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The Impact of Using the Van Hiele Model in Developing Geometric Thinking Levels among Tenth Grade Students in Jordan.

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The Impact of Using the Van Hiele Model in Developing Geometric Thinking Levels among Tenth Grade Students in Jordan.

Abstract:
This study aimed to investigate the impact of the usage of the Van Hiele model in the development of geometric thinking levels among tenth grade students in Jordan. The sample of the study was selected from tenth grade basic students in Amman schools. Two hundred and forty students studying the mathematics course in the circle unit were divided into two groups: experimental (using the Van Hiele model) and the control (using the traditional approach of teaching).To achieve the objectives of the study, a test of geometric thinking in the unit of the circle was developed. Validity and reliability of the test was verified. The instructional material was also prepared in the circle unit for the students of the tenth grade using the Van Hiele model of geometric thinking. Four mathematics teachers were trained on the model, and the content validity of the training material was verified. The results of the study showed a statistically significant difference (α=0.01) between the two arithmetic means of the experimental and control agencies in favor of the experimental group that used the Van Hiele model in geometric thinking in general, and in sub-levels (visual, descriptive, logical), and the study showed no statistical significance difference (α=0.01) between the arithmetic means of male and female in geometric thinking, also the study showed an interaction between the model variable and gender variable in geometric thinking.

Keywords: Geometric Thinking, Van Hiele Model, Geometry, Tenth Grade.

أثر استخدام نموذج فان هايل في تنمية مستويات التفكير الهندسي لدى طلبة الصف العاشر الأساسي في الأردن

الملخص:
هدفت الدراسة إلى تقصي أثر استخدام نموذج فان هايل في تنمية مستويات التفكير الهندسي لدى طلبة الصف العاشر الأساسي في الأردن، تكونت عينة الدراسة من طلبة الصف العاشر الأساسي في مدارس عمان في الأردن، والبالغ عددهم(240) طالباً وطالبة قسموا إلى مجموعتين: تجريبية(تستخدم نموذج فان هايل)، والضابطة(تستخدم الطريقة المعتادة في التدريس)، ولتحقيق أهداف الدراسة طور الباحث اختباراً في التفكير الهندسي، تم التحقق من صدقه وثباته. وأعدت المادة التعليمية في وحدة الدائرة المقررة على طلبة الصف العاشر الأساسي باستخدام نموذج فان هايل في التفكير الهندسي، ودرّب أربعة من معلمي الرياضيات على النموذج، كما تم التحقق من صدق المحتوى للمادة التدريبية.

أظهرت نتائج الدراسة فرق ذو دلالة احصائية(α=0.05) بين متوسطي درجات المجموعتين التجريبية والضابطة في التفكير الهندسي لصالح المجموعة التجريبية التي استخدمت نموذج فان هايل في التفكير الهندسي بشكل عام، وفي كل من المستويات الفرعية(البصري، الوصفي، المنطقي)، كما أظهرت الدراسة عدم وجود فرق ذو دلالة احصائية (α=0.05) بين متوسطي درجات الذكور والإناث في التفكير الهندسي، وأظهرت نتائج الدراسة تفاعل دال احصائيا بين النموذج التدريسي والجنس لصالح الإناث.

الكلمات المفتاحية: التفكير الهندسي، نموذج فان هايل، الهندسة، الصف العاشر.

Introduction

Mathematics is an important subject in school curriculum, through which the learner can apply options to solve problems in the field's knowledge; geometric, economic, technological, technical, and medical. Mathematics is viewed as the servant and queen of other sciences. It is one of the topics of regular training in the Ministry of Education in Jordan, which requires the curriculum preparer to take into account the curricula of mathematics education, educating strategies, and the coaching of teachers before and for the duration of the course of current instructing methods. This meets the goals of society, learners, and it tackles the academic difficulties confronted when working with students in schools.

To attain the desired consequences in mathematics education, the teaching methods of mathematics need to be improved, mainly geometry in the basic curriculum, where students in schools suffer from a clear weak spot in mathematics in general and geometry in particular. This weak spot was validated by using the Trends International Mathematics and Science Study (TIMMS) 2015, with Jordan's 2015 student score under the world level of about ninety one factors (National Centre for Human Resources Development, 2016).

According to Descartes, wondering is a tool used with the aid of mathematics as an intellectual activity and a complex sensory experience aimed at educating, monitoring and developing the learner in order to measure up with trends in the data age, digital technology, and existence competencies in the 21th century (Obaid, 2004).

Mathematics has a key function in the development of thinking, justification, and proof, and the schooling of thinking and justification is one of the pillars of the primary manner on which mathematics training is based. The international requirements of mathematics curriculum emphasizes the significance of growing the skills of school students in the employment of arithmetic in fixing mathematical problems; thinking, communicating, and valuing mathematics and students' self-assurance in their capability to solve mathematical problems. The utility of standards encourages the view of mathematics as an everyday undertaking students can utilize to make sense about the world around them. Teachers vary in employing training strategies that enhance and support students' thinking (Arab Open University, 2011).

Geometry is one of the important subjects of mathematical content, and the National Council of Teachers of Mathematics emphasizes the need to pay attention to geometry content, where students learn geometry, study geometric forms, geometric construction, evaluate the characteristics and traits of geometric shapes, positioning, description of spatial relationships, application of transformations, and the use of symmetry to analyze the mathematical position (NCTM, 2000).

The standards and principles of mathematics education confirm that geometry has a key role in the basic grades, and this has been evident in the development of mathematics curricula. Many students look forward to issues, concepts, and geometric manifestations as exciting and useful, but the study of traditional geometry has become ambiguous and frustrating, and in recent years research has been directed toward starting or highlighting the achievement of the agreement between the mathematical and psychological points of view in the teaching of geometry (Awad, 2014).

Geometry teaching in schools requires that school students be in a position to analyze the traits of two-dimensional and three-dimensional geometric shapes, improve mathematical arguments about geometry relationships, set coordinates, describe spatial relationships, the usage of coordinate geometry, and other illustration systems, utilize geometry transformations and symmetries to analyze mathematical positions, use visible representation, vacuum justification, and geometry models to clear up problems (NCTM, 2000).

The research of Van Hiele (1999) is centered on geometric training and thinking, geometric thinking levels, and the function of teaching strategies in enhancing those levels among learners. At the end of the 1950s, Van Hiele (1999) developed a special concept of geometric thinking degrees based totally on the idea that the learning method is not connected, but there are leaps in the learning curve, and has research in the United States on verifying this theory, reading the levels of geometry thinking, and how regular it is with school students at all stages of education.

The levels of geometric thinking as recognized by Van Hiele (1999) in his model of teaching geometry in 5 levels are:
1.Visual level: At this level learners research geometry through the sense of sight and examine the geometric shapes. Students understand the shapes through play, categorize them, and describe them in their personal style. They recognize examples and counter examples, and they draw geometric shapes, look at the kinds of angles and straight lines in an informal way (i.e. the examination does not encompass the scientific definition of these principles in a practical intuitive way).
2. Descriptive level: At this level, the learners classify the shapes and write or interpret the classification standards they use. They select and build geometric shapes, model the usage of geometric tools, and make use of triangles or different forms where they observe and write their observations about equal angles, triangles, equal shapes, and similar triangles. Using general formats, students measure the aspects and characteristics of these forms, justify their conclusions to these characteristics, write down the properties that have been deduced for all polygons, and then commence the system of sorting these characteristics in each form.
3. Logical: At this level, the learners arrange the characteristics logically, settles down one by means of one, and employs the characteristics he knows to shape definitions by which they justify relationships. At this stage, the scholar does not apprehend the basic essence of the meaning of the conclusion which is the function of the assumptions, definitions, and theories.
4. Inference level: Through it the learner employs the mathematical inference proof, which relies upon definitions, assumptions and theories and reverse them in proving the validity of a theory. In this stage the student thinks mathematically through the mathematical building that depends on the imposed assumptions and any change in these assumptions adjusts the mathematical construction.
5. Abstract level: In which the student is favored and valued to explore one-of-a-kind mathematics activities systems and the mathematical logical system. This level is generally related to university studies (Matthews, 2004).
Van Hiele believes that the transition from one level to other (Salameh, 2005) is now not only via maturity or age, but also relies upon on the teaching method and the content of geometry and education. The cognitive and mental development of geometry subjects is done through education, accelerated learning processes, and is done in five consecutive steps:
Step 1: Survey and information gathering: This step includes introducing the prerequisites for the principles to be learned. The teacher is able to identify splendid activities, and in this step, he will introduce college students to the basic standards and abilities of learning.
Step 2: Guided presentation: In this step the teacher encourages students to apply academic activities and discover geometry standards and characteristics. The teacher coaches and supervises students, and assists learners to use tools, and to pick out geometry types as primary information for all students.
Step 3: Free guidance: In this step learners practice free discovery in all its meanings, by means of carrying out tasks related to geometry topics without prior knowledge of the form or the help of the teacher, and the college students have the capacity to find out geometry generalizations and resolve geometry problems.
Step 4: Clarity: In this step, students linguistically categorize their experiences through the use of the language of geometry, exchange ideas about geometry structures, specify their views on geometric shapes and their characteristics, and the role of the teacher is guidance and preparation only, with the least possible instructions.

Step 5: Integration: In this step the instructor affords the opportunity for learners to summarize information, deduce unique characteristics, and give a holistic and integrated view of the lesson.

There are many previous studies that have examined the impact of the use of the Van Hiele model in the improvement of geometric thinking. Al-Harbi (2015) conducted a study to locate the effect of the Van Hiele model on the levels of geometric thinking in middle-class students in the governorate of Al-Qurayat. The study was applied to the geometry and spatial inference unit, and the results of the study confirmed a difference between the experimental group and control group in both the pictorial, analytical and quasi-inference levels in favor of the experimental group.

Kilani (2013) conducted a study to perceive the impact of the Van Hiele model in the development of geometric thinking and self-confidence amongst students of the Fifth Scientific Governorate in Damascus governorate. The results of the study showed a distinction between the arithmetic means of the two experimental and control groups in each geometry question and self-confidence in favor of the experimental group. The results of the study showed that the experimental is impact in creating geometry questions competencies to attain students to the level of abstract inference in the subjects of stereoscopic geometry.

Yenli & Korkmaz (2013) conducted a study about the relationship between self-efficiency in geometry and the degree of geometric thinking. In addition to analyzing differences in self-efficiency in geometry according to variables: sex, grade, educational achievement, and used the Van Hiele scale in geometry thinking, as well as a test of self-efficacy, and the results of the study showed a vulnerable correlation between self-efficacy and geometric thinking, as the results of the study showed variations in self-efficacy in accordance to the gender, class, achievement.

Skrbec & Cadez (2015) conducted a study to perceive the levels of geometric thinking among students in the primary stage in Slovenia; the study's results confirmed that there had been 4% of students at the zero level, 61% between the zero and first level, and 32% at the first level, and the 2d level only 1% of students. The results of the study also confirmed the weakness of students in the preference of geometry language.

Oral & Elhan (2012), investigated the levels of geometric thinking among secondary and primary teachers before service, and their relation to some variables, the results of the study showed that the teachers did not reach the required level, there are no differences between teachers in the secondary and primary levels, as well as no differences between the related to gender, and the type of secondary school certificate in the level of geometric thinking.

In a study conducted by Cacmac & Kubra (2014) to investigate the levels of geometric thinking of pre-service teachers in Turkey, the results of the study show that teachers are mostly in the third level, and there are no differences in the level of geometric thinking due to gender, age and the cumulative rate overall average.

Fidan & Turnuklu (2010) performed on fifth grade students. The results of the study showed that nearly half of the students did not reach the first level and 28% reached the first level, indicating a low level of geometric thinking in primary school students, and the results of the study showed differences related to gender as well as the level of parental education.

In the field of the need to train teachers before service, Koparan & Yilmaz (2016) conducted a study aimed at investigating the impact of designing geometry lessons on the development of the level of geometric thinking among pre-service teachers in Turkey, and the results of the study showed the impact of geometry lessons on raising the level of geometry thinking among teachers.

The current study differs from previous studies in the use of the Van Hiele model in the improvement of geometric thinking levels among the students of the tenth grade in Jordan and in the unit of the circle, and to grant an instruction model according to specific steps of current geometry theories, and to employ them in the development of levels of geometric thinking.

Problem of the Study:

The results of international research in mathematics and science carried out on Jordan's students indicated that Jordan's students in grades four and eight have been decreasing in comparison to the world's superior test countries where the average rating of Jordan's students in 2015 was beneath the world level. This required an examination of the causes such as an imbalance in the curriculum, and required the use of present day educating strategies and strategies tailored to modern necessities (National Center for Human Resources Development, 2016).

The regular report Program International Students Assessment (PISA) revealed that the results of Jordan students in the tenth grade in mathematics, science and languages are weak, and in all sub-areas of each, especially in solving the difficulty of mathematics, thinking, Sheikh (2007) shows a decline in mathematical achievement, mathematical thinking, and students' mastery of the basic abilities of Jordan students, and the study of compensation (2017) suggests a weak spot in geometric thinking amongst tenth-grade students in Jordan. According to the Study of Al-Khasawneh (2007), 19% of students did not attain the pictorial level of geometric thinking, and 9% of these have been no longer ranked at any level of geometric thinking.

The gender variable may have an effect on geometric thinking, as some studies indicated the existence of gender differences in geometric thinking, Sudihartinih & Wahyudin (2019) study showed that there are differences between males and females in favor of females, also Hamzah's study (2017) also showed that there is a difference in favor of females in engineering thinking among a sample of class teacher students in Jordan.

Based on the above, this study was primarily based on the impact of the Van Hiele model on the improvement of geometric thinking levels amongst students in the tenth grade in Jordan.

Questions of the Study:

1. What is the impact of the Van Hiele model on improvement of the geometric thinking levels amongst tenth graders in Jordan?
2. Do the levels of geometric thinking among the students of the tenth grade in Jordan vary according to gender (male, female)?
3. Is there an interaction between the teaching Model and gender in geometric thinking among the students of the tenth grade in Jordan?

Terminologies of the Study:

Geometric Thinking: Defined as a structure of geometric thinking or mental activity that is based totally on a set of mental processes that are the ability of students to raise out a set of activities unique to every level of geometric thinking: visual, descriptive and logical. It is measured by way of the mark obtained by the student through the geometric thinking test of the unit of the circle.

Van Hiele's instructing Model: An educating model for teaching geometric topics in accordance to the following steps: survey and information gathering, guided presentation, free guidance, clarity, and integration.

Importance of Study:

The mathematics curriculum is aimed at all levels of study for the improvement of thinking. Geometry is one of the branches of mathematics, and via the content of geometry students are educated in integral products such as the ability to clear up geometric problems, geometric thinking, and proof. Consequently, it is critical to supply applications and plans to assist students and instructors to advance their geometric thinking.

Geometry consists of essential skills such as drawing and measurement, as well as geometry concepts where it is acknowledged that a student's suitable appreciation of the notion constitutes a right mathematical structure, so that the learner is able to resolve geometric problems.

The teacher's consciousness of the ways and levels of development of geometric thinking, and his information of the level of thinking reached by the learner as a way to address the issues of novices in geometry, and taking into account that geometric thinking is an educational outcome that can be developed and measured through curricula and contemporary instructing models, where research emphasizes the significance of using techniques for teaching mathematical proof and geometric thinking in teaching mathematics (Cirillo, 2009). This study provides a model of how to instruct the content of geometry, display geometric theories, supply options to geometric problems, and study geometry in a way that develops students' ability to understand geometrically, and it provides a theoretical framework on the stages of geometric thinking, discovering the level of students in geometric thinking and ways of creating them.

Based on the significance of training in-service teachers on thinking development models, particularly geometric thinking, and the significance of geometry in the improvement of geometric thinking, present day research has gained importance in figuring out the impact of the Van Hiele model in the improvement of geometric thinking levels for students in the tenth grade in Jordan.

Limitations of the Study:

1. Students in the tenth grade for the academic year 2019/2020 in the governorate of the capital Amman in Jordan.
2. Geometric thinking was limited to levels: visual, descriptive, logical.

Methodology:

The sample of the study consisted of students in the tenth grade in the governorate of the capital Amman in Jordan. Four schools in Amman were selected randomly for the academic year 2019/2020 for the first semester, numbering (240) students. The sample of the study was divided into two groups, one experimental (119) students and the other control (121) students. The following table shows the distribution of the study’s sample members.

Table 1. The Sample of the Study Distributed According to Gender and Group.

	Experimental	Control	Total
males	60	60	120
females	59	61	120
Total	119	121	240

To achieve the objectives of the study, a test of geometric thinking was used. The test was aimed at measuring the levels of geometric thinking in the circle unit, and the test was prepared after reviewing the theoretical framework and levels of geometric thinking, reviewing related studies , for example: (Khasawneh, 2007), (Van hiele,1999).

The test consisted of 27 paragraphs distributed at the three levels:

Visual level: From nine paragraphs distributed three paragraphs for each of the following sub-skills: knowledge, analysis, and deduction.

Descriptive level: Nine paragraphs divided into three paragraphs for each of the following sub-skills: knowledge, analysis, and deduction.

Logical level: Nine paragraphs divided into three paragraphs for each of the following sub-skills: knowledge, analysis, and deduction.

Test reliability: The internal consistency of Cronbach (α) was used, with a test reliability factor (0.87) acceptable for the current study, and the following table shows reliability coefficients for each level of geometric thinking:

Table 2. Reliability Coefficients for Each Level of Geometric Thinking, and Total Reliability.

level	Visual	Descriptive	Logical	Total
Reliability coefficient	0.85	0.0.86	0.88	0.87

Test validity: The validity of the test was verified through the virtual integrity of the test paragraphs, where it was presented to a group of arbitrators with competence and experience in the field of mathematics teaching methods, and in the light of their observations some paragraphs were amended.

It was also verified using the construction validity of the test, where correlation coefficients were calculated for each level of geometric thinking with geometric thinking in general, and the following table shows the correlation coefficients:

Table 3. Coefficients of Correlation of Levels of Geometric Thinking with Macro Geometric Thinking.

Level	Visual	Descriptive	Logical	Total
Visual	1.0	0.98	0.95	0.96
Descriptive		1.0	0.92	0.97
Logical			1.0	0.95
Total				1.0

From the previous table, correlation coefficients were high and ranged from (0.92-0.97), indicating the high construction of this study with its domain.

Methodology of the study: The study used the quasi-experimental method, with two groups, one experimental and the other controlled, and the equivalence between the experimental and control groups in previous geometric thinking.

Procedures of the study:

1. Reviewing the theoretical framework and levels of geometry thinking, the teaching performances of the Van Hiele model in the development of geometry thinking, as well as previous studies with regard to geometry thinking.
2. Prepare the study tools and verifying their sincerity and consistency.
3. Select the study sample from the students of the tenth grade basic year 2019/2020 during the first semester, identify two male and two female schools, and divide the study sample into two groups, one of which is the experimental group (using the Van Hiele model in teaching), and the control group (using the usual method of teaching), and randomly distribute them into two groups.
4. The government's decision to grant a child-care grant to the child is a matter of concern to the child.
5. To verify the equivalence of the experimental and control study groups, the T test was used to study the differences between the two groups in previous geometry thinking in mathematics, and the following table shows this:

Table 4: Indication of Differences Between the Average Scores of Students of the Experimental and Female Studies in the Previous Geometric Thinking.

Group	No.	Arithmetic means	S. D	T-value	Sig.
experimental	119	71.04	10.45	0.390	0.811
control	121	71.45	10.12		

In the previous table, there is no difference between the averages of the experimental and controlled groups in geometric thinking, indicating the equivalence of the two groups: experimental and control.

Applying the geometric thinking test to the study groups (experimental and control).

6. Data dumping of students' responses to the tool on Excel, use of SPSS, extraction of arithmetic averages and standard deviations" for geometric thinking levels, and use of MANOVA multivariate analysis.

7. Reaching the results of the study, discussing it, and writing recommendations.

Results:

This study aims to reveal the impact of using the Van Hiele model in the development of geometric thinking levels among students in the tenth grade in Jordan.

To answer the study's first question:

1. What is the impact of the Van Hiele model on the development of geometric thinking levels among tenth graders in Jordan?

Arithmetic means and standard deviations of student scores were used in levels of geometric thinking (visual, descriptive, logical) and for both experimental and control groups, and the following table shows this:

Table 5: Arithmetic Means and Standard Deviations of Student Scores in Levels of Geometric Thinking (Visual, Descriptive, Logical) in Both Experimental and Control Groups.

Level	Gender	Experimental group			Control group		
		No.	means	S.D	No.	Means	S.D
Visual	Males	18	68.39	7.34	18	66.11	8.34
	Female	18	81.61	8.42	18	62.50	12.74
	Total	36	75.00	7.88	36	64.30	10.54
Descriptive	Males	24	73.37	10.79	24	58.79	10.61
	Female	24	79.00	9.55	24	54.75	5.57
	Total	48	76.19	10.47	48	56.77	8.63
Logical	Males	18	84.72	12.14	18	77.56	13.61
	Female	17	77.18	9.27	19	55.26	5.91
	Total	35	80.95	10.75	37	66.11	15.25
Total	Males	60	75.28	8.25	60	66.62	9.25
	Female	59	79.27	9.35	61	57.20	10.23
	Total	119	77.23	9.65	121	61.87	9.76

The previous table shows that the arithmetic means of students of the experimental group (77.23) is higher than the arithmetic means of the students of the control group (61.87), a difference of 15.36 and the previous rule applies to each male student group, with the average calculation of the experimental group (75.28), for the control group (66.62), for female students the average calculation of the experimental group (79.27) and for the control group (79.27).

There is an increase in the arithmetic means of experimental groups in geometric thinking that used the Van Hiele model of teaching on the arithmetic means of the control groups at each level of geometry thinking: visual, descriptive, and logical - consequently: 10.7, 19.42, 14.84.

To reveal the significance of the differences between the two experimental and control groups at each level of geometric thinking, and geometric thinking in general, MANOVA analysis was used as described in the following table:

Table 6: Multivariate Analysis of Variance (MANOVA) to Indicate Differences Between the Average Scores of Students of the Experimental and Control Groups in the Levels of Geometric Thinking.

	Source	Sum of squares	d.f	variance	F-value	Sig.
Visual	Group	1275.125	1	1275.125	8.854	*0.004
	Gender	415.681	1	415.681	2.886	0.094
	Group*Gender	2058.681	1	2058.681	14.295	*0.000
	Error	9792.833	68	144.012		
	Total	13542.319	71			
Descriptive	Group	9048.167	1	9048.167	103.074	*0.000
	Gender	15.042	1	15.042	.171	0.680
	Group*Gender	560.667	1	560.667	6.387	*0.013
	Error	8076.083	92	87.784		
	Total	17699.958	95			
Logical	Group	1635.673	1	1635.673	14.535	*0.000
	Gender	1768.248	1	1768.248	15.713	*0.000
	Group*Gender	2751.525	1	2751.525	24.451	*0.000
	Error	7652.210	68	112.533		
	Total	14027.875	71			
Total(Geometrical thinking)	Group	10432.72	1	10432.72	79.78	*0.000
	Gender	88.71	1	88.71	0.678	0.41
	Group*Gender	4738.31	1	4738.31	36.233	*0.000
	Error	30862.30	236	130.77		
	Total	46122.04	239			

In the previous table there is a statistically significant difference (α = 0.01) between the mathematical average of the scores of students of the experimental and control groups in favor of the students of the experimental group in geometric thinking in general, where the value of (P) for the students of the two groups (79.78) is statistically significant at the level (α = 0.01).

It is also noted that there is a statistically significant difference (α = 0.01) between the mathematical average of the scores of students of the experimental and control groups in favor of the students of the experimental group at each level of geometric thinking (pictorial, descriptive, logical).

To answer the study's second question:

2. Does the level of geometric thinking among the students of the tenth grade in Jordan vary by gender (male, female)?

Multivariate analysis of variance (MANOVA) was used to reveal the differences between the means scoring of male and female students, as shown in Table 6.

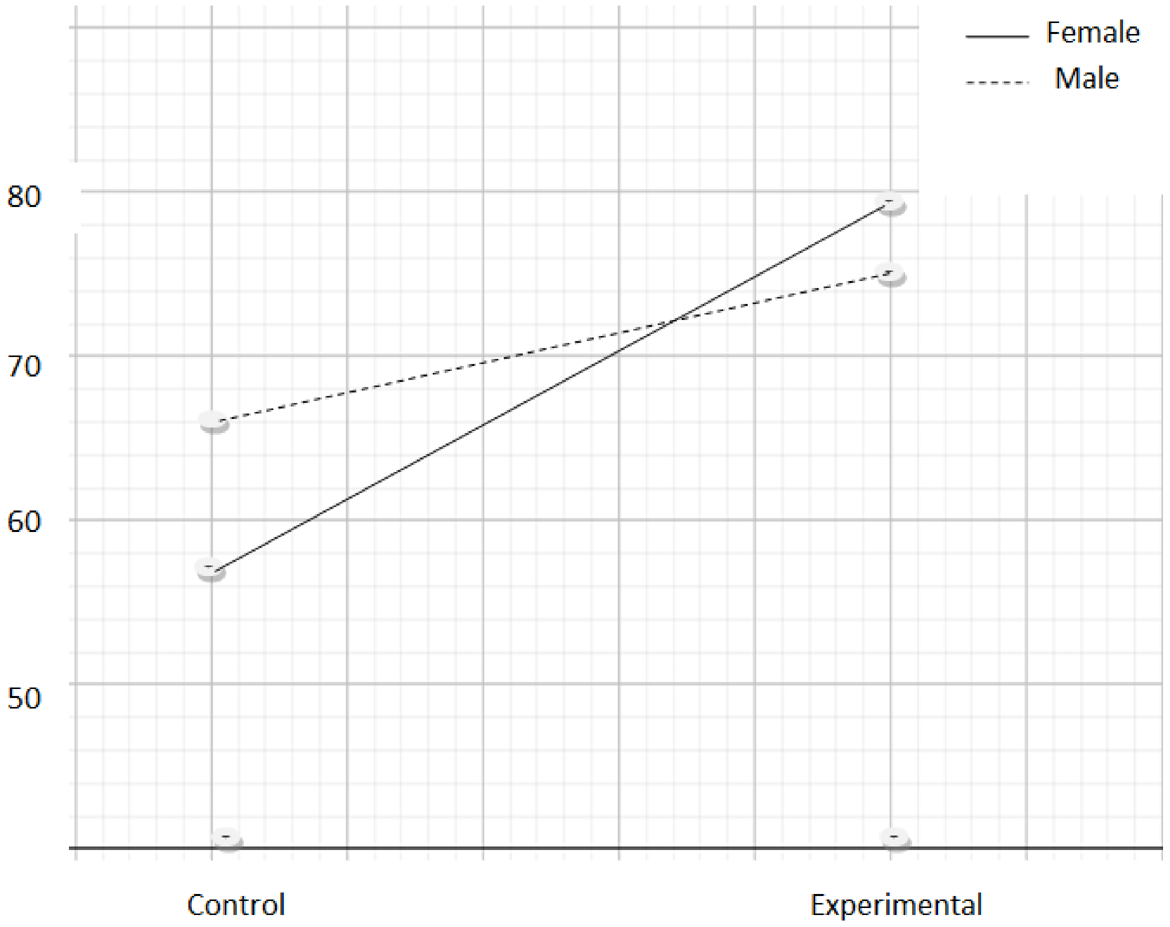
It is noted from Table 6 that there is no statistically significant difference (α = 0.01) between the arithmetic means of students' scores in geometric thinking, where the value of (F) for students of the two groups (0.678) is not statistically significant at the level (α = 0.01).

And to answer the third question:

3. Is there an interaction between the teaching Model and gender in geometric thinking among the students of the tenth grade in Jordan?

Multivariate analysis of variance (MANOVA) was used to reveal an interaction between the teaching Model and the gender in geometric thinking among the students of the tenth grade in Jordan, as shown in Table 6.

It is noted from Table 6 that there is a statistically significant interaction between the Model and the gender in geometric thinking among the students with f-value (36.233) and significant level (α =0.01), and the following figure shows the interaction:



Figur1. The interaction between the Model and gender in Geometric thinking.

The figure above indicates that the group variable (experimental and control) is not independent of the gender variable, and we notice that the lines intersect, which means that the model impacts the females more than the males, since that the increasing of females scores is (22.07), while for males is (8.66).

And to find out the significance of the gender differences in geometric thinking, Scheff'e Test was used between the means of the experimental and control groups, for both males and females, and the following table explains that:

Table 7. Dimensional comparisons of the differences between each of the two means according to the interaction between the group and gender variables.

		Gender variable	*differences*	*Sing.*
	control	*Females*	*3.99*	*0.000*
		males		
Group	*experimental*	*Females*	*-8.58*	*0.000*

variable		*Males*		

It is noticed from the above table that there are differences between the averages of males and females in engineering thinking in the experimental group in favor of females, while in the control group in favor of males.

Discussion

The results of this study shows the impact of using the Van Hiele model in the development of all levels of geometric thinking among the students of the tenth grade in Amman schools, where the teaching of geometric subjects and specifically the circle and its theories needs to employ a teaching model with its specific and clear procedures and steps, as demonstrated in the teaching model prepared in its five consecutive steps.

One of the advantages of Van Hiele's geometry teaching model is that in the first step it focuses on reviewing the previous requirements necessary for new learning, as confirmed by the Ausubel model of teaching.

One of the characteristics of the Van Hiele model is the sequence or hierarchy, which emphasizes the need for previous learning in order to teach subsequent experiences, juxtaposition, discrimination, segregation and acquisition, which means the ability to move students from a higher level of thinking (Fuys, et al, 1988).

The Van Hiele model also emphasizes the learner's self-confidence through encouragement, promotion, and active participation by the learner, and notes that the model provides an atmosphere of freedom and democracy in the implementation of activities, which drives students to learn and discover geometric theories and prove them, reduces academic anxiety related to geometry study, and infers geometry generalizations.

According to Salama (2005), the transfer of students from one level to another in geometric thinking depends on the strategy used in teaching, so it is possible that Van Hiele's model has the potential to develop students' geometry thinking and proof skills.

The Van Hiele geometric thinking model also helped teachers in the service acquire teaching skills with new models, as confirmed by the Koparan & Yilmaz study on the impact of Van Hiele's geometric thinking lessons in raising teachers' geometric thinking, and introducing them to the teaching steps of the Van Hiele model has an impact on increasing the level of geometric thinking among students.

Also, it was noted that there is an impact of the interaction between the teaching model and gender in the development of geometric thinking, meaning that the effect was greater for females than males, so the method of teaching is not independent of gender, and the increasing of male scores reached to (8.66), while for females (22.07), despite the impact of the teaching model for both males and females, but it has more impact in females, and this may be due to the nature of females in the Arab environment since they are more serious and commitment during the application of modern strategies.

This finding is consistent with the study of Ghonim (2012), Al-Harbi (2015) and Kilani (2013) on the impact of using Van Hiele's strategy to develop critical thinking, geometry thinking and self-confidence.

Also consistent with the study of Hamzah (2017) regarding the superiority of females over males in geometric thinking, especially in groups that receive training in geometric thinking.

Recommendations: The researcher recommends the use of the Van Hiele model in the development of geometric thinking among students of the tenth grade basic, specifically when teaching geometry content, because of the impact of this model in providing information and expertise in the field of geometry in an orderly, methodical and complementary way. This model is effective in the development of geometric thinking for both types (males and females). The researcher also recommends the need to train mathematics teachers on modern strategies and models in teaching geometry subjects, particularly geometry proofs, and how to present and prove geometry theories. The researcher also recommends further studies on the impact of the Van Hiele model on the development of geometric thinking in students of the basic, secondary and university stages, and further studies should examine the impact of the model in the development of other outcomes such as the problem solving, mathematics communication, representation, and mathematical thinking.

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