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Review Paper

Revisited Van Hiele's Model of Geometry in the Light of NEP-2020

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ABSTRACT

Geometry holds an important position within the mathematics curriculum, constituting a substantial segment of Indian school education across all levels. It is also relevant in everyday life and intersects with other mathematical disciplines. Individuals' understanding of geometry differs, indicating different cognitive processes and interpretive frameworks. There are various ways in which geometry instruction might be approached from a pedagogical perspective. Van Hiele investigated and proposed a significant method for classifying and assessing individuals' understanding of geometry. This model/theory involves five levels of geometrical understanding, particularly in understanding geometrical shapes and structures. Furthermore, through exploration, models offer a comprehensive framework for understanding spatial cognition. Consequently, educators gain valuable insights into students' geometric understanding levels. This understanding enables the development of instructional methods that support cognitive growth and nurture geometric reasoning skills. NEP-2020 envisions an educational framework that focuses on conceptual understanding and nurtures creativity, innovation, and problem-solving abilities among students, aligning with the overarching goals of Van Hiele's theory. In this study, Van Hiele's model has been revisited in light of the National Education Policy (NEP) 2020; the study suggested to modernising educational practices and adapting them to contemporary needs. The model's components, including its levels of understanding, characteristics, and instructional phases, are aligned with NEP-2020 principles to propose a comprehensive approach to geometry education. Furthermore, it is recommended that educators be provided with professional development opportunities to deepen their understanding of Van Hiele's theory and efficaciously incorporate it into their pedagogical practices. By adopting these recommendations, educational institutions can establish a more robust foundation for geometry education, equipping students with the requisite skills to navigate an increasingly complex and dynamic world.

Keywords: *Van Hiele's Model, Geometric Understanding, NEP-2020*

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Geometry, an integral component of mathematics education, has long been regarded as a cornerstone for students from the earliest stages of their academic journey. It systematically explores the relationships among points, lines, angles, planes, and spatial shapes. It offers ample opportunities for fostering mathematical reasoning, logical thinking, spatial awareness, and a deeper connection with everyday environments (Patkin & Levenberg, 2012). As a foundational discipline within mathematics, it examines the characteristics and arrangements of both two-dimensional and three-dimensional shapes (Atiaturrahmaniah & Ibrahim, 2017). In Indian education, a significant proportion of geometry is taught at every stage.

In the instructional setting, geometry is structured methodically, commencing with basic notions comprehensible to all, progressing to concepts necessitating precise definitions, and culminating in foundational assumptions known as axioms or postulates. From these foundational elements, theorems, formulae, and propositions are derived as provisional assumptions, mandating deductive verification (Nuraini & Ganda, 2021). Teaching geometry yields numerous benefits, enhancing students' capacity for visualization, critical thinking, converting three-dimensional shapes to two-dimensional shapes, assumption-making, logical inference, and proficiency in proofs (Battista, 2007). In addition, geometry emphasises the development and application of spatial concepts, allowing learners to accurately represent and understand their environment (Thompson, 2003). The significance of geometry and spatial cognition in mathematics curriculum has been emphasised by the "National Council of Teachers of Mathematics" (NCTM, 2000). It also focuses on equipping learners with the skills to effectively utilize visualization and spatial reasoning, improving problem-solving ability in various fields. The pedagogical framework for Geometry from kindergarten to grade twelve should allow for a comprehensive analysis of the properties and measurements of 2D and 3D geometrical shapes. Furthermore, it should encourage students to develop the ability to create detailed mathematical arguments, explaining the complex relationships inherent in geometric structures. Nevertheless, mastering geometry poses challenges, mainly conceptual understanding, as acknowledged by the "Conference Board of the Mathematical Sciences" (CBMS, 2001). Despite its importance, geometry remains among the most challenging subjects to teach and learn in many educational settings nationwide (Atebe & Schafer, 2009).

Various models have been developed and researched to elucidate learners' spatial ability and thinking, with Van Hiele's levels of geometrical understanding as the most important and remarkable model (Clements & Battista, 1992). One such influential theory is Van Hiele's Geometric Understanding Theory, proposed by Dina and Pierre Van Hiele, two Dutch educators in the 1950s. This theory revolutionized how educators perceive the acquisition of geometric knowledge among learners by delineating distinct levels of geometric thought processes.

In the education sector, the "National Education Policy 2020" (NEP-2020) of India signifies a concurrent paradigm transition. It places great importance on promoting the overall development of learners and nurturing their ability to analyze information critically. Furthermore, it also envisions an educational framework that focuses on conceptual understanding and nurtures learners' creativity, innovation, and problem-solving abilities, aligning with the overarching goals of Van Hiele's theory.

Theoretical framework of Van Hiele's Model

The Van Hiele theory is a framework which describes the various levels of understanding that learners progress through from a holistic understanding of geometric shapes to a higher-level understanding of geometric proof (Genz, 2006, p. 4). Dina and Pierre Van Hiele developed a theoretical framework that serves as a guide for teaching geometry. It has also been conceptualized and refined as an educational model in response to their dismay over their learner's struggles with grasping geometric concepts. It outlines five distinct progressive levels through which learners enhance their understanding of geometric concepts, starting from visual recognition and culminating in rigorous formal reasoning. Van Hiele's Theory outlines a hierarchical progression of five levels of geometric understanding, with each level building upon the preceding one:

- Visualizations: At this stage, learners recognize geometric shapes based on visual attributes but lack conceptual understanding.
- Analysis: Students can describe geometric shapes using informal language and basic properties.
- Abstraction: Learners begin to analyze geometric relationships and justify their observations using informal arguments.
- Deduction: Students develop formal deductive reasoning skills and understand geometric concepts based on axiomatic systems.
- Rigour: At the highest level, learners engage in rigorous mathematical reasoning, proving geometric theorems and conjectures using formal logic.

Furthermore, the characteristics of the levels have also been explained (Crowley, 1987; Usiskin, 1982). The levels exhibit five fundamental characteristics:

- Sequentially: The levels follow a specific sequential pattern, indicating that for learners to advance to higher levels of reasoning, they require sufficient experiences at lower levels (van Hiele, 1986).
- Intrinsic and Extrinsic: Geometric concepts that are implicitly recognized at one level are explicitly understood at the subsequent level (Clements & Battista, 1992).
- Linguistic Diversity: Every level is characterized by distinct language, symbols, and relational networks (van Hiele, 1986).
- Mismatch: A disparity between the student's proficiency and that of the teacher, instructional resources, and subject matter can hinder the desired learning outcome since the pupils cannot understand more advanced cognitive processes (Crowley, 1987).
- Progression: Moving from one level to another does not happen spontaneously; it requires well-organized teaching and learning instruction (Van Hiele, 1986:50).

Understanding these levels is crucial for educators to design instructional activities that scaffold students' learning experiences and facilitate progression through the geometric understanding hierarchy. Despite their efforts to adapt different teaching methods, Van Hiele encountered persistent challenges in teaching geometry. Van Hiele (1986, p. 39) reflected on his struggle, stating, "In the years that followed, numerous explanations were altered, but the problems persisted". The instructors seem to be speaking a whole different language every time. In response, a teaching-learning framework comprising distinct phases was formulated to guide educators in facilitating the progression of learners in geometry through levels of understanding. It also emphasizes the necessity of proper instruction for learners to advance through these levels of thinking in 1958 by Van Hiele-Geldof as cited in Fuys, 1984. Therefore, teachers must tailor their instruction to the appropriate Van Hiele level, enabling learners to reach their maximum potential within their learning environments.

The instructional phases outlined by Van Hiele (1986) offer a structured approach for educators to facilitate students' progression through geometric thinking. The phases are information, guided orientation, explicitation, free orientation, and integration. Previously, many studies are frequently encouraged to facilitate their learner's understanding of geometry by incorporating these five instructional phases into their practices (Groth, 2005; Ding & Jones, 2007; Serow, 2008; Erdogan & Durmus 2009; Connolly 2010; Abdullah & Zakaria, 2011; Meng & Idris, 2012; Abdullah & Zakaria, 2013; Siew, & Chong 2014; Tieng & Eu, 2015; Ramlan, 2016; Mostafa, Javad & Reza, 2017; Armah, Cofie & Okpoti 2018; Usman, Yew, & Saleh, 2019; Usman, Yew & Saleh, 2020; Mbusi & Luneta, 2021; Ansah, Asiedu-Addo & Kabutey, 2022; Mohammed & Zakariyya, 2023).

A brief overview of each instructional phase is provided below.

- Information: At this phase, the teacher or instructor assesses the student's understanding to customize preliminary activities suitable for the particular topic.
- Guided orientation: In this phase, learners are provided direction by the teacher or instructor. This is done through planned assignments that are specifically designed to help students make discoveries about the topic and assist them in advancing through different stages.
- Explicitation: At this phase, the teacher assesses the learners' knowledge by encouraging them to express their understanding using their language. Technical terminology replaces informal language in order to enhance formality.
- Free orientation: Students engage in open-ended and complex tasks, including hands-on activities, investigations, and collaborative discussions, to uncover concept connections. They are anticipated to utilize the vocabulary established in earlier stages.
- Integration: The teacher invites students to evaluate and condense the content covered, determining if they have thoroughly comprehended the issue.

Alignment with NEP-2020:

NEP-2020 emphasizes the cultivation of problem-solving, critical thinking and analytical skills among students and aligns with the goals of Van Hiele’s theory. Educators can foster deeper conceptual understanding by integrating Van Hiele’s framework into the curriculum outlined in NEP-2020. This approach strengthens geometric understanding and nurtures creativity, critical thinking, and reasoning skills, ultimately empowering learners to make logical decisions. Furthermore, Van Hiele’s theory advocates for active learning strategies such as hands-on activities, problem-solving ability, and collaborative learning, which resonate with the pedagogical approaches endorsed by NEP-2020. NEP 2020 emphasizes the significance of mathematics and mathematical thinking for India's future across various fields and professions. This emphasis is reflected in integrating mathematics and computational thinking throughout the school years, employing diverse, innovative pedagogical approaches and theories. These approaches and theories include utilizing puzzles and games to enhance the enjoyment and engagement of mathematical thinking from the foundational stages onward. This approach is consistent with Van Hiele's phase-based instructional design, which similarly prioritizes learners’ engagement by employing strategies like puzzles, games, inquiry, hands-on activities, etc., in teaching geometry.

Recommendations for Implementation

In order to align Van Hiele's Theory of geometry with NEP-2020, educators and policymakers must include Van Hiele's model in the mathematics curriculum. This will ensure that instructional strategies cater to students' different learning needs. It is essential to provide educators with professional development opportunities to enhance their comprehension of Van Hiele's theory and ensure its implementation. Developing evaluation instruments to measure student's progress in geometric understanding and providing prompt feedback improves their development. Furthermore, cultivating interdisciplinary links between mathematics and other disciplines facilitates comprehensive learning experiences that align with the goals of the NEP-2020, hence improving students' overall educational achievements.

CONCLUSION

In conclusion, Van Hiele's Geometric Understanding Theory offers valuable insights into students' cognitive development and provides a framework for fostering geometric reasoning skills. By aligning Van Hiele's theory with the principles outlined in NEP-2020, educators can create a conducive learning environment that nurtures students' critical thinking, creativity, and problem-solving abilities. Embracing the synergies between these frameworks holds the potential to transform mathematics education and empower learners to excel in the 21st-century world.

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Conflict of Interest

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