Implementation of the GeoGebra software tool for geometrical reasoning competition in ninth grade students

L N Medina Escamilla¹, H J Gallardo Pérez¹, and L S Paz Montes¹
¹Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: henrygallardo@ufps.edu.co

Abstract. The study developed, and which is presented succinctly in this report, aimed to implement an intervention plan with the GeoGebra software tool for geometric reasoning in ninth grade students of the San José Educational Institution of the city of San José de Cúcuta. Methodologically, it is a quasi-experimental study of pretest and posttest with control group. The pretest showed flaws in Geometric Reasoning in the students, both in the control and experimental groups. These results led to the design and implementation of a Treatment Plan for the experimental group using the GeoGebra software tool. After applying the posttest, it was demonstrated, through its results, that the Plan was highly significant, since a high percentage of the students of the experimental group correctly answered the questions of the instrument on geometric reasoning.

1. Introduction
This research studies the competence of geometric reasoning based on the implementation of the GeoGebra software tool in ninth grade students of the San José School of education in the City of San José de Cúcuta, Colombia. From the theoretical point of view, it is based on the contributions of Vygotzky [1] and on the theory of didactic situations of Brosseau [2]. Methodologically, it is a quasi-experimental pre-test and post-test study with a control group. The pretest demonstrated geometrical flaws in the students in both the control and experimental groups. After applying an intervention plan to the experimental group, this group improved its performance in the contents worked on in the plan.

2. Theoretical foundations
2.1. The geometric reasoning
Teachers, as professionals dedicated to teaching children and young people, have knowledge, learned from undergraduate studies, that logical reasoning starts from an early age, for which, the “Ministerio de Educación Nacional (MEN)”, Colombia, [3] states that, in the first grades must have physical and manipulative materials that help to understand that mathematics is not simply a memorization of rules and algorithms. In this way, as Brosseau points out [4], it is convenient that didactic situations propitiate reasoning in geometrical aspects. In such situations, several occasions can be used to recognize and check the coherence of a proposition with others previously accepted as theorems, axioms, postulates or principles, or when trying to refute it by its contradiction with others or by the construction of counterexamples.

Then, it becomes a priority, to define the geometric reasoning, for which part of the terms proposed in the dictionary of the royal Spanish academy [5], which in the reasoning entry means a series of
concepts aimed at demonstrating something. On this aspect, Samper, Leguizamón & Camargo [6] identify the geometric reasoning with the ability to establish new relationships between geometric concepts.

However, to characterize the geometric reasoning, we start, in this study, on the one hand, the levels of Van Hiele for the teaching of geometry, and on the other, the competence of geometric reasoning associated with the basic rights of learning and the basic standards of competencies, particularly those related to the geometry of the ninth grade in Colombian education.

With respect to the Van Hiele levels for the teaching of geometry, the postulates of Guillén [7] are followed, who state that these levels identify the different forms of geometric reasoning of the subjects and their progress can be assessed. Van Hiele proposes five levels of geometric thought development that show a way to structure the learning of geometry.

They only allow, in this study, an analysis in each of the items of the pretest and posttest, which helps to locate the percentage of students in each question at what level it is, to, from there, have elements on which contents are of greater learning by students. These levels are: Level 1: It is the level of visualization, also called familiarization, in which the student perceives the figures as a global whole, without detecting relationships between such forms or between their parts. Level 2: It is a level of analysis, knowledge of the components of the figures, their basic properties. Level 3: Sorting or classification call. Relations and definitions begin to be clarified, but only with help and guidance. Level 4: It is already deductive reasoning; in it the meaning of axioms, definitions, theorems is understood, but abstract reasoning is not yet made, nor is the meaning of the rigor of the demonstrations sufficiently understood. Level 5: Is the rigor; it is when the reasoning becomes rigorously deductive.

With regard to the competence of geometric reasoning, the MEN [8] states that the appropriation by students of physical and geometric space requires the study of different spatial relationships of solid and hollow bodies with each other. For this, in this study, it is important to keep in mind the basic rights of learning and the basic standards of mathematical competences, related to geometry, with particular attention to geometric reasoning.

In relation to the basic rights of learning, the MEN [8] proposes for the ninth grade the following rights in mathematics, associated with geometry with their respective learning evidences, which are: Identify and use relationships between the volume and the capacity of some round bodies (cylinder, cone and sphere) with reference to school and extracurricular situations. It uses theorems, properties and geometric relationships (Thales theorem and the Pythagorean theorem) to propose and justify strategies for measuring and calculating lengths. Conjecture about the regularities of two-dimensional and three-dimensional shapes and make inferences from the criteria of similarity, congruence and basic theorems.

On the basic competency standards, the MEN [8] proposes five general processes for the teaching of mathematics. These are formulating and solving problems; model processes and phenomena of reality, communication, reasoning; formulate, compare and exercise procedures and algorithms. As for the reasoning, object of interest in this research, it can be achieved that it begins with the logical reasoning which occurs in the first grades supported in the physical contexts and materials that allow to perceive regularities and relationships; make predictions and conjectures; justify or refute those conjectures; give coherent explanations; propose interpretations and possible answers and adopt them or reject them with arguments and reasons. On the other hand, in higher grades, the reasoning becomes independent and the student can work directly with propositions and theories.

2.2. Teaching strategies of geometric reasoning

For the teaching of any object of knowledge, you can raise a number of strategies based on different paradigms. However, in this research only the sociocultural paradigm of Vygotsky [1] and the theory of didactic situations of Brosseau [2] will be explained, which support the teaching strategies in the experimental group treatment plan, since the activities are developed based on the active participation of students. For Vygotsky [1] the relationship between subject and object of knowledge is not a bipolar relationship as in other paradigms, for it becomes an open triangle in which the three vertices are
represented by subject, object of knowledge and sociocultural instruments. In this way, it is suggested that the influence of the cultural context, in Vygotsky's theory, plays an essential role.

Similarly, Vygotsky [9] and [1] refer to two constructs of his theory, such as the concept of the zone of near development and the subject of mediation. The zone of proximal development is considered as the distance between the real level of development, determined by the competence to solve a problem, and the level of potential development, determined through the resolution of a problem under the guidance of an adult or in collaboration with another more capable partner.

Therefore, the role of social interaction with others mainly with significant adults as teachers and parents is of fundamental importance for the psychological, cognitive and affective development of the student that allows better levels of understanding of geometric thinking. In addition to social relations, mediation through instruments, such as the GeoGebra tool, allow for the development of the learner in topics associated with geometry through collaborative learning.

Collaborative learning, according to Chamorro [10] alludes to the methodologies that foster collaboration between people to know, share or expand individual knowledge, sharing in discussion spaces. In this regard, Brousseau (1986) raises the theory of didactic situations and in that sense [2], Castillo & Popayán [11] state that the theory of didactic situations is based on Piaget's constructivist theory, since according to Brousseau (1986) the student learns adapting to a medium that is a factor of contradictions, of difficulties, of imbalances [2].

2.3. The GeoGebra tool as an instructional medium

Within the range of geometry software, GeoGebra is observed, which according to Del Pino [12] is a dynamic program for teaching and learning mathematics for education at all levels. Dynamically combines geometry, algebra, analysis and statistics in an operational set. Among the most important features of GeoGebra, Rojano [13] and Saidon [14] mention that this tool has the facility to create a dynamic web page from the construction, simply by selecting the corresponding option in the menus it offers.

The use of GeoGebra can promote geometric thinking and facilitate visual, algebraic and conceptual support in students. Then, with GeoGebra technology can be brought to the classroom, for the teaching of geometric reasoning. However, the presence of innovative technologies in educational centers does not guarantee innovation in its real meaning. Innovation must be understood as the change produced in the conceptions of teaching by teachers and in educational projects.

3. Method

This research is based on positivist studies, which in the words of Hernández, Fernández & Baptista [15] and Shunk [16] have been dominant in the educational field since the 19th century. Therefore, it is part of the quantitative approach with a quasi-experimental pretest and posttest design with a control group. On this design, it can be said that in quasi-experimental research the scientist manipulates one or more independent variables and determines their effects on other dependent variables. In this investigation, there are two groups, one of control and the other experimental. The pretest is applied simultaneously to these, then the treatment plan is applied to the experimental group and, at the conclusion of the treatment, the two groups are administered the posttest. If the experimental group shows a better performance, the researcher could conclude that the treatment plan with GeoGebra influences the use of geometric reasoning. The population is constituted by the two groups of students enrolled in the ninth grade of the San José School Educational Institution of the city of San José de Cúcuta, constituted by 33 students in each group. The measuring instrument for the variable Geometric Reasoning was a battery of 10 questions taken from different tests developed by the “Instituto Colombiano para el Fomento de la Educación Superior (ICFES)” [17], with adaptation of the researchers and others prepared by the authors.
4. Results

4.1. Pretest results
The results of the pretest allow to demonstrate shortcomings in the geometric reasoning in the research subjects. These show that the sample subjects from both the control and experimental groups gave correct answers in very low percentages in the ten questions raised. In this regard, the research subjects during this pre-test are located at the Van Hiele levels for the teaching of geometry following the postulates of [7], in level 2 as they identify and analyze particular parts and properties of the geometric figure. With respect to the basic rights of learning, proposed by the MEN [8] these students have consolidated the calculation of the surface area and the volume of pyramids, cones and spheres. Aspect that is related to the Basic Standards of competences of the MEN [8]. This can be related to the contents of geometry of the MEN [8] and extended by Jaime and Gutiérrez [18] on properties of flat figures or representation of three-dimensional objects in different positions and from different points of view.

4.2. Plan of intervention
The results of the pretest led the researcher to design and execute an intervention plan for the experimental group. It was organized as follows: description of the context, justification, theoretical sustenance, competences, design; and implementation of the intervention plan. The design specifies the objectives and contents and consists of five didactic situations related to each of the contents required for the geometric reasoning competence. During a period of four weeks the following contents were developed, with the use of the GeoGebra Tool: properties of congruence and similarity between two-dimensional figures and between three-dimensional objects in the solution of problems, properties and geometric relationships used in demonstrations of basic theorems (Pythagoras and Thales de Mileto), congruence and similarity between triangles in the resolution and formulation of problems, geometric representations to solve and formulate problems in mathematics and other disciplines.

4.3. Postest results
When analyzing the results of the posttest, the results show in the students, of the experimental group, that the correct answers increased significantly in relation to the incorrect ones. Situation that did not occur in the control group who remained in the same percentages of the pretest. However, the students of the experimental group in a high percentage are still located in Van Hiele levels for the teaching of the level 2, however, there are some percentages that tend to pass to level 3, because they identify and analyze parts and particular properties of the geometric figures. In addition, they can reproduce copies of the figures by their properties and solve problems.

With respect to the basic rights of learning, proposed by the MEN, the students of the experimental group increased the scores in questions associated with the properties of geometric figures that are involved in the measurement processes. They give reasons why a figure fulfills certain properties. Aspect that is related to the basic standards of competences in geometric systems referred to the use of geometric representations to solve and formulate problems in mathematics and other disciplines. Also, it recognizes properties and geometric relationships used in demonstrations of basic theorems. Which can be related to the contents of geometry on classification of polygons according to their properties, number of sides, number of angles, length of the sides.

The results of the test carried out before the intervention show similarity between the control and experimental groups, in both around 45% of the students responded correctly to the test; after the didactic intervention, there is a significant difference, since in the control group only 39% achieved correct answers with respect to 57% in the experimental group.

5. Discussion
The analysis is carried out by comparing the results of the pretest with those of the post test on the basis of the dimensions of the study supported by the competence of geometric reasoning. In this sense, when analyzing the results, a significant positive difference can be observed between the pretest and the
posttest in the experimental group. That is to say that in the questions the students of the experimental group improved their result. While in the control group it is observed that there was no increase in the scores in this first question. This is interesting, since it can be established that the proposal of intervention to the experimental group in relation to the developed contents was highly significant. And, as Cabero [19] and Marqué\'s [20] suggest, the use of technological tools can improve the imagination and creative, communicative and collaborative skills, valuing the possibilities offered by information and communication technologies in the personal field of students that help you get better learning. In this regard, it brings to the discussion the approaches of Carrera, & Mazzarella [21] who allude that when the teaching processes are innovative, as in this study, with the use of GeoGebra, the student reconstructs the knowledge by intermingling personal construction processes and authentic process in collaboration with others who, in one way or another, intervene in the learning process. Therefore, Wertsch [22] argues that the knowledge learned, thanks to the processes of teaching with technologies, end up being owned by learners, thanks to the degree that they can use tools such as GeoGebra and can make active use of new knowledge of conscious and voluntary way.

The results can also be analyzed from the point of view of Vigotsky [1] who raises the importance of collaborative teaching. For this scientist, the relationship between subject and object of knowledge is not a bipolar relationship as in other paradigms, for it becomes a triad in which the three vertices are represented by subject, object of knowledge and sociocultural instruments. And it is open to the influence of its cultural context. In this way, Moll [23] suggests that the influence of cultural context, in Vygotsky’s theory, plays an essential and determining role in the development of the subject who does not passively receive the influence, but actively reconstructs it.

Therefore, the role of social interaction with others, mainly with significant adults as teachers is of fundamental importance for the psychological, cognitive and affective development of the student that allows better levels of understanding of geometric thinking. In addition to social relations, mediation through instruments, such as the Geogebra tool allow for the development of the learner in the topics associated with geometry.

In this study, without trying to be exhaustive in each of the points analyzed, it has been tried to synthesize the basic aspects that involved the design and implementation of the GeoGebra tool to contribute to the competence of geometric reasoning in ninth grade students of the “San José” institution in San José de Cúcuta, Colombia. It can be concluded that the constant changes and evolution of society regarding the use of technologies in general and in the educational field in particular, are enhancing the undeniable fact that it is important to make use of information and communications technology. This results in the change of routine learning environments by others, characterized by constant transformation and innovation. Therefore, the use of GeoGebra allowed students new ways to learn content associated with geometric reasoning.

6. Conclusions

The didactic proposal with the GeoGebra software tool to contribute to the learning of geometric reasoning became an enriching experience. The activities developed allowed an active participation of the students. Thus, the use of GeoGebra as a tool that comes from new information and communication technologies, with an appropriate pedagogical approach, allowed students to find new ways of learning, as they felt motivated, interested and attracted by the activities.

In the development of the didactic proposal with the incorporation of the GeoGebra software, there are still great challenges. The experience in the classroom with students learning with GeoGebra, has shown that its instrumentalization is done through didactic activities, which privileges the technical aspect over the pedagogical. However, it is insufficient to ensure that students have spontaneous access to the use of the tool, but the most important thing is the effective use of it and that they incorporate it naturally into academic practices. This depends on the effectiveness and efficiency of teaching and learning processes and school management, as well as on the capacities of the actors involved and their interactions with electronic resources in the classroom.
References
[1] Vygotsky LS 1979 *El desarrollo de los procesos psicológicos superiores* (Barcelona: Grupo Editorial Grijalbo)
[2] Brousseau G 1986 Fundamentos y métodos de la didáctica de las matemáticas *Recherches en Didactique des Mathématiques* 7(2) 33
[3] Ministerio de Educación Nacional (MEN) 2006 *El plan decenal de educación 2006-2016. La educación que queremos para el país que soñamos* (Colombia: Ministerio de Educación Nacional)
[4] Brousseau G 2007 *Iniciación al estudio de la teoría de las situaciones didácticas* (Buenos Aires: Libros del Zorzal)
[5] Real Academia Española 2001 *Diccionario de la Real Academia Española* (España: Real Academia Española)
[6] Samper C, Leguizamon C y Camargo L 2001 *Razonamiento en geometría* Revista EMA 6(2) 141
[7] Guillén Soler G 2004 El modelo de Van Hiele aplicado a la geometría de los sólidos: describir, clasificar, definir y demostrar como componentes de la actividad matemática *Educación Matemática* 16(3) 103
[8] Ministerio de Educación Nacional (MEN) 1998 *Matemáticas. Lineamientos curriculares* (Colombia: Ministerio de Educación Nacional)
[9] Vygotsky LS 1981 *Pensamiento y lenguaje* (Buenos Aires: La Pléyade)
[10] Chamorro M 2003 *Didáctica de las matemáticas* (Madrid: Pearson)
[11] Castillo V and Popayán Y 2017 Aplicación de la teoría de las situaciones didácticas a las ciencias sociales *Educere* 21(70) 539
[12] Del-Pino J 2013 El uso de Geogebra como herramienta para el aprendizaje de las medidas de dispersión *Probabilidad Condicionada: Revista de didáctica de la estadística* 1 243
[13] Rojano T 2003 Incorporación de entornos tecnológicos de aprendizaje a la cultura escolar: Proyecto de innovación educativa en matemáticas y ciencias en escuelas secundarias públicas de México *Rev. Iberoamericana de Educación* 33 135
[14] Saidon L 2013 *Guía de Inicio Rápido* (Argentina: GeoGebra)
[15] Hernández R, Fernández P and Bapttista L 2008 *Metodología de la investigación* (México: Mc. Graw Hill)
[16] Shunk D 2012 *Teorías del aprendizaje una perspectiva educativa* (México: Pearson)
[17] Instituto Colombiano para el Fomento de la Educación Superior (ICFES) 2015 *Informe nacional resultados nacionales 2014-2 - 2016-2 saber 11* (Colombia: Instituto Colombiano para el Fomento de la Educación Superior)
[18] Jaime A and Gutiérrez A 1995 *El grupo de isometrías del plano* (Barcelona: Síntesis)
[19] Cabero J 1998 *Impacto de las nuevas tecnologías de la información y la comunicación en las organizaciones educativas* (Granada: Universitario)
[20] Marqués Graells B 2012 *Impacto de las TIC en la educación: funciones y limitaciones* 3c Tic, *Cuadernos de Desarrollo Aplicados a las TIC* 3 14
[21] Carrera B and Mazzarella C 2001 Vygotsky: Enfoque sociocultural *Educere* 5(13) 41
[22] Wertsch JV 1988 *Vygotsky y la formación social de la mente* (Barcelona: Paidós)
[23] Blanch G 1990 Vygotsky: The man and his cause *Vygotsky and education: Instructional implications and applications of sociohistorical psychology* ed L Moll (Cambridge: Cambridge University Press)