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INNOVATIVE STRATEGIES FOR TEACHING VOCATIONAL, SCIENCE, TECHNOLOGY AND MATHEMATICS EDUCATION: CLASSROOM PRACTICES

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PREFACE

The electronic book (e-book) acknowledges that traditional methods in Vocational, Science, Technology and Mathematics Education: Classroom Practices may not be sufficient to equip students with the necessary skills for a rapidly evolving technological landscape.

Therefore, it advocates for the adoption of Innovative teaching approaches that promote a more dynamic and effective learning experience.

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TABLE OF CONTENT

FOREWORD

This book entitled "**Innovative Strategies for Teaching Vocational, Science, Technology and Mathematics Education: Classroom Practices",** is a book of readings on various innovative classroom pedagogies. It is a welcome literature for Education System and a very important resource book for teachers who are functioning in the disciplines of Vocational Education, Science, Mathematics and Technology education and training. It is a compendium of most of the **active learning strategies** aimed at producing graduates who have been prepared for adaptation to the conditions of the 21st century world of fluidity. The 21st century world accommodates soft skills which the individual can edit from time to time as the conditions of socio-cultural, economic and technological environments change constantly and uncontrollably. A century in which cross-border job openings are important means of employment, a century where attitude is more important than subject-based excellence, a century where collaboration, innovation and creativity are irreducible demands by employers of labour, a century where adaptive skills are critical for entrepreneurship, creation of jobs and wealth.

All categories of teachers at all levels of education would find this resource book interesting and professionally helpful for their teaching practice. Because conditions of the modern world are in perpetual flux, teachers have to re-skill in order to produce adaptive graduates and the era of lecture method is literally over. It is these modern innovative instructional strategies that would enable teachers to produce such graduates who would survive and then succeed in the 21st century global economy.

This book would also be very useful to researchers and innovators in the envisioned pedagogic paradigm shift of this era. I therefore, proudly recommend this book, a compendium on innovative pedagogies to all classes of teachers and researchers on pedagogies and curriculum reforms in the modern era.

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DEDICATION

This book is dedicated to educators in the world

CHAPTER 14

INSTRUCTIONAL APPROACH AND PROOFS OF PYTHAGORA'S THEOREM FOR PROBLEM-SOLVING

Madu Cletus Ifeanyi
Abur Cletus Terhemba

Abstract

This chapter explores effective instructional approaches and various proofs of Pythagoras' theorem to enhance problem-solving skills in mathematics education. Pythagoras' theorem, a fundamental principle in geometry, serves as a critical tool in both mathematical and real-world applications. An applied research approach was employed, emphasizing the integration of multiple proof techniques including geometric, algebraic, and visual proofs within instructional strategies to cater to different learning styles. The chapter engages students in discovering and validating the theorem through hands-on activities and critical reasoning, guiding them to develop a deeper understanding and promote analytical thinking. It also discusses how these approaches foster problem-solving proficiency by enabling learners to apply the theorem flexibly across a variety of mathematical contexts. Ultimately, the combination of diverse proofs and instructional methods supports a robust learning experience, empowering students to approach complex problems with confidence and creativity. It also considers the impact of the theorem on mathematics and science. It concludes that Pythagoras' theorem can be applied to solving everyday problems in schools, at home, in industries, and in construction. Therefore, teachers should adopt practical instructional approaches (e.g., geometric, algebraic, trigonometric, and proof by similar triangles) when teaching for problem-solving purposes. The chapter recommends that teachers emphasize the application of Pythagoras' theorem during instruction to help students solve problems both inside and outside the classroom. Additionally, the government and stakeholders are encouraged to organize seminars, workshops, and symposiums on the practical instructional methods of Pythagoras' theorem to enhance problem-solving skills in mathematics and science.

Keywords: Pythagoras theorem, Problem-solving.

Introduction

Pythagoras was an ancient Greek philosopher and mathematician, born on the island of Samos. He later moved to southern Italy, where he founded a religious and philosophical school known as the Pythagorean Brotherhood**.** Pythagoras and his followers believed that numbers were the essence of all things and that mathematical relationships had mystical significance. They studied mathematics, music, astronomy, and ethics. Though Pythagoras himself left no written records, his ideas were passed down by his followers. Much of what is attributed to him may actually be the work of the Pythagorean school (Rosjanuardi, Rudi & Suryadi, 2020). The Pythagorean Theorem **states that in a** right-angled triangle, the square of the length of the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides. That is $a^2 + b^2 = c^2$ where a and b are the other two sides and c the hypotenuse. Study.com. (2023), note that although the theory was named after Pythagoras, the theorem was known to Babylonians and Indians centuries earlier. The earliest recorded found it in the Babylonian Clay tablets like Plimpton 322 show they knew about specific sets of numbers (e.g., 3-4-5) that satisfied the relationship $a^2 + b^2 = c^2$. This is crucial for analytic geometry, which combines algebra and geometry. The idea of the Pythagorean Theorem likely evolved gradually through observation properties of triangles and practical problem-solving**,** long before Pythagoras formally proved it.

Statement of the Problem

Despite the foundational importance of the Pythagorean Theorem in mathematics and science, many students find it difficult to understand and apply effectively in problem-solving contexts. This difficulty may stem from traditional instructional approaches, which often emphasize rote memorization of concepts and formulas rather than fostering a deep conceptual understanding of the theorem, its proofs, and applications. Such approaches hinder students' ability to transfer knowledge to more complex mathematical problems involving geometry, trigonometry, and real-world scenarios. Although various proofs of the Pythagorean theorem exist ranging from algebraic to geometric, some instructional methods fail to integrate these diverse approaches in a way that promotes students' understanding and problem-solving skills. There is a need to adopt appropriate instructional strategies, particularly those that incorporate multiple proofs of the theorem, to enhance students' comprehension and ability to solve mathematical problems effectively. The researchers' instructional approach to teaching Pythagoras' theorem and its proofs offers a promising solution. It has the potential to strengthen students' mental abilities, applied skills, which enables them to understand and use the theorem to solve real-life problems.

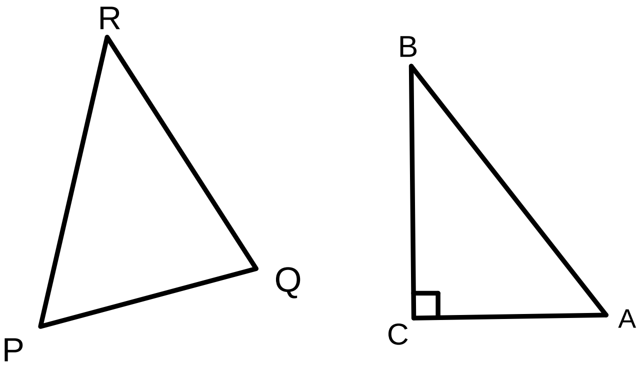
Objective of the Study

The main objective of this study is to apply appropriate instructional approach that utilizes various proofs of the Pythagorean theorem in enhancing students' problem-solving abilities in mathematics. Specifically, the study aims to:

1. Explore different types of proofs (e.g., geometric, algebraic, visual) of the Pythagorean Theorem used in instruction.
2. Apply Pythagorean theorem in solving daily-life problems inside and outside the classroom settings
3. Examine impacts of Pythagoras' theorem to mathematics and science.

Concept of Triangle

A triangle is a two-dimensional shape with three sides and three angles. A right angle triangle is a type of triangle in which one of the angle is 90^0 as shown in figure 1.



(a) a triangle **(b)** a right angle triangle

Fig 1: Triangle QRP and a right-angle triangle ABC

In triangle ABC, side $c$is known as the hypotenuse, which is the longest side of a right angle triangle and is opposite the right angle. Side $a$and side $b$are known as the adjacent sides because they are next to the right angle. If any of the two sides of the triangle are known, then the other side can be calculated by using Pythagoras Theorem.

Proofs of Pythagoras Theorem for Problem-Solving

Pythagoras Theorem state that in a right angled triangle, the square of the hypotenuse side is equal to the sum of squares of the other two sides; such that $a^2 + b^2 = c^2$this is demonstrated as seen below:

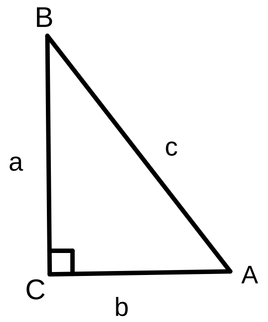
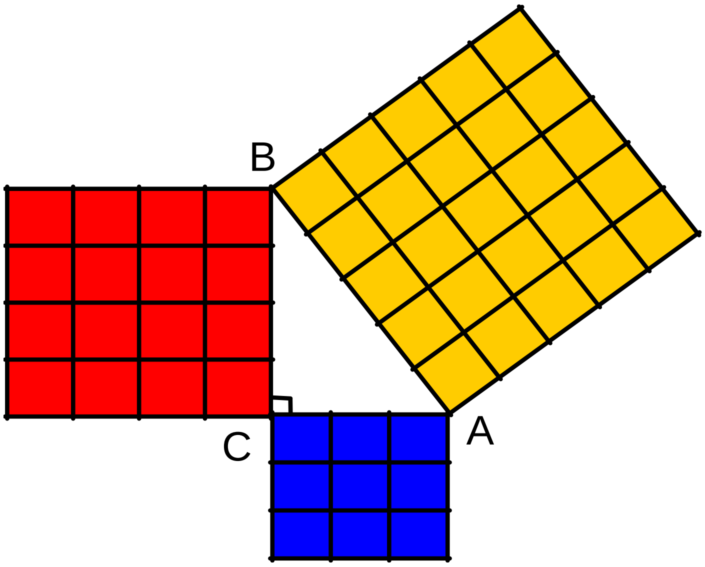
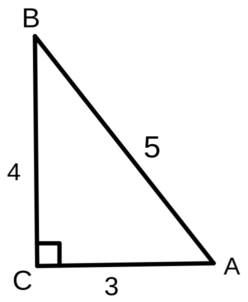


Fig II: Right angle triangle showing Pythagoras Theorem.
According to Pythagoras: $a^2 + b^2 = c^2$

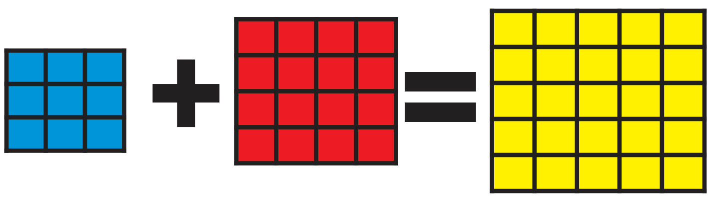
Geometrical Proof of Pythagoras Theorem
Consider a right-angled triangle with legs of length 3 and 4; and hypotenuse of length 5 squares respectively as seen in figure 3.



(a) Pythagoras Theorem using squares



(b) Pythagoras Theorem using numbers



(c) Pythagoras Theorem using square numbers

In each case of a, b and c ⇒ $3^2 + 4^2 = 5^2$ Pythagoras Theorem
So that in any of a, b and c ⇒ $a^2 + b^2 = c^2$ Pythagoras Theorem

Fig III: Practical demonstration of Pythagoras Theorem using squares and numbers

Algebraic Proof of Pythagoras Theorem
Consider a right-angled triangle with legs a, b, and hypotenuse c as seen in the figure IV.

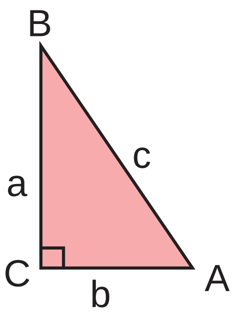


Fig IV: A right –angle triangle ABC

Let $|CB| = a, \ |CA| = b$ and $|AB| = c$

Using the formula for the length of the hypotenuse,

$$c = \sqrt{(a^2 + b^2)}$$

Square both sides to have

$$c^2 = a^2 + b^2 \quad \text{This gives the Pythagoras Theorem}$$

Trigonometric Proof of Pythagoras Theorem

Consider a right-angled triangle with legs a, b and hypotenuse c.

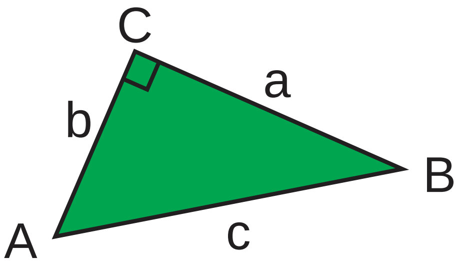


Fig V: Trigonometric proof

Using trigonometry, $CosA = \frac{adj}{hyp} = \frac{b}{c} SinA = \frac{opp}{hyp} = \frac{a}{c}$

Applying the trigonometric identity

$$Cos^2A + Sin^2A = 1,$$

Substitute to have: $\left(\frac{b}{c}\right)^2 + \left(\frac{a}{c}\right)^2 = 1$

Open bracket $\frac{b^2}{c^2} + \frac{a^2}{c^2} = 1$

Simplifying: $b^2 + a^2 = c^2$ Pythagoras theorem

Proof by Using Similar Triangles

Consider right angle triangle ABC as seen in figure VI.

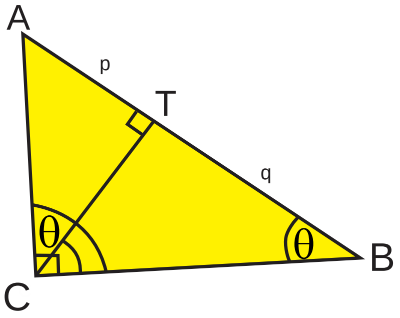


Fig. VI: Proof of Pythagoras theorem using similar triangles

This proof is based on the proportionality of the sides of three similar triangles. The proof is based on the fact that; the ratio of any two corresponding sides of similar triangles is the same regardless of the size of the triangles.

Let ABC represent a right angle triangle, with angle 90^0 located at C, as shown on the figure vi. Draw the altitude from point C to meet at point T that intersects with side AB. Point T divides the length of the hypotenuse into parts p and q. The new triangle, ACT, is similar to triangle ABC, because they both have a right angle (by definition of the altitude), and they share the angle at A, meaning that the third angle will be the same in both triangles as well, marked as θ in the figure. By a similar reasoning, the triangle CBT is also similar to ABC. The proof of similarity of the triangles requires the triangle postulate: The sum of the angles in a triangle is two right angles, and is equivalent to the parallel postulate. Similarity of the triangles leads to the equality of ratios of corresponding sides, such that;

$\frac{BC}{AB} = \frac{BT}{BC}$ and $\frac{AC}{AB} = \frac{AT}{AC}$ (i)

The first result equates the Cosines of the angles θ, whereas the second result equates their Sine.

These ratios can be written as:

$Bc^2 = Ab \times BT$ and $AC^2 = AB \times AT$ (ii)

Add (i) and (ii) to obtain

$BC^2 + AC^2 = AB \times BT + AB \times AT = AB(AT + BT) = AB^2$

Simplifying to have

$BC^2 + AC^2 = AB^2$Pythagoras Theorem

Application of Pythagoras Theorem for Problem-solving

Example 1: Calculate the length of the hypotenuse in a right angle triangle if the other two sides are 6 and 9 respectively. Correct your answer to two decimal places.

Solution

Let the length of the hypotenuse to be a

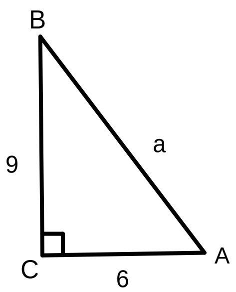


Fig VII: A right angle triangle with unknown hypotenuse side

$9^2 + 6^2 = a^2$ Pythagoras Theorem
$81 + 34 = a^2$
$115 = a^2$
$a = \sqrt{115}$
$a = 10.72$

Example 2: A ship sails 9km East and then 12km North. Find the ship's distance from its starting point.

Solution
Let the length of the longest side be a

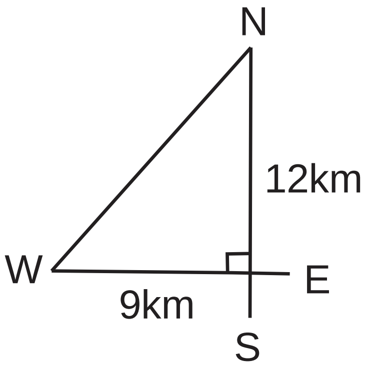


Fig. VIII: Movement of the ship

From figure Viii; let the ships distance from the starting point be a
$9^2 + 12 = a^2$ Pythagoras Theorem
$81 + 144 = a^2$
$a = \sqrt{225} = 15km$
The ship distance from the starting point is 15km.

Example 3: The pole of a sailing boat is supported by a rope from the top of the pole to an anchor point on the deck. The pole is 6.5 m long and the rope is 8 m long. Calculate the distance from the base of the pole to the anchor point of the roe on the deck to two decimal points.

Solution

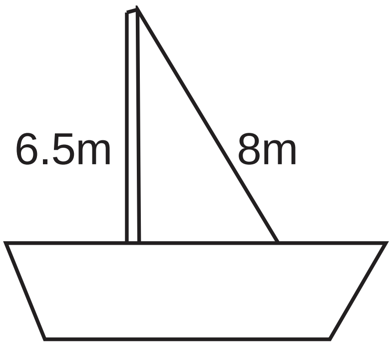


Fig IX: The ship and the pole

Let the distance from the base of pole to the anchor point of the rope on the deck be $a$meters such that
$(6.50)^2 + a^2 = 8^2$ Pythagoras Theorem
$42.25 + a^2 = 64$
$a^2 = 64 - 42.25 = 21.75$

$a = \sqrt{21.75} = 4.66m$
The distance from the base of the pole to the anchor point of the rope on the desk is 4.66 meters.

Example 4: An electric pole is supported by a wire of 60 meters length from its top to the level ground. If the distance along the ground from the pole to the wire is 20 meters. Calculate the height of the pole to the nearest meters.

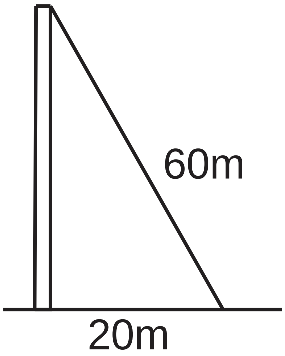


Fig X: The pole and the wire

Let the height of the pole to be h meters

$h^2 + 20^2 = 60^2$ Pythagoras Theorem
$h^2 + 400 = 3600$
$h^2 = 3600 - 400 = 3200$
$h = \sqrt{3200} = 56.5685m = 57m$
The height of the pole is 57 meters.

Impact of Pythagoras Theorem to Mathematics and Science

a. Pythagoras Theorem marked a shift from empirical observation to **systematic mathematical proof** which serves as a cornerstone of modern mathematics.

b. The Pythagorean Theorem is a **cornerstone of Euclidean geometry because i**t provides a method to calculate **distances** between points in 2D and 3D space.

c. Trigonometric functions like sine, cosine, and tangent are based on **right triangles**. The theorem helps establish key relationships between angles and sides, enabling the development of **trigonometric identities**.

d. In **physics**, it's used to calculate distances, forces, velocities, and in vector analysis.

e. In **engineering**, it's used in construction, design, mechanics, and structural analysis.

f. It plays a role in **graphics programming**, **game development**, and **robotics** for collision detection, movement, and 3D modeling.

g. Algorithms involving spatial data often rely on **distance calculations** using the Pythagorean Theorem.

h. The theorem allows for the calculation of distances between points on a grid. For example $(x^2 - x^1)^2 + (y^2 - y^1)^2 (x_2 - x_1) + (y_2 - y_1)$

Conclusion

Effective teaching and application of Pythagoras' theorem require a combination of visual and analytical instructional methods that clearly demonstrate the theorem's proofs in a way that allows students to visualize the foundational skills and approaches needed for problem-solving. This approach can enhance students' understanding, foster creativity, and promote diverse and logical reasoning skills by helping them grasp the contextual aspects of the theorem. Pythagoras' theorem can be applied to solving real-life problems in schools, at home, in industries, and in construction. Therefore, teachers should adopt practical instructional approaches such as geometric, algebraic, trigonometric proofs, and proofs by similar triangles during instruction to support effective problem-solving.

Recommendations

The study recommends that;

1. Teachers should emphasize application of Pythagoras theorem during instruction so as to help students solve problems inside and outside the classrooms.
2. Government and stakeholders should organized seminal, workshops and symposiums on the practical instructional method of Pythagoras Theorem for problem solving skills in mathematics and science.
3. Pythagoras' theorem should be taught with relevant instructional materials so as to encourage students' visual, creativity and applied skills.

Reference

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