

Research Article

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The Most Common Conceptual Errors in Primary School Geometry

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Abstract

Background/purpose. It is an urgent necessity to identify geometric conceptual errors among students at different levels. These errors cannot be ignored, as they hinder the learning of related concepts. Teachers need to be aware of these errors, which are often embedded in students' cognitive structures, so that they can work on eliminating them and providing mathematically accurate alternative concepts. Some fruitful efforts have been made in exposing misconceptions in geometry; however, more research is required in this area, especially in Jordan, where the researcher works as a faculty member in the field of mathematics education at the Arab Open University. To the researcher's knowledge, no studies have been conducted on identifying conceptual errors in geometry or methods to address them among students in Jordan.

The Purposes of the Current Study are as follows: 1. To identify the most common conceptual errors in geometry among sixth-grade students. 2. To explore mathematics teachers' perceptions of students' conceptual errors in geometry. 3. To propose strategies for eliminating conceptual errors in geometry.

Materials/methods. Both quantitative and qualitative methods were employed to achieve the study's objectives. The researcher administered the Geometric Test (GT) to identify common conceptual errors in geometry among sixth-grade students and designed the Face-to-Face Interview Protocol (FFIP) to explore mathematics teachers' perceptions of students' conceptual errors in geometry.

Results. The results of this study show that all students exhibited a variety of misconceptions in geometry. All conceptual errors targeted by the Geometric Test (GT) were present in varying proportions among sixth-grade students. In most cases, the teachers interviewed demonstrated a high level of awareness regarding the conceptual errors commonly made by students at this level. The researcher presented a set of suggestions for addressing conceptual errors in geometry, based on both the literature and the viewpoints of sixth-grade mathematics teachers.

Conclusion. Misconceptions in geometry are common among sixth-grade students. They exhibit several misunderstandings related to plotting points, right and straight angles, complementary angles, translation, reflection, quadrilaterals, polygons, and the distinction between a chord and a diameter. Undoubtedly, these conceptual errors negatively affect students' achievement and performance in geometry. Teachers need to be aware of these misunderstandings and identify them by presenting contradictory information that supports the process of conceptual change during geometry lessons.



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1. Introduction

Mathematical concepts form the foundation of mathematical knowledge. Students with a strong conceptual understanding are better equipped to progress to advanced mathematical topics and complex knowledge structures. Such concepts are acquired through various sources, including the surrounding environment, classrooms, teachers, and peers (Al-Rababaha et al., 2020). When a mathematical concept is incorrectly formed in a learner's mind, it results in a misconception (Karadeniz et al., 2017). These conceptual errors, often deeply embedded in cognitive structures, hinder the comprehension of new mathematical knowledge and obstruct progress across different branches of mathematics and related disciplines.

Geometry education enables students to analyze their surroundings, interpret daily phenomena involving shapes and solids, and accurately calculate areas and volumes. Geometric concepts broaden students' understanding of their environment. Numerous studies (e.g., Mosia et al., 2023; Uygun & Altıntaş, 2023; Gida et al., 2020; Aktaş & Ünlü, 2017; Öçal, 2017; Özerem, 2012; Kembitzky, 2009) have documented the prevalence of conceptual errors in school geometry and their detrimental effects on student performance and achievement. According to Cho and Win (2020), learners often become emotionally and intellectually attached to their misconceptions, having either actively constructed them or relied on ready-made problem-solving methods. These misconceptions interfere with learning by influencing how students explain new experiences.

Detecting geometric misconceptions across educational levels is imperative. Ignoring these errors undermines students' acquisition of accurate mathematical concepts. Teachers must recognize these misconceptions, frequently rooted in students' cognitive frameworks, in order to address and correct them, replacing flawed ideas with mathematically accurate alternatives. Within the constructivist paradigm, error correction and misconception modification are vital for learning development. Errors are not merely inevitable, but they also serve as valuable indicators of the learning process (Kembitzky, 2009). Aktaş and Ünlü (2017) emphasize that classroom assessment of misconceptions plays a crucial role in leveraging them to improve conceptual understanding. Therefore, developing and implementing strategies that enable teachers to use misconceptions as learning tools is essential.

In Jordan, the mathematics curriculum features a sequential and interconnected set of geometric concepts across grade levels. Like their international peers, Jordanian students are expected to encounter common conceptual errors in geometry. The TIMSS 2023 results, focusing on geometry and measurement, revealed a significant decline in mathematics achievement among Jordanian students in grades 4 and 5. Similarly, PISA 2022 results highlighted concerns regarding Jordanian students' performance in mathematics. This study focuses on geometry concepts taught in grades 5 and 6, which serve as foundational years for more advanced topics. At this stage, the curriculum encompasses fundamental concepts, including straight angles, full rotation angles, polygons, triangles, quadrilaterals, translation, reflection, circles, and the coordinate plane. A solid understanding of these concepts is essential for students to successfully engage with more complex geometry in later grades and to apply their knowledge in novel contexts.

Although some research has addressed misconceptions in geometry, further investigation is needed, especially in Jordan, where this study is based. As future educators, students at the Arab Open University and other institutions must be aware of common conceptual errors to prevent and address them effectively in their teaching. This research aims to provide an empirically validated list of prevalent conceptual errors in geometry, supported by examples and frequency data. To the researcher's knowledge, no prior studies have systematically identified geometric misconceptions or effective interventions among Jordanian students. Understanding and detecting these errors is

critical to improving student outcomes in geometry and addressing the underlying causes of poor performance. The Purposes of Current Study are as follows:

1. To identify the most common conceptual errors in geometry among sixth-grade students.
2. To explore mathematics teachers' perceptions of students' conceptual errors in geometry.
3. To propose strategies for eliminating conceptual errors in geometry.

2. Literature Review

2.1. *Misconceptions Related to Shapes and Transformations*

Students' misconceptions in geometry can lead to confusion, frustration, and a lack of confidence, ultimately hindering the development of a positive attitude towards mathematics and an appreciation for its structure and beauty (Cho & Win, 2020). They have identified frequent misconceptions related to triangles, triangle congruence, quadrilaterals, circles, angles, parallel lines, and the Pythagorean theorem. Özerem (2012) observed that many learners struggle to distinguish between types of angles in parallel lines, such as corresponding and alternate angles, and have difficulty differentiating between quadrilateral types and their respective properties.

Solaiman et al. (2017) found that most learners function at Level 2 of the Van Hiele model of geometric thinking—the visualization level—where they interpret geometric concepts based on appearance rather than properties. This often results in misconceptions. Likewise, Alex and Mammen (2016) noted that students tend to apply visual reasoning when tasks require logical reasoning at Level 3 of the Van Hiele model. Biber et al. (2013) confirmed this by reporting that students perceive geometric shapes as whole visual entities without recognizing or understanding their properties.

Brijlall and Abakah (2022) argue that a lack of foundational knowledge prevents learners from applying appropriate methods to solve problems in circle geometry. Learners often fail to make necessary conceptual connections across different areas of geometry. In the same vein, Mosiaa et al. (2023) focused on misconceptions related to the theorem concerning the angle at the center of a circle. They found that many students were unable to correctly identify the relationship between central angles and inscribed angles that subtend the same arc. Some learners classified cyclic quadrilaterals based on visual appearance rather than on logical or property-based reasoning. Okal (2017) attributed these misconceptions to incorrect or misleading content in teaching materials and emphasized the usefulness of dynamic geometry software such as GeoGebra in diagnosing and addressing such errors.

Aktaş and Ünlü (2017) found that some students incorrectly believed that the image of a figure under transformation must be identical rather than actually similar. They also observed that students often identified rhombuses based on mental images rather than analyzing properties, sometimes mistaking squares for rhombuses. Kemberitzky (2009) noted that many students failed to recognize congruent or supplementary angle relationships formed by a transversal intersecting parallel lines and could not justify the hierarchical properties of quadrilaterals within a logical framework.

2.2. *Misconceptions Related to Area and Volume*

Gida et al. (2020) emphasized the lasting impact of geometric misconceptions, noting that mathematics concepts are interrelated and not isolated. They categorized geometric misconceptions into three main types:

- a. Theoretical: Errors in applying formulas for surface area and volume of solids.
- b. Correlational: Misunderstandings about relationships between geometric shapes, such as quadrilaterals.

c. Classification: Incorrect identification or categorization of triangles and other figures.

Özerem (2012) found that the oral presentation of formal proofs in geometry often leads to cognitive overload, contributing to conceptual errors. For instance, some students calculate the area of a triangle by simply multiplying the base and height without dividing by two, or they mistakenly divide the area of a parallelogram by two.

Uygun and Altıntaş (2023) raised concerns about misconceptions held by secondary school mathematics teachers themselves. Some teachers incorrectly defined basic terms, such as the concept of a “dot,” or believed that the side faces of all prisms must be rectangles. For primary school teachers, common misconceptions were found in basic geometric concepts, especially regarding quadrilaterals and prisms. Mbusi (2016) reported that most pre-service teachers had not progressed beyond Level 2 of the Van Hiele model, which further limited their ability to teach geometry effectively and contributed to the perpetuation of misconceptions.

2.3. Addressing Conceptual Errors: Gaps and Opportunities

The current study aimed to identify both expected and previously underexplored misconceptions among sixth-grade students. These include incorrectly assigning points to the axes or quadrants on the coordinate plane, misapplying rules for translation, misidentifying image points under reflection across the x-axis or y-axis, confusing the diameter and chord of a circle, miscalculating unknown angles on a straight line, and failing to correctly identify regular shapes based on their properties. In addition to identifying misconceptions, the study qualitatively explored mathematics teachers' perceptions of these errors, their underlying causes, and strategies for addressing and proactively preventing such misconceptions in geometry instruction.

3. Methodology

3.1. Research Design

Both quantitative and qualitative methods were employed to achieve the objectives of this study. The researcher administered a Geometric Test (GT) to uncover common conceptual errors in geometry among sixth-grade students and developed a Face-to-Face Interview Protocol (FFIP) to explore mathematics teachers' perceptions of students' conceptual errors in geometry. Based on the findings from the literature and the insights of sixth-grade mathematics teachers, the researcher proposed a set of recommendations for addressing these conceptual errors. The study involved 56 male sixth-grade students and 10 mathematics teachers from Irbid City, Jordan.

3.2. Instruments

3.2.1. Geometric Test (GT)

To identify students' conceptual errors in geometry, the GT included questions designed to expose 14 common conceptual errors. A content analysis of fifth- and sixth-grade mathematics curricula was conducted to identify the conceptual errors most likely to occur. The GT tasks required students to:

- Place different points on the coordinate plane, both within quadrants and on the axes.
- Determine the coordinates of a point based on its location relative to another point.
- Identify the rule for translating an object from one location to another on the coordinate plane.
- Determine the image of a point under reflection across the x-axis or y-axis.
- Identify the relationship between diameter and a chord in a circle.

- Calculate the value of an unknown angle on a straight line.
- Classify a four-sided figure into as many categories of quadrilaterals as possible.

3.2.2. Face-to-Face Interview Protocol (FFIP)

The FFIP was used to collect qualitative data from mathematics teachers. Interview participants were asked to:

- Predict the types of conceptual errors that each GT item might reveal.
- Explain the underlying causes of these errors.
- Suggest strategies for addressing the errors.
- Recommend proactive measures teachers could take to prevent such errors.

3.2.3. Validity and Reliability

The GT was reviewed by three experts in mathematics education to ensure that each item effectively targeted one or more common misconceptions in geometry. Similarly, the FFIP was validated by the same experts to confirm that each interview question was appropriate for identifying teachers' perceptions and eliciting suggestions to address conceptual errors. To assess the internal consistency of the GT, Cronbach's alpha was calculated. The result was 0.765, indicating an acceptable level of reliability (Yasin et al., 2018).

4. Results

The results of this study indicate that all students exhibited a variety of misconceptions in geometry. All the conceptual errors targeted by the Geometric Test (GT) were present among sixth graders, though in varying proportions. The misconceptions identified in this research were categorized into four subsections as follows:

4.1. Misconceptions in Assigning Points on the Coordinate Plane

The most common misconception in this category was the incorrect placement of points on the coordinate plane axes. Approximately 52% of students incorrectly placed points $B(0, 3)$ and $C(-5, 0)$ on the wrong axes. Additionally, 29% of the students placed point $A(3, -4)$ in the wrong quadrant or incorrectly within the fourth quadrant.

Table 1. Samples of students' geometric misconceptions in the first category

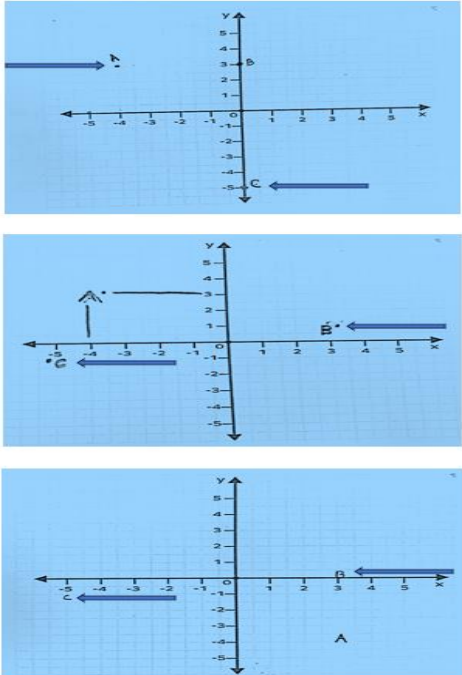
Item	Some students' answers
1. Plot each of the following points on the coordinate plane: A (3, -4), B (0, 3) and C (-5, 0).	

Table 2. Percentages of the most common misconceptions about assigning points to the coordinate plane misconceptions

Misconceptions	No. of Students	Percentages
Placing points on a wrong axis	29	52%
Placing points in a wrong quadrant or in a wrong place	16	29%

The teachers interviewed demonstrated a high level of awareness regarding the conceptual errors made by students in this category. They indicated that some students place points incorrectly, fail to distinguish between the x-axis and the y-axis, and misuse the signs of coordinates. They identified several reasons for these misconceptions:

Teacher 1: "These misconceptions occur as a result of the teaching method or the incorrect approaches that parents use when teaching geometric concepts to their children."

Teacher 2: "Students rely on rote memorization of these concepts, so they confuse the variables x and y when trying to assign points."

The use of teaching methods that rely on rote memorization often leads to a weak understanding of geometric concepts, limiting students' ability to solve related problems. When taught through memorized formulas alone, students struggle to apply geometric concepts in new or unfamiliar situations.

4.2. Misconceptions related to translation and reflection

The participants demonstrated several misconceptions related to translation and reflection. Approximately 55% of them incorrectly wrote points such as (9, -4), (1, 10), (8, -3), or (2, 3) as the

image of the point $(5, -7)$ after a translation of 4 units to the left and 3 units up, instead of the correct image, $(1, -4)$.

The second misconception involved incorrectly determining the rule for the translation of an object from one location to another on the coordinate plane. Fifty percent of the participants were unable to identify the correct translation rule, and none of them expressed it in the standard form $(x + a, y + b)$.

The third most common misconception in this category was inaccurately finding the image of a point under reflection about the x-axis or y-axis. About 25% of students incorrectly wrote points such as $(3, -5)$ or $(-3, -5)$ as the image of the point $(3, -5)$ reflected over the x-axis, instead of the correct image, $(3, 5)$. Similarly, they wrote points like $(2, 3)$ or $(-2, -3)$ as the image of the point $(-2, -3)$ reflected over the y-axis, instead of the correct image, $(2, -3)$.

Table 3. Samples of students' geometric misconceptions in the second category

Item	Some students' answers
1. Find the image of the point $(5, -7)$ after a translation 4 units left and 3 units up.	$(8, -3)$
2. Find the rule of translation that moves the airplane from site A to the Site:	7 وحدات لليسار و ٥ وحدات للأسفل 7 units left and 5 units down
3. Find the image of the point $(3, -5)$ under reflection about x-axis.	$(3, 5)$
4. Find the image of the point $(-2, -3)$ under reflection about y-axis.	$(2, 3)$

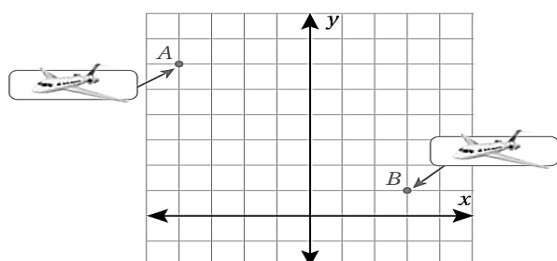


Table 4. Percentages of the most common misconceptions related to translation and reflection

Misconceptions	No. of Students	Percentages
Finding the image point after a translation incorrectly	31	55%
Finding a rule for translation incorrectly	28	50%
Finding reflection over x-axis or y-axis incorrectly	14	25%

The teachers interviewed demonstrated a partial understanding of the conceptual errors made by students in this category. They indicated that some students:

- Start counting from the same point when trying to determine the rule for translating a point from one location to another.

- Incorrectly change the sign of the x-coordinate when reflecting a point over the x-axis.
- Incorrectly change the sign of the y-coordinate when reflecting a point over the y-axis.
- Are unable to connect signs with directions to find the correct translation rule.
- Do not distinguish between x- and y-coordinates when dealing with translations and reflections of points.

However, there was no clear understanding among the teachers regarding the conceptual error of assigning a pair of coordinates to represent a point after a given translation, instead of producing a single correct coordinate pair. The teachers interviewed repeated the same reasons they gave in the first category and added the following:

Teacher 3: “These concepts are completely new to students, and the prior learning associated with them is not enough.”

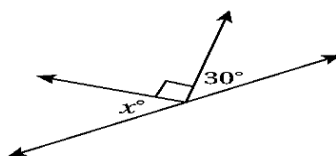
Teacher 4: “Teachers often devote less time than they should to the geometry unit, especially since it is included in the last part of the textbook.”

Teacher 5: “Teachers often explain these concepts orally, and therefore students do not reach a deep understanding of them, which forces students to rely on memorization to answer questions related to them.”

The teachers interviewed cited practical, realistic reasons for students’ errors in this category. Some teachers neglect to address the prior knowledge required for the meaningful understanding of new geometric concepts. They also reported that geometry units are often listed at the end of textbooks. As a result, insufficient time may be allocated to these topics, or delays in completing earlier units may reduce the time remaining to cover geometry effectively.

4.3. Misconceptions related to right and straight angles

Fifty-nine percent of participants were unable to find the measure of an unknown angle on a straight line.



Some of them concluded that $x = 30^\circ$, based on the value of the acute known angle shown in the figure. Others wrote that $x = 150^\circ$, ignoring the presence of the right angle.

Table 5. Samples of students’ geometric misconceptions in the third category

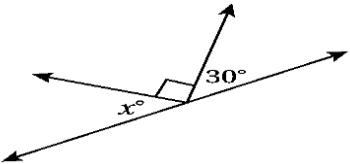
Item	Some students’ answers
1. Find the value of x in figure? Justify your answer.	 30° $x = 180 - 30 = x = 150$

Table 6. Percentage of finding measure of unknown angle on a straight-line misconception

Misconception	No. of Students	Percentages
Finding measure of unknown angle on a straight-line inaccurately	33	59%

The teachers interviewed showed a high level of awareness regarding the conceptual errors made by students in this category. They indicated that some students overlook the presence of a right angle or are unaware of its measurement. Moreover, students often lack understanding of key concepts such as straight angles, supplementary angles, and the right-angle symbol. They also tend to provide minimal justification for their correct solutions. They identified several reasons for these misconceptions:

Teacher (6): “These misconceptions occur because basic concepts related to angles, and their measurements are not well established in the students' cognitive structure.”

Teacher (7): “Teachers and parents often neglect verbal exercises, which limits students' ability to justify mathematically. They do not provide enough opportunities for students to express and justify their ideas.”

The teachers interviewed emphasized the importance of avoiding conceptual errors in this category by offering students ample opportunities to verbally express and justify their mathematical thinking. This practice allows teachers to assess students' understanding and implement corrective interventions in a timely manner. These suggestions align with the Mathematical Process Standards developed by the National Council of Teachers of Mathematics (NCTM), which stress the importance of communication and reasoning in mathematics.

4.4. Misconceptions related to polygons and circles

In this category, a smaller percentage of participants believed that the diameter is not a chord of a circle. Only 16% of students did not answer “no” when asked if the statement was true. However, most of the students who responded “yes” did not explain their answers.

Participants were also asked to determine whether a shape composed of a square and a regular pentagon with the same side length is a regular shape. About 29% of them answered “yes.” They concluded that the shape was regular based solely on the equality of the side lengths, ignoring the fact that all internal angles must also be equal for a shape to be considered regular.

The third misconception in this category was related to classifying a given shape into as many quadrilaterals as possible. A total of 84% of students were unable to classify the given shapes into the maximum possible number of quadrilateral categories. This reflects a clear weakness among students in identifying and understanding the relationships between different types of quadrilaterals.

Table 7. Samples of students' geometric misconceptions in the forth category

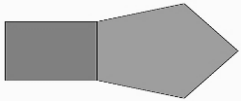
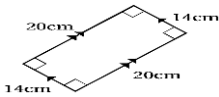
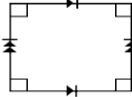
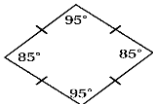
Item	Some students' answers
1. Khaled said: "Every diameter is a chord of a circle". Is he right? Justify your answer.	لا لأن القطر يمر بالمركز والوتر لا يمر بالمركز "No, because the diameter passes through the center, but the chord doesn't".
2. Determine whether a shape made up of a square and a regular pentagon with the same side length is a regular shape.	منتظم لأن كل أضلاع متساوية "Regular, because all sides are equal".
	
3. Classify the given shapes into the maximum possible number of quadrilaterals.	 مستطيل "Rectangle"  مربع "Square"  معيّن "Rhombus"

Table 8. Percentages related to polygons and circles

Misconceptions	No. of Students	Percentages
Inability to determine the correct relationships between quadrilaterals	47	84%
Inability to identify regular shapes according to their properties	16	29%
Not distinguishing between the diameter and the chord in a circle	9	16%

The teachers interviewed demonstrated a high level of awareness regarding the conceptual errors made by students in this category. They indicated that many students rely on visual appearance rather than geometric properties when classifying plane shapes. Moreover, students often fail to correctly identify the relationship between the diameter and the chord, and they do not accurately distinguish between different types of quadrilaterals.

Teacher (8): "These misconceptions are caused by teaching methods that rely heavily on memorization."

Teacher (9): "These concepts are more appropriate for students in higher grades and require more foundational knowledge."

Teacher (10): "Students tend to use only one label for each quadrilateral, basing their decision on appearance rather than properties."

In this category, teachers offered explanations similar to those shared in previous categories. They emphasized that many students do not progress beyond the visualization level of Van Hiele's geometric reasoning levels, particularly when asked to classify a given shape into multiple quadrilateral categories.

Suggested Solutions for Addressing Conceptual Errors in Geometry

Based on the literature and teachers' perceptions, the following recommendations are suggested to prevent and address conceptual errors in geometry:

- Integrate conceptual change into instruction: Conceptual errors in geometry are common and can serve as valuable instructional guides.
- Create cognitive conflict: Teachers should directly confront students' misconceptions, encouraging cognitive conflict that helps them replace incorrect concepts with accurate ones (Kabaca et al., 2011).
- Anticipate common errors: Teachers should be familiar with typical conceptual errors in geometry to better prepare and address them during instruction.
- Use sensory and real-life objects: Introducing new geometric concepts with tangible items from the students' environment can aid conceptual understanding.
- Emphasize formal mathematical language: Teachers should consistently use and reinforce correct mathematical terminology during instruction and practice (Özerem, 2012).
- Encourage mathematical communication: Students should be given ample opportunities to justify their solutions and articulate their reasoning using mathematical language.
- Utilize visual aids: Given the challenges students face with geometry, teachers should provide numerous diagrams and visual representations.
- Support meaningful learning: Teachers should strive to understand the factors that promote deep learning and continually improve their pedagogical content knowledge (Cho & Win, 2020).
- Incorporate computer-based exercises: Technology-based activities can enhance students' understanding and engagement with geometric concepts.

5. Discussion

The results of this study show that all students had a variety of misconceptions related to plotting points, right and straight angles, complementary angles, translation, reflection, quadrilaterals, polygons, chord, and diameter. This finding aligns with the results reported by Cho and Win (2020). Both studies agree that students' misconceptions in geometry can lead to confusion, frustration, and hinder learners from building confidence and a positive attitude toward mathematics. The results of this study are also consistent with those of Özerem (2012), who found that students struggled to distinguish between types of quadrilaterals and their properties.

This finding supports the conclusions of Gida et al. (2020), who argued that misconceptions have a lasting impact on learners because mathematical concepts are interconnected rather than isolated. Both studies noted that students had misconceptions about relationships between quadrilaterals. These results align with Okal's (2017) study, in which the researcher attributed errors or misconceptions to conceptually incorrect content in educational materials. Okal also indicated that GeoGebra, a dynamic mathematics software, is useful for identifying errors that may cause misconceptions in students. This finding is consistent with the suggestions made by teachers interviewed in the current study regarding the importance of computer-based exercises in improving students' understanding of geometric lessons.

The results of the current study align with those of Brijlall and Abakah (2022), who reported that learners do not fully understand circle geometry concepts, resulting in difficulties in making connections across geometric topics to solve problems. Similarly, Mosiaa et al. (2023) found that students classify geometric shapes based on their visual appearance rather than their properties.

Teachers interviewed in this study confirmed that students tend to assign only one label to each quadrilateral based on its shape, rather than its properties. This aligns with Solaiman et al. (2017), who found that learners operate mostly at Level 2 of Van Hiele's theory, the visualization level of geometric thinking, which contributes to many misconceptions. Alex and Mammen (2016) similarly indicated that learners remain at the visualization level even when questions require Level 3, reasoning. Biber et al. (2013) confirmed that students focus primarily on the physical appearance of geometric shapes and fail to recognize their properties.

The findings of this study also align with those of Aktaş and Ünlü (2017), who identified errors students make when translating points in the coordinate system. Kemberitzky (2009) found that many participants were unable to consistently justify the axiomatic relationships between properties of quadrilaterals within a hierarchy. In the current study, students were unable to recognize relationships between quadrilaterals; for example, some classified a particular quadrilateral as a square but ignored that it was simultaneously a parallelogram, rectangle, and rhombus.

Overall, the current study and previous research agree on the seriousness of conceptual errors made by students in school geometry. This study highlights an additional set of such errors in the same classroom context and emphasizes the urgent need for teacher intervention to address or prevent them. To this end, teachers should be trained in the process of conceptual change as part of their professional development. For example, teachers should consistently emphasize precise definitions and the unique characteristics of each quadrilateral to help students differentiate between them. Additionally, teachers should present quadrilaterals as part of a taxonomic hierarchy rather than as isolated shapes. Activities involving sorting, matching, and comparing quadrilaterals would be useful in this regard.

Regarding misconceptions related to plotting points on the coordinate plane, teachers should employ sensory and visual strategies to address these errors. For example, movement analogies such as "walk" followed by "up" can be used to grasp what each axis represents. Additionally, using video games, creating a life-sized coordinate plane on the floor, labeling and color-coding each quadrant differently, and circling or underlining negative signs in coordinates before plotting points can all be helpful.

To address misconceptions related to translation and reflection, teachers should incorporate movement activities, such as using a floor grid and having students physically walk through the translation. Visual grid-based tools, such as Desmos, and color-coding both original and image points can help students develop a physical sense of direction and movement. For reflection misconceptions, teachers can use mnemonic devices such as "x stays, y changes" (or vice versa), color-coded axes and quadrant labels, practice with tables, reverse tasks, and repetition.

6. Limitations

This study has several limitations that may affect the generalizability of its findings. The sample consisted of only 56 students and 10 teachers from a single educational directorate in Jordan, which restricts the applicability of the results to other regions or educational contexts. Moreover, student feedback, which could have provided deeper insight into the conceptual errors, was not collected. The study focused solely on geometric misconceptions among sixth graders, excluding other geometric concepts. While the instrument demonstrated satisfactory validity and reliability, future research should incorporate larger, more diverse samples across different geographic locations and educational levels to enhance the robustness and generalizability of findings.

7. Conclusion

Misconceptions in geometry are common among sixth graders. They have several misunderstandings related to plotting points, right and straight angles, complementary angles,

translation, reflection, quadrilaterals, polygons, chords, and diameters. Undoubtedly, these conceptual errors have a negative impact on students' achievement and performance in geometry. Additionally, they hinder the acquisition of new, related engineering concepts. Teachers need to be aware of students' misunderstandings and detect these misinterpretations by providing critical situations that help facilitate the process of conceptual change in geometry lessons. Conceptual change should be implemented wherever conceptual errors exist. Teachers' proper awareness of these errors contributes significantly to effective conceptual change. Research in this field should continue to expand to identify effective instructional strategies for addressing different types of misconceptions in geometry and other branches of mathematics.

8. Suggestions

This study suggests that teachers need to be aware of geometric conceptual errors at various levels of school geometry, which will enable them to adapt their teaching strategies to address these errors. Educational administrations must provide adequate support to teachers in this regard and include the process of conceptual change in their professional development programs.

Visual and tactile aids, interactive tools, and games help students deepen their understanding of geometry concepts in primary school. This purposeful, interactive learning enables students to engage with more abstract geometry concepts in later grades. Computer-assisted learning programs, such as GeoGebra, promote the development of conceptual understanding in geometry by visualizing and dynamically modifying geometric shapes. These programs, which can be downloaded onto tablets and mobile phones, provide valuable opportunities for primary students to learn geometric concepts. Such powerful tools offer students a sustainable resource for a comprehensive understanding of geometry.

Future research should explore appropriate instructional strategies to reduce and address conceptual errors in geometry. Cognitive conflict, an instructional strategy used to promote conceptual change in various branches of mathematics, is particularly worthy of further study.

Declarations

Author Contributions. The author confirms sole responsibility for the conception of the study, presentation of the results, and manuscript preparation.

Conflicts of Interest. The author declares no conflict of interest.

Funding. No funding

Ethical Approval. This study was conducted in compliance with ethical standards. All participants provided informed consent prior to participation, and their privacy and confidentiality were protected throughout the study.

Data Availability Statement. The data that supports the findings of this study are available from the corresponding author upon request.

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