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Towards Improved Geometry Instruction: Learners' Experiences with Technology-Enhanced and Conventional Van Hiele Phased Instruction

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ABSTRACT

This study investigated learners' experiences and understanding of transformation geometry using two instructional strategies: Conventional Van Hiele Phased Instruction (CVHPI) and Technology-Enhanced Van Hiele Phased Instruction (TVHPI), incorporating GeoGebra as a digital tool. Through semi-structured interviews, qualitative data were collected from 48 Senior Three secondary school learners who participated. Thematic analysis revealed that TVHPI, supported by GeoGebra, enhanced visual learning and dynamic interaction with geometric concepts, though learners faced technical challenges and limited practice time. CVHPI, while providing structured and step-by-step instruction, particularly benefited lower achievers but was less effective in addressing complex misunderstandings. As a result of this study, a Geometry Pedagogical Improvement Cycle (GeoPIC) framework was developed to improve the teaching and learning of geometry through a continuous and systematic process. The GeoPIC framework emphasizes adopting instructional strategies, tailoring them to individual needs, aligning with learner expectations, and incorporating feedback through a cyclical reflection and adjustment process. This study highlights the potential of combining technology-enhanced tools with conventional instruction and presents GeoPIC as a model for refining pedagogical approaches in geometry education.

Keywords: Transformation Geometry, learners' experiences, Van Hiele levels, Technology, GeoGebra, and GeoPIC.

Introduction

It has long been acknowledged that geometry instruction is an essential part of mathematics since it provides fundamental knowledge for various fields, such as computer science, engineering, and architecture (Çavuş & Deniz, 2022; Smith & Jones, 2020; Sunzuma & Maharaj, 2019). Transformation geometry is one of the numerous subfields of geometry that is particularly essential because of its real-world applications and ability to help develop spatial reasoning and problem-solving skills. However, despite its importance, transformation geometry can be complex for learners to understand using traditional teaching techniques due to the subject's abstract nature (Bradley, 2005; Brijlall & Abakah, 2022; Ndungo et al., 2024).

In this regard, several studies have brought attention to the ongoing challenges that learners encounter when trying to grasp geometric concepts; these challenges frequently result in worry, anxiety, and eventually low academic achievement among learners. Consistently low achievement levels in geometry have been reported in countries including Indonesia, South Africa, Nigeria, Pakistan, Sri Lanka, and Italy (Ayebale et al., 2020; Ubi et al., 2018; Silmi Juman et al., 2022). These results highlight a widespread issue and critical need for educational interventions to raise geometry competency among learners (Ayebale et al., 2020).

Ngirishi and Bansilal (2019) have observed that many learners cannot comprehend basic geometry concepts, analyze geometric properties, and recognize shapes. As a result, children frequently function at lower geometric thinking levels, which hinders their capacity to understand more complex ideas and progress to advanced levels of geometric thinking. Additionally, educators frequently use conventional teaching techniques, which might not be able to meet all of their students' learning demands (Kivkovich & Chis, 2016). This antiquated method may cause learners to disengage and impede their comprehension of fundamental geometric concepts.

Erroneous beliefs and unfavorable perceptions regarding geometry intensify these difficulties. Many learners find it challenging to apply formulas and theorems, evaluate arguments, and comprehend geometric vocabulary, making geometry seem challenging and uninteresting (Kivkovich & Chis, 2016). Furthermore, learners frequently struggle with mathematical tools like compasses and protractors, leading to missed questions and further obstacles with problem-solving (Luneta, 2015). To tackle these problems, Moru et al. (2021) suggested that a concentrated effort must be made to improve conceptual understanding and implement effective instructional strategies. Enhancing geometry instruction can help learners better understand the topic and improve their general mathematical aptitude.

Educational theorists have investigated various teaching strategies to improve learners' geometric thinking and overcome these issues. In particular, the Van Hiele Phased Instruction model is well known for its precise approach to teaching geometry. This model guides learners from fundamental shape recognition to more complex reasoning about geometric features and transformations by emphasizing the progression through five levels of geometric understanding. Even though Conventional Van Hiele Phased Instruction (CVHPI) has proven to be successful in assisting learners in understanding, there is increasing interest in incorporating technology into this framework to improve learning results even more (Machisi & Feza, 2021; Zalman, 1982).

Moreover, Technology-Enhanced Van Hiele Phased Instruction (TVHPI) using programs like GeoGebra allows learners to interact actively and visually with geometric concepts. With GeoGebra's interactive visualization features, learners can modify geometric shapes, see transformations in real time, and more concretely investigate the links between geometric objects. This method has the potential to close the knowledge gap between learners and abstract geometric concepts, increasing the accessibility and interest level of transformation geometry (Adelabu et al., 2022; Iannone & Miller, 2019; Mthethwa et al., 2020; Vágová & Kmetová, 2019; Ndungo, 2024).

Technology integration in education has expanded significantly, aligning with curriculum trends emphasizing active learning through interactive tools like tablets, smartphones, and specialized software (Diaz-Nunja et al., 2018). Learners with information and communication technology tools support their integration into mathematics education, providing more significant learning opportunities and fostering engagement and discovery-based learning (Mosese & Ogbonnaya, 2021). Technology integration in teaching geometry is further emphasized by Uganda's new lower secondary curriculum and other recent related studies (National Curriculum Development Center, 2019; Ndungo et al., 2025).

Research highlights the benefits of GeoGebra in enhancing geometric reasoning and engagement. For example, Abdullah and Zakaria (2013) found that learners using dynamic software like GeoGebra made significant progress in geometric understanding compared to traditional methods. Other studies indicate that GeoGebra supports visualization, spatial reasoning, and problem-solving, making mathematics more engaging and enjoyable (Mollakuqe et al., 2020; Celen, 2020). It has also proven effective in teaching diverse topics, including circles, linear functions, 3D geometry, and trigonometry, helping learners explore mathematical concepts more thoroughly (Mudaly & Fletcher, 2019; Uwurukundo et al., 2021; Yildiz & Baltaci, 2016). Over the past few decades, there have been substantial changes in how geometry is taught. Increasingly, the emphasis is on developing conceptual understanding rather than rote memorization of processes (Clements & Sarama, 2021). Formal deduction has supported traditional geometry teaching methods, yet it is less successful for younger learners or those without prior knowledge of geometric ideas (Van de Walle et al., 2016). Early in life, developing spatial thinking and visualization abilities is crucial to comprehend more complex geometric ideas like transformation geometry (Sinclair & Bruce, 2015).

However, despite these advancements, the literature reveals ongoing challenges in effectively teaching transformation geometry, particularly in contexts where learners struggle with abstract concepts like rotations, reflections, and dilations (Sunzuma & Maharaj, 2019). Silmi Juman et al. (2022) noted that applying geometric theorems and resolving complex problems are two significant obstacles that learners encounter when learning geometry. Their research demonstrated how activity-based learning strategies might help learners overcome these challenges and increase their comprehension and engagement.

Similarly, the current study furthers this foundation by examining the contribution of teaching strategies such as CVHPI and TVHPI to improving learners' understanding of transformation geometry. This study investigates the additional effects of incorporating technology, notably GeoGebra, into the learning process, whereas Silmi Juman et al. (2022) concentrated on active learning methodologies. This study closes a significant knowledge gap by investigating the use of technology-enhanced learning in the Ugandan environment. It offers insights into how such tools can address enduring difficulties in geometry teaching.

Theoretical Underpinning

This study is grounded in Cognitive Constructivism (Piaget), emphasizing active learning through progression in the Van Hiele Model of Geometric Thought. It integrates Social Constructivism (Vygotsky), highlighting the role of social interaction and teacher scaffolding within the Zone of Proximal Development (Allen, 2022). This study also incorporates Technology-Enhanced Learning, using GeoGebra to support interactive and visual learning in transformation geometry. The Van Hiele theory provides a framework for understanding the progression of geometric thinking through five levels: Visualization, Analysis, Abstraction, Deduction, and Rigor (Crowley, 1987; Vojkuvkova, 2012). The theory further proposes a five-phased instructional approach to geometry that aligns with these cognitive stages, ensuring that teaching methods are suited to the learners' current level of understanding (Abdullah & Zakaria, 2013; Moru et al., 2021).

Instructional Strategies

This paper explores how the two instructional strategies, CVHPI and TVHPI, influence learners' experiences and understanding of transformation geometry. The following sections detail these instructional strategies.

The Van Hiele's Phased Instructional Strategy (CVHPI)

The Van Hiele Phased Instruction (Conventional Van Hiele Phase Instruction in this study) is a structured framework for teaching geometry to support learners' understanding and progression through the Van Hiele levels. This model guides educators in designing lessons that help learners advance through increasingly complex levels of understanding with teacher support (Bonyah & Larbi, 2021; Machisi & Feza, 2021; Moru et al., 2021; Pujawan et al., 2020; Tahani, 2016). Figure 1 shows the five phases of instruction according to the Van Hiele Phased Instruction model.

Figure 1

Showing the Five Van Hiele Phases of Instruction

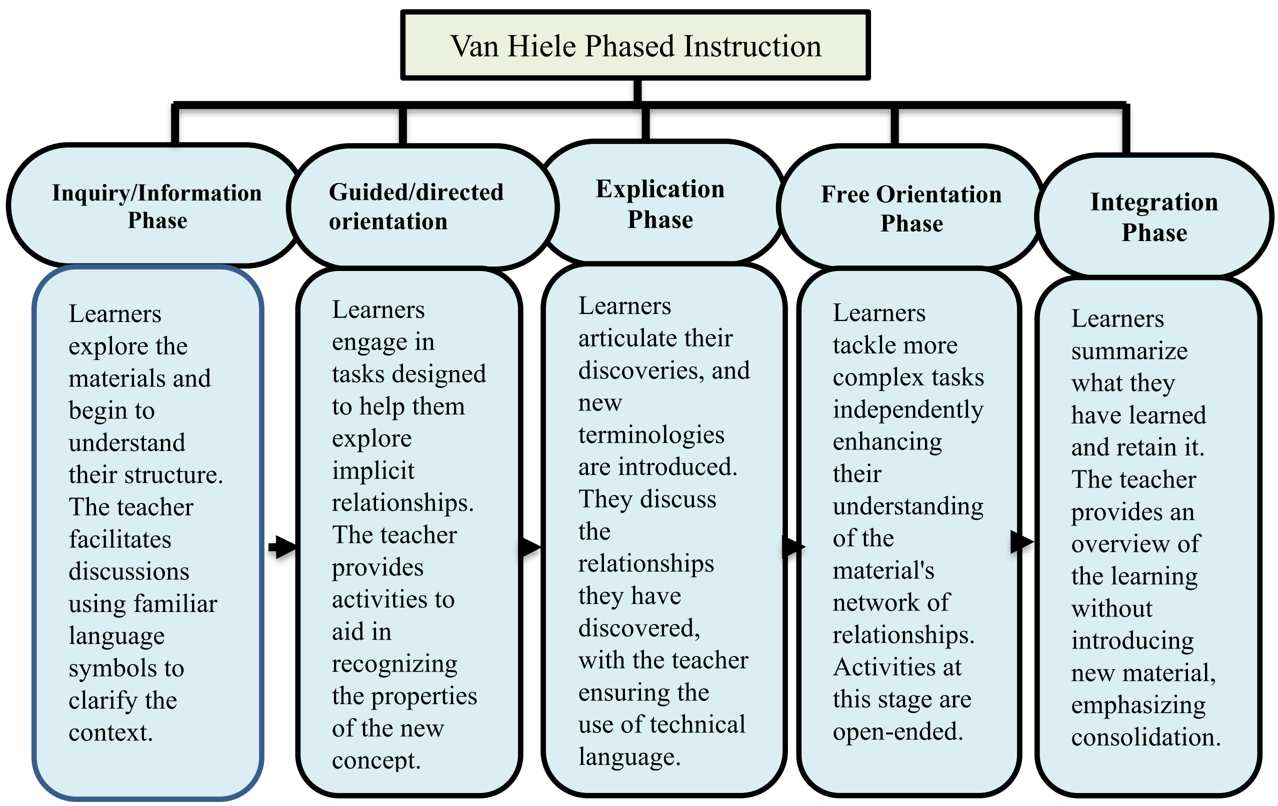


Figure 1 illustrates the five phases of the CVHPI: (1) Inquiry, where learners explore concepts; (2) Directed Orientation, focusing on exploration activities; (3) Explication, where learners articulate understanding; (4) Free Orientation, applying knowledge to complex problems; and (5) Integration, consolidating concepts for deeper comprehension.

Technology-enhanced Van Hiele Phased Instructional Strategy (TVHPI)

Building on the principles of CVHPI, TVHPI integrates technology into the learning process. The current study used GeoGebra to enhance visualization and interactivity in geometry lessons. TVHPI aims to engage learners more effectively by offering dynamic representations of geometric transformations, fostering an interactive and collaborative learning environment. By incorporating GeoGebra, TVHPI addresses diverse learning styles and aims to improve learner motivation and engagement in geometry education (Uwurukundo et al., 2021). Figure 2 shows a GeoGebra environment.

Figure 2

GeoGebra Environment: Showing How to Find the Angle of Rotation Given Two Rotated Shapes.

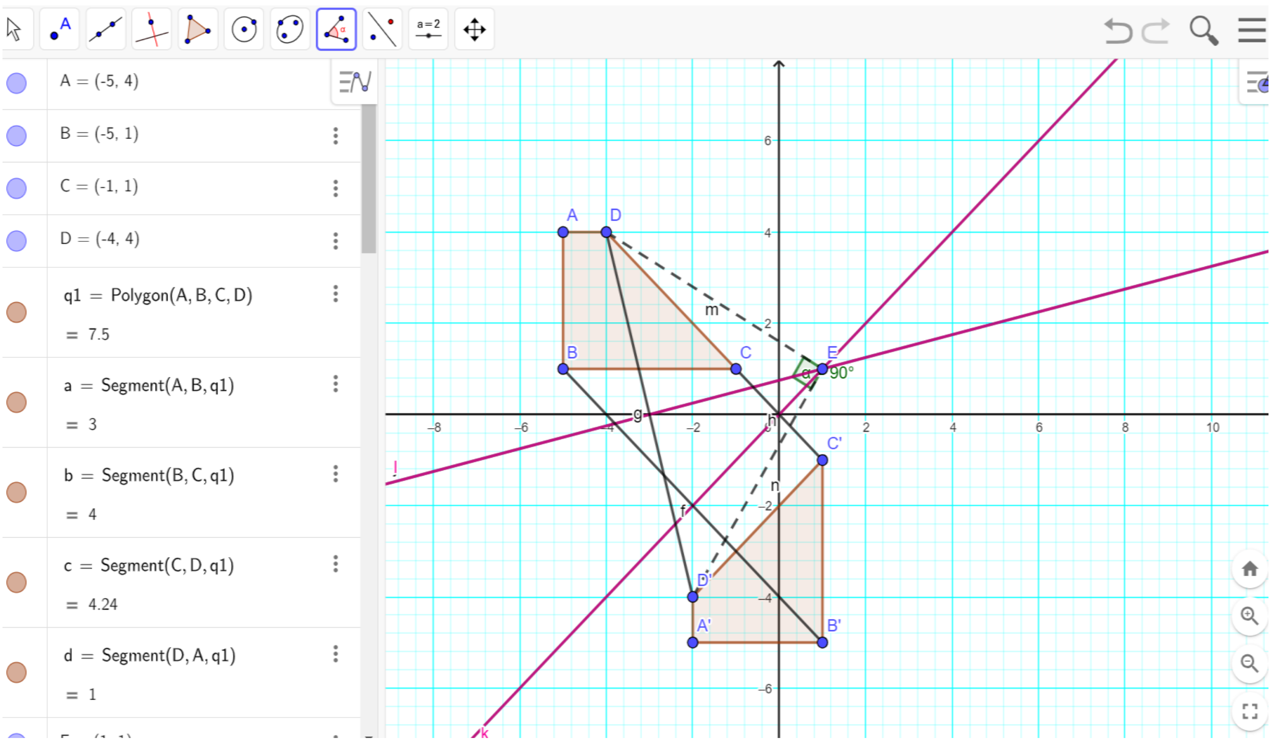


Figure 2 depicts the GeoGebra interface with a GeoGebra-generated diagram for finding the rotation angle given two rotated shapes. The figure demonstrates line segments, perpendicular bisectors, and an angle of rotation of 90^0. GeoGebra tools allow users to dynamically adjust rotation angles, reflection lines, enlargement scale factors, and observe real-time changes, enhancing their understanding of transformations. The interface has two interactive environments, the analytical and the graphical, that support the analytical and graphical analysis of geometric shapes and transformations. This enables learners to explore geometric transformations with precision and clarity.

The key differences in how teachers can implement CVHPI and TVHPI lie in the mode of preparation, instruction, learner activities, visualization, feedback, and assessment in transformation geometry. For example, CVHPI relies on physical tools such as graph paper, mirrors, and rulers, requiring manual demonstrations and learner activities focused on drawing, plotting points, and performing calculations that lead to transformation. In contrast, TVHPI utilizes GeoGebra, enabling dynamic, real-time visualization of transformations. While CVHPI provides static visualization through blackboard drawings and physical manipulatives, TVHPI encourages interactive exploration. Feedback in CVHPI is given manually, with teachers reviewing learners' work, whereas TVHPI delivers instant feedback via GeoGebra's outputs. CVHPI operates at a teacher-controlled pace with repetitive exercises, while TVHPI supports self-paced learning through interactive tasks. Exploration in CVHPI is guided by limited opportunities for independent discovery, unlike TVHPI, which promotes learner experimentation and exploration of concepts. In CVHPI, the teacher's role is directive, leading each step, while in TVHPI, the teacher acts as a facilitator. In CVHPI, assessment focuses on procedural accuracy in written and drawn work, whereas TVHPI evaluates learners' ability to perform and interpret transformations digitally.

Problem Statement

The Van Hiele Phased Instruction model has been extensively explored and proven to be a practical approach to teaching geometry, particularly in fostering learners' geometric thinking (Machisi & Feza, 2021; Narh-kert & Sabtiwu, 2022; Office of the Prime Minister, 2020; Savec, 2019). However, learner engagement and conceptual understanding challenges persist despite its success, especially with complex transformations. In the Ugandan context, limited research has been conducted on the implementation and effectiveness of CVHPI, leaving a gap in understanding how this model functions within local educational environments. With the current trend in education emphasizing technology integration to enhance learning outcomes, there is a growing need to investigate how CVHPI can be improved by incorporating technology-enhanced tools like GeoGebra. While GeoGebra has shown potential to support visualization and engagement, its impact when combined with CVHPI has not been thoroughly examined in Uganda. This study seeks to address this gap by exploring how TVHPI can further support learners' learning, improve understanding, and help overcome the difficulties learners face in geometry.

Research Questions

The main research question is: How do learners' experiences and understanding of geometry differ between TVHPI and CVHPI?

The research questions are: (1) what are the challenges and support needs associated with TVHPI and CVHPI? Furthermore, (2) what is the learners’ perception of the effectiveness of CVHPI and TVHPI in enhancing their understanding of transformation geometry?

Methodology

Research Design

The research followed a quasi-experimental design, but this paper's primary focus is on the qualitative component of the main study. Semi-structured interviews were used to gather detailed data on learners' experiences with CVHPI and TVHPI. The qualitative design allowed an in-depth exploration of how each instructional strategy impacted the learning of transformation geometry. The study provided a robust framework for examining the differences in learners' experiences and engagement with transformation concepts by comparing two distinct instructional approaches within the same learning environment.

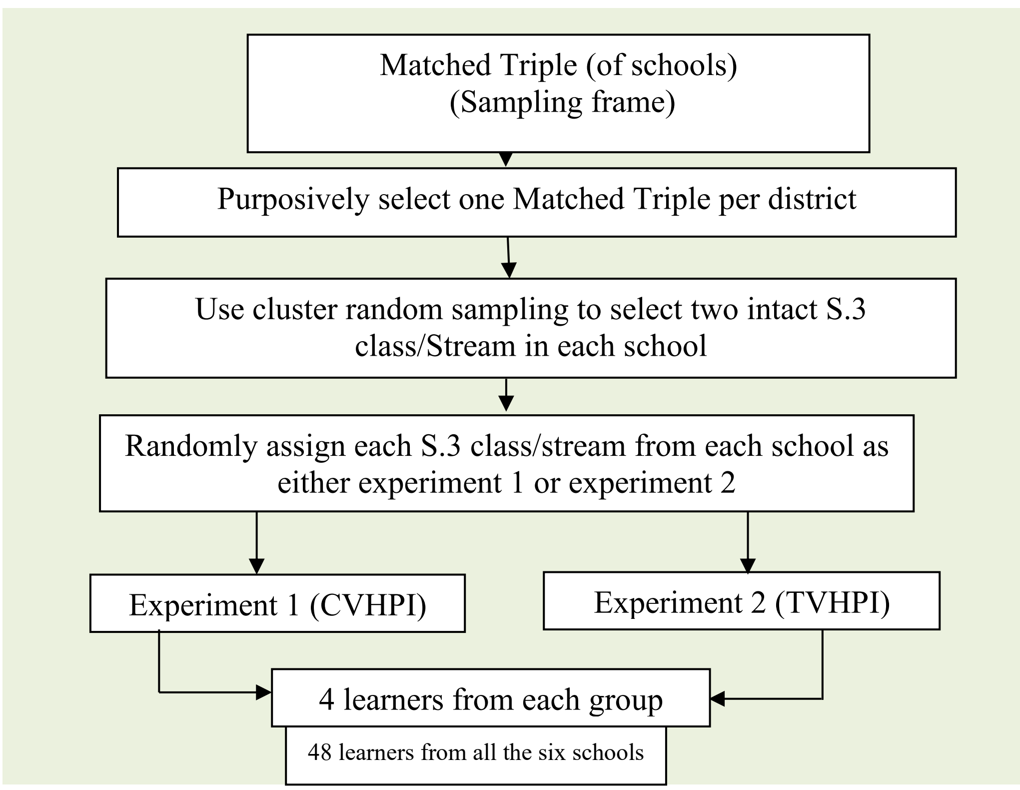
Study Population, Sampling, and Sample

The population for this qualitative component comprised Senior Three (S.3) learners attending secondary schools in both a rural and an urban district within Midwestern Uganda. The two districts (one rural and one urban) were selected for their contrasting settings and diversity in educational contexts. According to 2024 data from the respective education departments, the rural district had 98 secondary schools with an average of 80 S.3 learners per school, yielding an estimated 7,680 learners. The urban district had 19 secondary schools with an average of 150 S.3 learners per school, resulting in approximately 2,850 students. This gave a combined population of 10,530 S.3 learners. The selection of S.3 learners was purposive due to their advanced engagement with the geometry curriculum. By this level, learners have built foundational knowledge in geometric concepts and reasoning, making them suitable participants for examining the impact of instructional strategies on their understanding of transformation geometry. Their maturity and cognitive readiness further contributed to the study's feasibility and potential for insightful outcomes.

The study employed a combination of matched and purposive sampling techniques. Initially, schools within the two districts were assessed against inclusion criteria, such as administrative flexibility, the availability of multiple S.3 streams, and access to computer laboratories. Matched triples were created to ensure comparability across selected schools, with one triple (three schools) chosen from each district. Two senior classes in each school were randomly assigned to experiment one (CVPHI) or two (TVHPI) groups. Thus, CVHPI and TVHPI were implemented in the same schools to control external variables. The critical difference was the instructional method: Group content sharing had no significant effect as the hands-on, technology-enhanced experience remained exclusive to TVHPI. Figure 3 shows the sampling procedures that were followed in the study.

Figure 3

Showing the Flow of the Sampling Procedures



Initially, 651 learners from six schools participated in the broader quasi-experimental study (317 from rural schools and 334 from urban schools). Following attrition due to dropouts and incomplete data, 483 learners (245 in CVHPI, 238 in TVHPI) were retained for the final analysis of the learners' Van Hiele levels (quantitative results on Van Hiele levels and attitudes are not within the scope of the current article). For the qualitative phase, a purposive subsample of 48 learners was drawn from the larger sample, selected based on their Van Hiele Levels. Ensuring the inclusion of diverse learners equally distributed across gender (24 males and 24 females), location (24 urban and 24 rural), achievement level (24 lower achievers and 24 higher achievers), and instructional strategies (24 taught using TVHPI and 24 using CVHPI).

Data Collection Instruments

The primary data collection tool for the qualitative component was semi-structured interviews that allowed for flexibility in responses while maintaining a consistent structure, ensuring that key themes were addressed across all participants. The researchers designed the interview questions to explore four main areas: Learning Experience, Instructional Impact, Teaching Effectiveness, and Difficulties Encountered. This approach allowed learners to share their personal experiences in detail while ensuring that the researchers could gather comparable data across participants.

Procedures

The study began with a two-day training program to equip teachers with the necessary skills to deliver lessons using the TVHPI and CVHPI methods. The training covered the theoretical framework and practical application of the Van Hiele Phases of instruction, focusing on how to guide learners through different levels of geometric thinking. Teachers were also trained in using GeoGebra to teach transformation geometry, including how to construct geometric figures, apply transformations such as reflection, rotation, translation, and enlargement, and visualize geometric relationships dynamically.

To ensure consistency in lesson delivery, the first author and the teachers collaboratively developed standardized lesson plans covering all learning outcomes specified for the intervention. These plans detailed instructional content, learner activities, and lesson organization, ensuring that all participating teachers followed a uniform approach. Following the training, pretests were administered to the participating learners to assess the learners' baseline Van Hiele levels (achievement) and attitudes toward transformation geometry, so that subsequent changes could be attributed to the instructional methods used.

The intervention covered six weeks, with both groups (CVPHI and TVHPI) receiving four lessons of 40 minutes per week, amounting to 24 lessons by the end of the intervention, delivered following the regular school timetable. To maintain consistency, the same teacher instructed both groups while the first author monitored and supported teachers during the intervention to ensure fidelity. The experiment two group (TVHPI) received lessons from the computer laboratory, using GeoGebra to facilitate interactive and dynamic learning experiences. The setup for GeoGebra was installed on all the computers in the school computer laboratories; the teachers used projectors to deliver lessons, while the learners used the computers to perform different transformations. This group's first lesson was designed to introduce learners to the GeoGebra software. In contrast, the experiment one group (CVHPI) was taught in regular classrooms without technology; the teacher used a chalkboard set to illustrate transformations, while the learners used graph books/papers and mathematical set instruments to perform transformations.

At the end of the intervention, post-tests were administered to all learners to measure any changes in their attitudes and achievement following the six weeks of instruction. Finally, interviews were conducted one week after the intervention concluded. These interviews provided qualitative insights into learners' experiences and understanding of the geometry content, allowing the research team to gather in-depth information beyond the quantitative test results. The 30- to 45-minute interview sessions were held early in the mornings and the evenings to prevent interfering with regular lessons. The current paper presents only results from the qualitative part of the main study.

Data Analysis Methods

The data were analyzed using thematic analysis, following the six-step process outlined by Lapolla (2020) and Meyer and Avery (2009). First, the researchers familiarized themselves with the data by reading and re-reading the transcripts, allowing them to gain an immersive understanding of the content. Following this, anonymization of data was done using a system of unique identifiers based on the learner's gender, achievement level, school location, and method of instruction (e.g., MHA/TVHPI/R1 for a male(M), higher achiever(H) from a rural school(R1), taught using TVHPI). With great care, each transcript was divided into more manageable, insightful segments, with each unit illustrating a distinct subject, concept, or experience related to the study questions. The process yielded 438 different data units, allowing for a more concentrated and in-depth examination since each data unit represented a distinct component of the participants' responses, including their experiences with instructional strategies or the difficulties they had while learning geometry (Lapolla, 2020; Meyer & Avery, 2009). After the data was split and anonymized, it was organized, systematically coded, categorized, and thematically analyzed using Excel. Although our primary analysis is qualitative, utilizing pivot tables allowed for a comprehensive examination of the learners' experiences and the effectiveness of the instructional strategies by summarizing and highlighting links between themes, categories, and codes (Miller, 2014; Ngulube, 2015). This ensured a data-driven approach in drawing findings and offering recommendations by providing a concise summary of the data that served as a basis for examining the learners' experience of instructional strategies and transformation geometry.

Ethical Considerations

The study was conducted under ethical approval from the Mbarara University of Science and Technology (MUST) Research Ethics Committee and the Uganda National Council for Science and Technology (approval numbers MUST-2024-1519 and SS2857ES). Informed consent was obtained from parents or guardians, and assent was sought from learners themselves. For participants aged 18 and above, informed consent was obtained directly. All data were anonymized using unique identifiers to protect participants' privacy, and learners were informed of their right to withdraw from the study at any time.

Several strategies were employed to ensure the trustworthiness of the findings. Credibility was enhanced through member checking, where participants were invited to review their transcripts and confirm the accuracy of their responses. This process ensured that the findings accurately reflected the participants' experiences. Additionally, peer debriefing provided an external check on the data analysis process, as colleagues reviewed the coding and theme development to ensure the findings were consistent with the data.

Dependability was maintained through an audit trail, documenting all decisions made during the research process, from data collection to analysis. This audit trail provides a clear record of the steps taken, allowing the research process to be replicated in future studies. Finally, confirmability was established through reflexivity, where the researchers engaged in self-reflection throughout the study to identify and mitigate any potential biases and control the researchers' potential influence of professional backgrounds in mathematics education. This process helped identify potential biases and ensure they did not unduly influence the analysis. The researchers' belief in the potential benefits of technology-enhanced learning, for example, was explicitly acknowledged as a possible source of bias, and steps were taken to remain objective throughout the study. Lastly, CVHPI learners were granted one week of access to GeoGebra after the study concluded, ensuring ethical fairness in technological exposure.

Results

This study investigated the differences in learners' experiences and understanding of transformation geometry between two instructional strategies: CVHPI and TVHPI. In particular, it looked at how each approach affected learners' understanding of important geometric transformations, including rotations, reflections, and matrix transformations. In addition, the study sought to evaluate how well these strategies supported students' learning and dealt with issues that came up during teaching.

The sample consisted of 48 learners, equally distributed across gender, location, achievement level, and instructional strategies. Before analysis, the data were anonymized, with each learner assigned a symbol representing their contextual characteristics, such as gender, location, achievement level, and instructional strategy, rather than using names or identification numbers. This ensured confidentiality while maintaining relevant context for analysis. The data was organized in Excel and thematically analyzed. Two key themes emerged from the learners' experiences with CVHPI and TVHPI in learning transformation geometry.

Theme 1: Challenges and Support Needs

This theme explores learners' barriers to understanding geometry and the interventions required to address them. It emerges from three categories: *Learning Challenges and Obstacles, Metacognition and Self-Regulated Learning, and External Learning Support.* These categories highlight the interplay between procedural and conceptual difficulties, the role of self-regulation and reflection, and the importance of external assistance. Learning challenges often arise from difficulties in following steps, grasping abstract concepts, or accessing adequate resources. Metacognition involves learners' ability to focus, reflect on progress, and maintain motivation, which is influenced by instructional methods. External learning support emphasizes the need for guidance, tailored interventions, and structured practice to help learners navigate these challenges effectively. The theme highlights the complexity of overcoming learning barriers and the critical role of internal strategies and external resources.

Theme 2: Instructional Effectiveness and Learner Satisfaction

This theme captures how instructional methods impact learning outcomes and align with learners' needs. It evolves from five categories: *Instructional Support and Guidance, Learning and Differentiated Instruction, Practical Learning and Reinforcement through Practice, Role of Instructional Strategy in Learning, and Learners' Expectations*. These categories highlight the importance of effective guidance, tailored instruction, practical application, and structured strategies in facilitating understanding. Instructional methods aim to resolve misunderstandings, enhance visual learning, and provide opportunities for step-by-step reinforcement. Additionally, aligning instructional approaches with learners' expectations is essential for fostering engagement and satisfaction. This theme emphasizes the interconnectedness of instructional quality, strategy, and learner perceptions in shaping meaningful learning experiences in geometry. The detailed findings for each of these themes are discussed in the preceding sections.

The Challenges and Support Needs Associated With TVHPI and CVHPI

This section looks at the challenges and support requirements associated with CVHPI and TVHPI. It draws attention to learners' challenges in understanding geometry and the help needed to improve their learning through hands-on training and individualized guidance. Table 1 illustrates the occurrence of different codes in the data for each category in theme one.

Table 1

Showing a Count of Codes and Categories (Theme 1)

Row Labels	TVHPI	CVHPI	Total
Challenges and Support Needs	**77**	**89**	**166**
Learning Challenges and Obstacles	**49**	**60**	**109**
Challenges in Seeking Help	1		1
Difficulty Following Steps		3	3
Struggling with Geometry Concepts	16	38	54
Technical and Resource Challenges	32	19	51
Metacognition and Self-Regulated Learning	**2**	**9**	**11**
Concentration	2		2
Interest in Learning Geometry Concepts		2	2
Self-Reflection		7	7
External Learning Support	**26**	**20**	**46**
Need for Extensive Use of GeoGebra for Mastery	6		6
Need for Individualized Support and Time for Practice	20	20	40

Learning Challenges and Obstacles

Based on the data values in Table 2, learning challenges and obstacles were the most common experiences for learners in both instructional techniques, with 109 occurrences (49 in TVHPI and 60 in CVHPI). All learners encountered different challenges while trying to grasp transformation geometry. These challenges were classified as *struggling with geometry concepts, technical and resource challenges, and difficulties seeking help during the lesson.*

Struggling with geometry concepts was more pronounced in the CVHPI group, with 38 responses mentioning this difficulty compared to 16 in the TVHPI group. For example, one TVHPI participant noted: "Reflections were easier for me, but when we started working with enlargements, I got lost because I did not understand the scale factors" (FLA/TVHPI/R2). Similarly, a CVHPI participant shared: "But rotations were hard for me when we had to apply them on the grid. More examples would have helped" (FHA/VHPI/U2). The more significant number of learners struggling with geometry in the CVHPI group suggests that traditional methods of instruction are less effective for some learners. The fact that participants in the TVHPI group had this code indicates that learners who used this method had comparable difficulties, although less common than in the CVHPI group. Technical and resource-related difficulties could cause difficulties in understanding geometric ideas, since most of the learners in the TVHPI group reported this challenge compared to the CVHPI group. For example, a TVHPI participant said, "The computer was slow, and the power went out while the teacher was explaining rotations, so I still found matrix transformations and rotations difficult" (FLA/TVHPI/R1).

The differences in the technical and resource issues presented by the two instructional strategies highlight the direct impact that the mode of instruction has on the kinds of problems that learners encounter. Moreover, in some cases, learners shun away from seeking help when they encounter challenges. For example, one participant from the TVHPI group noted, "I got lost a lot and didn't ask for help enough" (FLA/TVHPI/U1), indicating that they had trouble asking for assistance during classes. Even while this problem was only occasionally mentioned, it brings to light a particular difficulty with technology use because learners can be less inclined to ask for help when using new digital tools. While not noticed in the CVHPI group, this issue highlights a possible disadvantage of technology-enhanced instruction: learners may experience a sense of isolation in their learning. This suggests that educators should create a setting where learners feel free to seek assistance, and encourage peer-to-peer interaction and group work, more than individualized learning.

The aforementioned difficulties highlight the necessity of metacognitive and self-regulated learning, which several learners still identified as areas of difficulty. These abilities (discussed in the following subsection) are essential for empowering learners to take charge of their education and identify when they need help, particularly in settings where technology or teaching strategies present extra challenges.

Metacognition and Self-Regulated Learning

Although fewer instances were recorded in the Metacognition and Self-Regulated Learning category (2 in TVHPI and 8 in CVHPI), this area shows how learners used self-regulation strategies to deal with their learning difficulties. These techniques played a crucial role in how learners overcame their learning challenges. The learners reported techniques such as *concentration, forging an interest in learning, and self-reflection after the lessons.*

Remarkably, a few participants in the TVHPI group (2 instances) stated that concentration or focus was necessary to get beyond obstacles when learning geometry. Learners could concentrate better on activities that improved their comprehension of the subject matter. "The shapes moved, but it did not always make sense to me. I think the learners who did better spent more time on the computer and paid more attention" (FLA/TVHPI/U1), a participant from the TVHPI group reported. This implies that technology can improve cognitive engagement, which helps learners understand complex geometric transformations more fully. It should be noted that this focus could be influenced by the learners' level of interest in what is being learned. Relatedly, two of the CVHPI group's participants stated that they overcame challenges because they were motivated to master geometry concepts.

Accordingly, learners in the CVHPI group more frequently mentioned self-reflection. One learner explained: "The teacher explained it, but sometimes I did not ask for more help, but after class, I would think about what we did, and that helped me understand better." (MLA/VHPI/R1). The reliance on self-reflection in CVHPI suggests that learners in traditional instructional settings often need to take more initiative in their learning process, potentially due to the lack of interactive feedback mechanisms available in technology-enhanced settings.

External Learning Support

The different types of help that learners thought they required to successfully navigate their learning experiences are included in this subsection. With a total of 46 instances (26 in TVHPI and 20 in CVHPI), it was evident that learners in both instructional modalities needed extra support to get beyond their obstacles. The categories of help that emerged from the participants included *extensive use of GeoGebra*, *Need for individualized support from the teacher, and allowed time for continuous practice*. Primarily, learners in the TVHPI group (six instances) underlined that knowledge of transformation geometry requires considerable use of GeoGebra. They admitted that even while the program made learning easier, proficiency still required a lot of practice as one of the participants stated: "More time on the computer would have helped" (FLA/TVHPI/R3). This emphasizes how crucial it is to practice technology on a regular and consistent basis to improve conceptual understanding

Moreover, this emphasizes the ongoing need for individualized support and increased practice time, since learners need both unique direction and chances to solidify their understanding of the subject matter. For example, with an equal frequency of 20 occurrences in each group, it was clear that both learners needed time for practice and specialized (external) support. A learner from the TVHPI group and CVHPI group respectively commented: "I think it would help if we had more time on the computer and more help from the teacher during the hard parts" (FLA/TVHPI/R1). "If the teacher gave me more time on that, it would have been better for me" (MHA/VHPI/U2). The fact that both groups have this desire emphasizes the shortcomings of both instructional strategies.

Instructional Effectiveness and Learner Satisfaction.

This theme looks at five emerging categories: beginning with the *Role of Instructional Strategies in Learning,* which forms the foundation for *Instructional Support and Guidance*. This support is then adapted through *Personalized Learning and Differentiated Instruction*, ensuring learners receive targeted help. Learners engage in Practical Learning and Reinforcement through this tailored approach, applying their knowledge in hands-on activities. Ultimately, the effectiveness of these methods is assessed against *Learners' Expectations*, evaluating how well the instructional strategies met their expected learning outcomes. These categories demonstrate the different experiences that the two groups had and show how each teaching strategy impacted learners' overall satisfaction and helped them learn. The occurrence of different codes in the data for each category and code is illustrated in Table 2.

Table 2

Showing a Count of Codes, and Categories (Theme 2)

Row Labels	TVHPI	CVHPI	Total
Instructional Effectiveness and Learner Satisfaction	**147**	**125**	**272**
Role of Instructional Strategy in Learning	**91**	**47**	**138**
Ability to Resolve misunderstanding	40	14	54
Enhanced Visual Learning	44	8	52
Step-by-Step Learning Approach	7	24	31
Instructional support and Guidance	**8**	**2**	**10**
Benefits of Multiple Explanations		2	2
Desire for More Time with GeoGebra	8		8
Personalized Learning and Differentiated Instruction	**2**	**6**	**8**
Enhanced Visual Learning	1		1
Importance of Prior Knowledge		5	5
Repeated Explanation and Personal Attention	1	2	3
Practical Learning and Reinforcement	**21**	**46**	**67**
Understanding through Examples	13	31	44
Improvement Through Practice	8	15	23
Learners expectations	**25**	**24**	**49**
The method didn't meet most of the learner's expectations		13	13
The method met most of the learner's expectations	25	11	36

Role of Instructional Strategy in Learning

A total of 138 responses emerged in this category (91 in TVHPI and 47 in CVHPI); it is clear that the instructional strategy played a significant role in shaping learners' learning outcomes and their ability to engage with geometry concepts. The roles of instructional strategies that emerged under this category are the *ability to resolve misunderstandings*, *enhanced visual learning*, and a *step-by-step learning approach*. Learners in the TVHPI group overwhelmingly reported that the instructional strategy helped them resolve misunderstandings. A TVHPI learner shared: "Using GeoGebra helped me a lot because I could see the shapes change right in front of me. I understood what I had misunderstood" (FHA/TVHPI/R1).

In contrast, fewer learners in the CVHPI group mentioned resolving misunderstandings through the instructional strategy. One CVHPI learner said: "Reflections were easier for me, but when we moved on to rotations, they were confusing at first, but after following the steps I saw some light" (FLA/VHPI/R3). This finding suggests that the interactive and visual nature of TVHPI, particularly through the use of GeoGebra, allowed learners to identify and correct their mistakes more easily compared to CVHPI.

In support of this result, the role of visual learning was significantly more prominent in TVHPI, with 44 occurrences compared to eight in CVHPI. A TVHPI learner remarked: "GeoGebra made a big difference for me because I could see how the shapes were changing, (FHA/TVHPI/R1). Meanwhile, CVHPI learners noted the limitations of traditional visual aids, with one learner explaining: "I remember one lesson where the teacher showed us how to use symmetry, and that helped me" (FHA/VHPI/U3). The emphasis on visual learning in TVHPI highlights the advantage of technology in providing dynamic, real-time demonstrations of geometric concepts. The use of visual aids in TVHPI improved understanding through dynamic visualization; however, in CVHPI, the lack of visual aids necessitated a planned, systematic progression to lead learners through each concept and guarantee mastery at every level. The step-by-step learning approach was more commonly reported by CVHPI learners, with 24 occurrences compared to seven in TVHPI. The approach employed in CVHPI emphasizes the significance of Instructional Support and Guidance in fostering learner confidence through its organized and progressive approach. The continuous need for teacher support was evident in both CVHPI and TVHPI, as the former relied on direct teacher interaction and the latter needed explicit advice to supplement its visual aids.

Instructional Support and Guidance

Instructional support and guidance played a critical role in helping learners navigate their learning experiences. With 10 occurrences in this category (eight in TVHPI and two in CVHPI), the level of support provided was a key factor in shaping learners' perceptions of the effectiveness of their instructional strategy. This category was built on two codes: *desire for more time with GeoGebra and benefits of multiple explanations*.

To improve their understanding, learners in the TVHPI group frequently stated that they needed more time to spend with GeoGebra. This wish emphasizes how beneficial technology can be to education, especially when learners feel sufficiently supported. However, it also implies that the amount of time allotted to using these tools would not have been enough to achieve mastery, which might have reduced overall satisfaction with the teaching approach. For example, one learner remarked: "I think I needed more time with GeoGebra to understand" (MLA/TVHPI/R2). This result is consistent with the previous theme on Challenges and Support Needs, where learners stressed that to improve understanding, they needed to practice GeoGebra a lot.

While learners in the TVHPI group stated that more time spent using GeoGebra improved their comprehension, those in the CVHPI group highlighted that teacher explanations and multiple examples were crucial to their improvement, emphasizing the unique advantages of each instructional strategy in promoting learner learning. For example, a participant in the CVHPI group said, "The way the teacher taught us helped me get better because we practiced a lot" (MHA/VHPI/U2). Learners in this group also emphasized the advantages of hearing repeated explanations. Learners' overall pleasure with the method was probably influenced by the CVHPI instructor's ability to tackle a single concept from multiple perspectives. This is related to the notion that, although TVHPI is superior in visual and interactive learning, the instructor's flexibility in providing various forms of assistance makes CVHPI so strong. While both groups gained from their different teaching strategies, CVHPI learners from teacher explanations and various examples, and TVHPI learners from more time spent with GeoGebra, TVHPI had a greater capacity for encouraging independent learning.

Personalized Learning and Differentiated Instruction

This category highlights the importance of adapting instruction to meet the needs of individual learners. With eight occurrences overall (2 in TVHPI and 7 in CVHPI), it is clear that CVHPI provided more opportunities for personalized and differentiated learning. *Repeated explanations, personal attention, and the importance of prior knowledge* were the primary focus of this category. A CVHPI learner said that direct teacher intervention helped clear up uncertainty regarding rotation. On the other hand, it seems that CVHPI provides more regular chances for this customized advice. This result supports the idea of learner assistance more broadly by demonstrating that although technology like GeoGebra can enhance understanding, it cannot wholly replace one-on-one instructor interaction in helping learners learn complete ideas. This dependence on human attention and repeated explanation is also related to the importance of prior knowledge, since learners frequently need extra help to fill in the gaps between what they already know and new geometric concepts.

Practical Learning and Reinforcement

Practical learning and reinforcement were significant factors in shaping students' learning experiences and their overall satisfaction with the instructional strategies. With 67 occurrences (21 in TVHPI and 46 in CVHPI), both groups heavily emphasized this category, though it was more prominent in CVHPI. The two principal codes that emerged under this category were *the role of examples and practices in enhancing understanding*. Examples were critical to enhancing learners' understanding, with CVHPI learners reporting this benefit more frequently. The higher frequency of occurrences in CVHPI suggests that examples may have a more substantial impact on reinforcing understanding, possibly due to the nature of the instruction. However, the TVHPI method also proved effective in using examples, particularly through visual and interactive demonstrations provided by GeoGebra. This finding reinforces the idea that both instructional strategies offer valuable forms of reinforcement, though in different ways, and connect to the larger discussion of instructional support and guidance. All the instructional strategies were equally represented in the code "improvement through practice", with eight occurrences each. A learner from the TVHPI group remarked: ″I thought it would be confusing, but GeoGebra made everything clearer for me, especially with enlargements after practicing" (FHA/TVHPI/U3). Similarly, a CVHPI learner explained: ″I found reflections easier because we practiced them a lot" (MLA/VHPI/R3). The equal emphasis on practice across both instructional strategies emphasizes the importance of consistent reinforcement in mastering geometry concepts. Whether through digital tools or traditional exercises, learners recognized that repeated practice was key to their improvement.

Learners' Expectations

This examines how the instructional strategies and learners' expectations for learning geometry correspond. Throughout 49 instances (25 in TVHPI and 24 in CVHPI), learners from the two groups expressed differing opinions about how well the instructional strategies fulfilled their expectations for their learning. The surfaced codes represent the different experiences and satisfaction with the instruction strategies, including *the Method Met Most of the Learners' Expectations, and the Method Did Not Meet Most of the Learners' Expectations*.

All 25 mentions from the TVHPI group stressed that the instructional strategy met the learners' expectations compared to 13 out of 24 from the CVHPI. For example, one TVHPI learner explained: ″I did not think I would enjoy using the computer for geometry, but I was surprised at how much fun it was" FHA/TVHPI/R2).

Meanwhile, a CVHPI learner noted: ″I thought reflections would be the most confusing part, but I was surprised at how fast I picked them up" (FHA/VHPI/U1). The higher satisfaction reported by TVHPI learners suggests that the use of technology supported learners' understanding and aligned more closely with their expectations for a modern, interactive learning experience. This finding connects back to the earlier codes related to visual learning and the ability to resolve misunderstandings, which likely contributed to learners feeling that their expectations were met. However, the CVHPI method, while effective in many ways, may have fallen short for learners seeking more dynamic or interactive elements in their learning experience. However, even if CVHPI was effective in many ways, learners who had hoped for a more engaged or participatory approach might not have been delighted. This led to multiple reports from the CVHPI group saying that the procedure fell short of what they had anticipated. One CVHPI learner said, ″I did not think I would be so confused with symmetry. I expected it to be simpler, but I kept making mistakes when it came to figuring out where the lines went. It surprised me how much more attention I needed to pay" (FLA/VHPI/U1). This narrative reveals that learners in CVHPI did not receive the expected experiences and understanding of transformation geometry, resonating from the challenges faced.

Discussion of the Findings

This discussion addresses the research questions by analyzing the challenges and support needs associated with TVHPI and CVHPI, as well as learners' perceptions of the effectiveness of these methods in enhancing their understanding of transformation geometry.

Challenges and Support Needs Associated with TVHPI and CVHPI

The findings reveal that both TVHPI and CVHPI present unique challenges, though the nature of these challenges varies. Consistent with prior research, learners in the CVHPI group reported struggling more with conceptual understanding, particularly for abstract transformations like rotations and scaling. This aligns with studies emphasizing the limitations of traditional instruction in fostering geometric reasoning without dynamic visual aids (Açıkgül, 2022). In contrast, TVHPI learners highlighted challenges related to technical and resource constraints, such as unreliable electricity and insufficient exposure to GeoGebra, supporting literature that emphasizes the need for robust infrastructure in technology-enhanced learning (Adelabu et al., 2022; Afshari et al., 2009; Roxana, 2019). This is consistent with studies on the digital divide, which argue that disparities in access to technology can exacerbate educational inequalities (Moore et al., 2018). While TVHPI offers significant pedagogical advantages, its success is contingent on addressing these infrastructural challenges, particularly in under-resourced contexts.

However, learners in the TVHPI group frequently mentioned the benefits of enhanced visual learning. The ability to manipulate geometric shapes through GeoGebra allowed learners to move through the Van Hiele levels more effectively, as they could simultaneously engage with the conceptual and procedural aspects of transformations. This aligns with cognitive load theory (Plass et al., 2010), which suggests that reducing the cognitive demands associated with abstract problem-solving tasks (such as visualizing geometric transformations) allows learners to focus more on understanding the underlying principles.

Consequently, learners in both groups expressed a need for individualized support and extended practice, emphasizing the universal role of teacher scaffolding and repetition in mastering geometry concepts. Interestingly, TVHPI learners noted a reluctance to seek help, potentially due to a sense of isolation when engaging with technology. This finding contrasts with studies suggesting technology fosters collaboration and engagement (Zheng et al., 2022), highlighting the importance of creating supportive environments in technology-enhanced instruction.

Learners' Perception of Effectiveness of TVHPI and CVHPI in Enhancing Understanding

Regarding perceptions of instructional effectiveness, TVHPI was consistently praised for its ability to enhance conceptual understanding through dynamic visualization. Learners frequently noted that GeoGebra allowed them to "see" transformations in real-time, facilitating deeper comprehension of abstract concepts like rotations and reflections. This aligns with Sunzuma (2023) and Wachira and Keengwe (2011) findings on the power of technology to make abstract geometric concepts more accessible. In contrast, CVHPI learners benefited more from the structured nature of conventional instruction, which helped reinforce procedural mastery. This is consistent with research suggesting that conventional methods remain effective for learners who rely heavily on explicit guidance and the fact that the method uses the structured way of teaching emphasized by Van Hiele (Bonyah & Larbi, 2021; Hattie, 2009; Machisi & Feza, 2021; Moru et al., 2021; Tahani, 2016).

However, satisfaction levels differed between the groups. TVHPI learners expressed greater alignment between their expectations and instructional outcomes, likely due to the engaging and interactive nature of the technology. This finding supports literature highlighting the growing preference for technology in modern classrooms (Adelabu et al., 2022; Afshari et al., 2009). Conversely, CVHPI learners valued the multiple explanations and personalized attention provided by their teachers, suggesting that conventional methods retain strengths in areas where technology cannot fully replicate human interaction (Ardeleanu, 2019; Lessani et al., 2017; Roxana, 2019; Tularam, 2018).

Despite these positive perceptions, both groups emphasized the importance of external support, particularly through teacher guidance and extended practice opportunities. The shared reliance on teacher intervention underscores the complementarity of instructional strategies, with technology enhancing conceptual understanding and conventional methods reinforcing procedural skills.

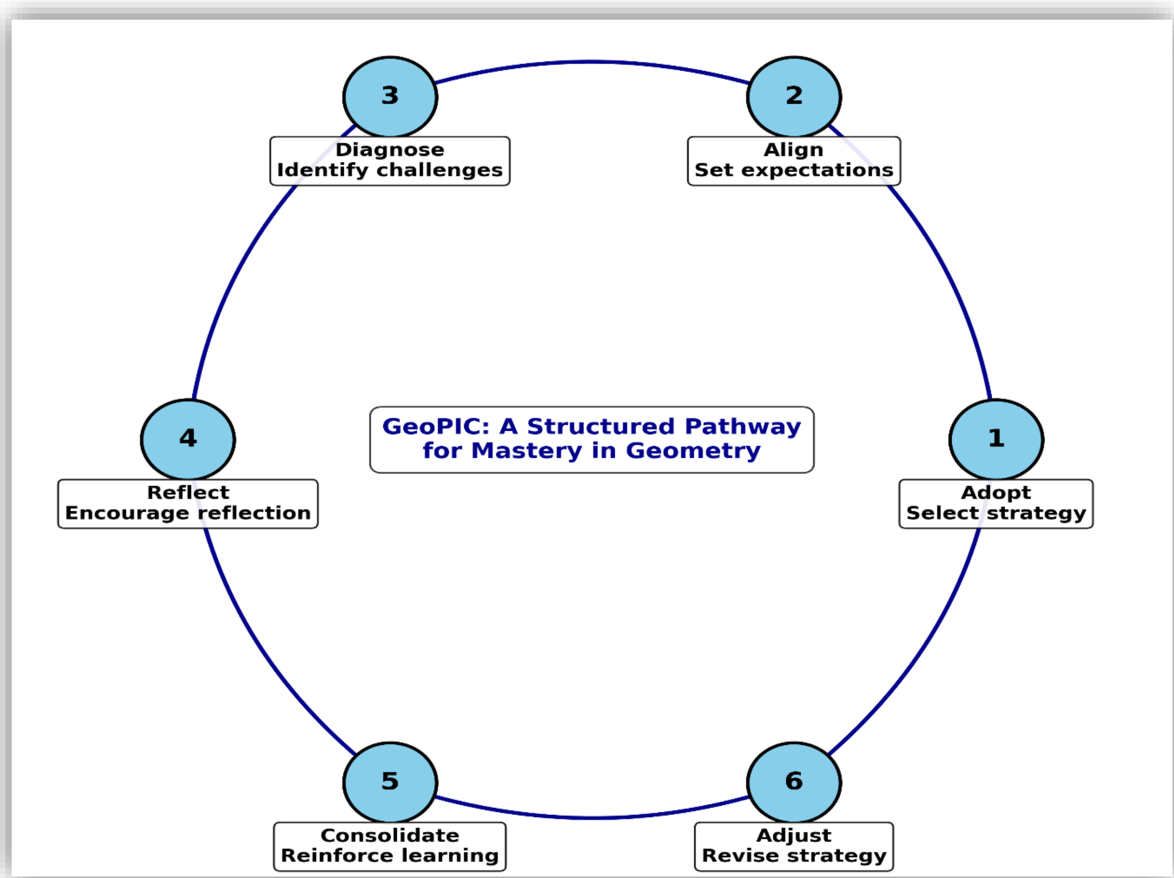
Synthesis of Findings

The findings reveal that while TVHPI addresses conceptual challenges effectively, it introduces technical barriers that require careful planning and support. Conversely, CVHPI fosters procedural understanding and self-regulation but may fall short of meeting learners' expectations and seeking interactive experiences. These insights suggest that neither method is inherently superior. Instead, their effectiveness depends on aligning instructional strategies with learners' needs and preferences. As a result, the study suggests a Geometry Pedagogical Improvement Cycle (GeoPIC-Framework) that provides a structured pathway for learners to advance from basic shape recognition to abstract geometric reasoning, ensuring a seamless transition through Van Hiele's levels of geometric thinking. This cycle is illustrated in Figure 4.

The cycle begins with adopting an instructional strategy that aligns with the learners' abilities and learning objectives/outcomes. Teachers must determine whether to employ traditional hands-on tools like graph paper, mirrors, and rulers or to enhance learning through technology using dynamic visualization platforms such as GeoGebra. Once a strategy is in place, the focus shifts to aligning expectations, where learners are introduced to the structure of their learning journey; understanding what they will learn, how they will engage with geometric transformations, and how their progress will be assessed. This alignment ensures that learners are not merely following procedures but actively constructing their understanding of geometric concepts.

Figure 4

Showing the Geometry Pedagogical Improvement Cycle (GeoPIC-Framework)



With expectations set, the next critical step is diagnosing learning challenges to establish each learner's entry point in the learning process. Through pre-tests, discussions, and observation of learner interactions, educators identify misconceptions and conceptual gaps that may hinder progress. This diagnosis is essential in structuring subsequent instruction to address weaknesses while reinforcing foundational geometric principles. Once challenges are identified, the cycle moves to reflection, where learners and teachers critically analyze learning experiences. Learners engage in self-explanation and problem analysis, strengthening their metacognitive awareness and helping them transition from visual recognition to logical deduction. Meanwhile, teachers assess the effectiveness of their instructional approach, refining strategies to improve conceptual clarity and engagement.

Following reflection, learning is consolidated through practice and application. Learners apply their understanding in guided activities, structured problem-solving tasks, and real-world scenarios using manual drawing techniques and interactive digital explorations. Technology, particularly GeoGebra, is crucial in reinforcing geometric transformations by allowing learners to manipulate figures dynamically, observe patterns, and test conjectures. This phase cements knowledge, enabling learners to analyze and apply transformations confidently rather than memorize rules.

However, learning is not static. As learners engage in practice, adjustments must be made to enhance instruction further. Teachers evaluate progress and refine their approaches, modifying teaching pace, instructional materials, and learner support strategies to better align with evolving needs. This continuous refinement ensures that learners do not stagnate but advance systematically through increasingly complex geometric reasoning tasks.

The GeoPIC framework is not a linear process but an ongoing cycle, looping back to adoption and realignment as new insights emerge. Each iteration strengthens learners' understanding, moving them from basic spatial visualization to higher-order geometric reasoning. By integrating traditional instructional techniques with dynamic digital tools, this framework provides an adaptive, research-driven approach to teaching geometry, ensuring that learners not only master transformations but also develop the ability to think, reason, and engage with geometric concepts at a deeper level. The iterative nature of this cycle ensures that learning is continuous, responsive, and progressively builds toward geometric mastery, equipping learners with the essential skills to analyze spatial relationships, apply logical reasoning, and connect geometric principles to real-world contexts.

The continuous feedback loop also ensures improvement in teaching effectiveness and student learning outcomes. GeoPIC is based on key educational theories, including the Van Hiele Theory of Geometric Thinking, Differentiated Instruction, and constructivist principles. It emphasizes tailoring strategies to learners' needs, active learning, and continuous reflection; Crowley, 1987; Vojkuvkova, 2012). Formative assessment guides the cycle's feedback stages, while its cyclical process mirrors the Plan-Do-Check-Act model for continuous teaching improvement (Pratik & Vivek, 2017).

Limitations of the Study

The study's sample size (48 Senior Three learners from six Ugandan schools) limits generalizability, as findings may not fully apply to other grade levels. While Senior Three was chosen due to its alignment with transformation geometry content, future studies could explore the effectiveness of TVHPI in other classes to assess broader applicability. Additionally, although teachers were trained and standardized lesson plans were developed, variations in teaching styles and instructional delivery were inevitable and may have influenced some results. Despite these limitations, the study's qualitative depth, diverse school selection, and rigorous methodology ensure credible insights.

Conclusions and Recommendations

The study identified challenges and support needs associated with TVHPI, particularly its reliance on digital tools, which posed obstacles such as electricity instability and limited device access in low-resource settings. Since CVHPI is embedded within TVHPI, it remains a viable alternative when technology is unavailable, ensuring learners experience Van Hiele Phased Instruction through traditional tools. To address these challenges, a hybrid approach integrating offline GeoGebra use and paper-based simulations could enhance accessibility. Additionally, while TVHPI promotes individual exploration, some learners reported feeling isolated compared to the collaborative nature of CVHPI. Peer-to-peer interactions and structured group tasks within TVHPI would help maintain learner engagement while maximizing technology's benefits.

Regarding learners' perceptions of effectiveness, TVHPI enhanced understanding of transformation geometry by providing dynamic visualization, especially for rotations and reflections, allowing learners to manipulate shapes and observe transformations in real time. Within TVHPI, CVHPI remained essential for structured reinforcement, supporting procedural accuracy through manual plotting, mirrors, and graph paper. While TVHPI strengthened conceptual understanding, CVHPI ensured learners developed procedural fluency, highlighting the need for a balanced integration of both approaches to optimize learning in transformation geometry.

Schools should prioritize TVHPI as the primary instructional strategy, leveraging its interactive and visual capabilities while retaining CVHPI's structured support for personalized learning. Teachers should receive comprehensive training on GeoGebra and digital tools, integrated into continuous professional development with hands-on practice. Addressing technical challenges, such as power reliability and device access, is crucial for seamless integration. GeoGebra can be used as a dynamic board to enhance visualization where devices are limited. A hybrid approach would optimize learner learning by combining TVHPI's visualization strengths with CVHPI's structured guidance. The GeoPIC framework should guide continuous instructional improvements.

At the policy level, teacher training should transition from CVHPI to TVHPI, ensuring educators develop strong foundational skills before integrating technology. Policymakers should invest in affordable digital solutions and offline learning resources, expanding access in low-resource settings. Hybrid models integrating technology and traditional tools should be supported to ensure inclusive learning environments.

Further research should explore TVHPI's effectiveness across more extensive and diverse samples. Additionally, the practicality of the GeoPIC framework should be assessed to refine instructional strategies. Longitudinal studies should evaluate knowledge retention and higher-order reasoning skills, ensuring sustainable benefits of TVHPI in mathematics education.

Contribution: By examining the Van Hiele Phased Instruction (VHPI) model in Uganda and investigating the effectiveness of Technology-Enhanced Van Hiele Phased Instruction (TVHPI) with the integration of GeoGebra, this study enhances the instruction of mathematics. This research sheds light on how different approaches to instruction affect the learner's understanding of transformation geometry and tries to fill the gap in the literature. In addition to improving geometry instruction, this study presents the Geometry Pedagogical Improvement Cycle (GeoPIC), a framework that can address learner obstacles and improve teaching strategies.

Data Availability: The data for this study can be accessed through this link:
https://docs.google.com/spreadsheets/d/1aIfYwD3LX1SBOGRpqPq-22-f-On0BuGD/edit?gid=1200165066#gid=1200165066

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