysis begins by examining measures of central tendency (mean, median, and mode) and measures of dispersion (standard deviation, variance, and range) to compare performance before and after the intervention.

Descriptive Statistics

This section presents the descriptive statistics for the study which is summarised in Table 1 below.

Table 1: Summary of Descriptive Statistics (n = 45)

| Measures (n = 45) | Pre-test | Post-test |
|-------------------|----------|-----------|
| Mean | 63.889 | 78.333 |
| Median | 60 | 80 |
| Mode | 50 | 100 |
| Range | 95 | 90 |
| Sum | 2875 | 3525 |

The results indicate that the mean score increased from 63.889 in the pre-test to 78.333 in the post-test, representing a difference of 14.441 (23%). This suggests a substantial improvement in student performance. Similarly, the median increased from 60% to 80%, reflecting a 20% improvement. The mode shifted from 50% (7 students; 16%) in the pre-test to 100% (11 students; 24%) in the post-test.

Furthermore, both the standard deviation and variance decreased in the post-test, indicating that the scores were less dispersed compared to the pre-test. This is supported by the range, which decreased slightly from 95% in the pre-test to 90% in the post-test. The total cumulative score increased by 650 marks (23%), further confirming the effectiveness of the intervention.

In addition to the fore going descriptive statistics, Table 2 below presents the five-point data summary of the pre-test and post-test.

Table 2: Five-point data summary of the pre-test and post-test

| (n = 45) | Pre-test Marks (%) | Post-test Marks (%) |
|-----------------|---------------------------|----------------------------|
| Lowest | 5 | 10 |
| Q1 | 50 | 65 |
| Q2 | 60 | 80 |
| Q3 | 80 | 95 |
| Max | 100 | 100 |

The pre-test scores ranged from 5% to 100%, indicating substantial variability (range = 95%). In the post-test, scores ranged from 10% to 100% (range = 90%), showing a slight improvement.

The median increased from 60% to 80%, reinforcing the conclusion that overall performance improved after the intervention.

Notably, the third quartile (Q3) of the pre-test (80%) is equal to the median (Q2) of the post-test. This indicates that while only 25% of students scored 80% or above in the pre-test, 50% achieved this level in the post-test, demonstrating a clear improvement.

The foregoing data were also used to present the box and whisker plots as shown below in Figure 1.

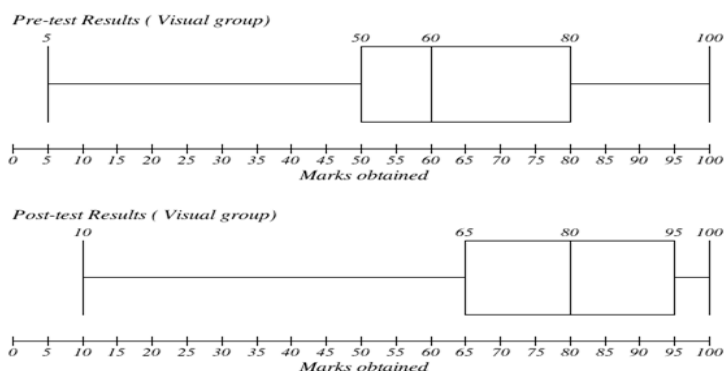


Figure 1: Box-and-whisker plots

The box-and-whisker plots (Figure 1) illustrate differences in performance between the pre-test and post-test. The post-test distribution appears more symmetrical, while the pre-test distribution is positively skewed.

The interquartile range for both tests is 30%; however, the lower quartile increased from 50% to 65%, indicating improved performance among lower-achieving students. This suggests that the intervention had a positive effect across the group.

It was also necessary to compare each student's pre and post-test score as shown in Figure 2 below.

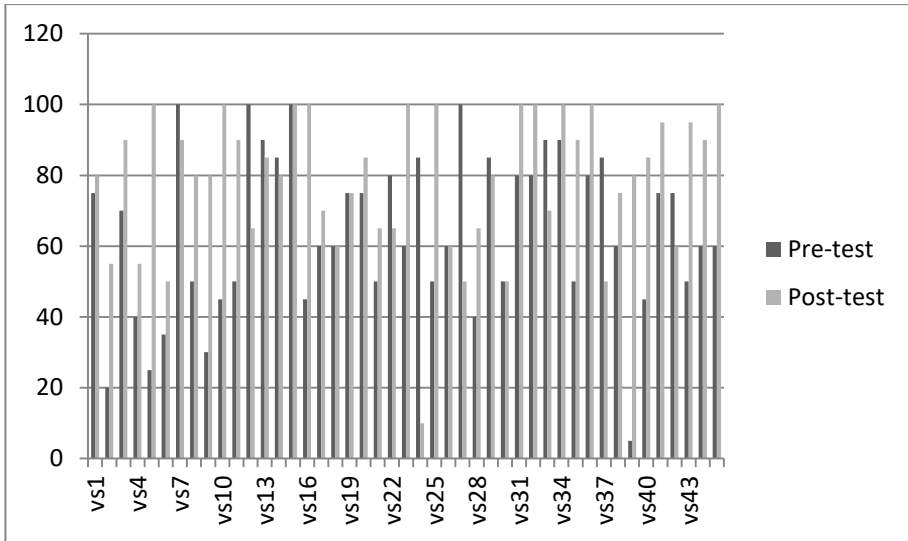


Figure 2: A comparison of the pre- and post-test scores (n = 45)

Figure 2 shows that 11 students (22%) experienced a decline in performance after the intervention, indicating that the treatment had a negative effect for a small proportion of participants. The largest decrease was 75% (from 85% to 10%), while the smallest decrease was 5%.

Five students (10%) showed no change in performance, suggesting that the intervention had no effect on these individuals.

However, the majority of students (29; 68%) demonstrated improved performance. Notably, 11 students achieved 100% in the post-test, compared to only one student in the pre-test

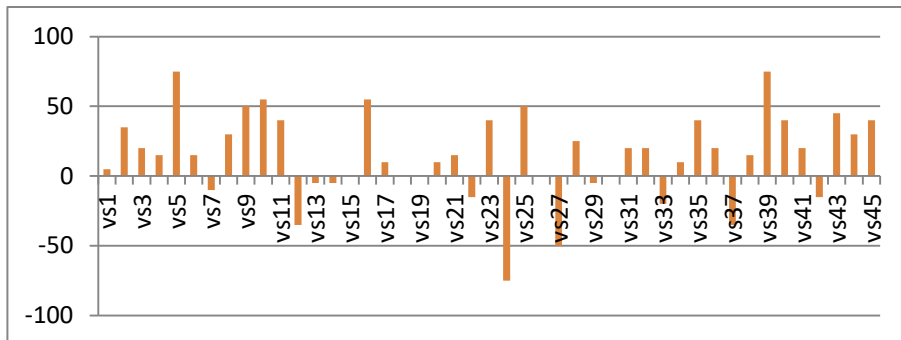


Figure 3: Individual performance difference of students between their pre-test and post-test scores (n = 45)

Figure 3 shows that the lowest increase in marks was 5%. Only one student's marks has increased by 5% from 75% to 80%. Furthermore, only four students scored 100% on the pre-test while 11 students scored 100% on the post-test (see also Table 1).

Inferential Statistics

A paired sample *t*-test was conducted to compare pre-test and post-test scores; the results are presented in Table 3 below.

Table 3: The t-test results

| | Post-test | Pre-test |
|------------------------------|-----------|----------|
| Mean | 78.333 | 63.889 |
| Pooled Variance | 395.455 | |
| Observations | 45 | 45 |
| Hypothesized Mean Difference | 0 | |
| df | 44 | |
| t-Stat | 3.158 | |
| P(T<=t) one-tail | 0.001 | |
| t Critical one-tail | 1.680 | |
| P(T<=t) two-tail | 0.002 | |
| t Critical two-tail | 2.015 | |

Since $p < 0.005$, the null hypothesis, which states that the mean scores are equal, is rejected in favour of the alternative hypothesis that the mean scores differ. The results presented in Table 3 indicate a statistically significant difference in test scores, $t(44) = 3.16$, $p < 0.002$, at $\alpha = 0.05$.

The *t*-test results are consistent with the descriptive findings reported in Tables 1 and 2, as well as Figures 1, 2, and 3, all of which indicate that

the intervention had an effect on students' performance in the visual learning group. Specifically, students' performance improved following the treatment, suggesting that learners in this group benefit from instruction that incorporates visual aids, regardless of random assignment

The results corroborate the findings of Karlimah and Risfian (2016, 2017), who reported that learners perform better when instructional methods are aligned with their learning styles. Furthermore, the study indicates that the visual learning style yields improved performance among students

Cohen's d was calculated to determine the magnitude of the effect:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(s_1^2 + s_2^2)/2}}$$

The calculated value ($d = 0.67$) indicates a moderate effect size, suggesting that the intervention had a meaningful impact on performance.

Conclusions

The study aimed to investigate the academic performance of first-year students using visual learning strategies when solving quadratic equations at the University of Namibia, guided by Fleming's VARK model (1987).

The results revealed a statistically significant improvement in post-test performance at $\alpha = 0.05$, confirming the effectiveness of the intervention. The findings also indicate that aligning teaching methods with visual learning styles enhances students' academic performance.

Recommendations

Based on the findings, the study recommends the following:

- Lecturers should incorporate appropriate visual teaching strategies to enhance student performance.
- Students should utilise visual learning aids when studying first-year Mathematics

Possible Areas for Further Studies

The study suggests that future research should:

- Extend the investigation to other subject areas and institutions.
- Explore additional learning styles, as this study focused only on visual learning in Mathematics.

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