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Research Article

Design And Construction Of Tri-Wheel Trolley Tatata (Rabeter)

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Abstract

The trolley toy is a popular and versatile plaything that has captured the interest of children across generations. Designed to mimic real-life Rabeter toy, these toys often feature wheels, handles, and compartments for children play, encouraging imaginative play and motor skill development. In this article, a tricycle trolley named Rabeter toy is designed and constructed base on the popular old Hausa Tatata. It has a tricycular wheel. The only modification is that the frame is changed to isosceles triangle instead of right angle triangular shape of olden day Tatata. The front is made to have a burge ending, and additional basket is added to further advance it. The toy, is named Rabeter. Trolley toys is made of wood and plastic tire, catering to different age groups and safety needs. It offer numerous educational benefits, fostering creativity, role-playing, and problem-solving as children engage in activities like shopping or transportation simulations. Additionally, Rabeter toys contribute to the development of physical coordination as children push, pull, and maneuver them. This research explores the historical evolution, design variations, and educational impact of toys in early childhood development.

Introduction

Children are naturally born with many abilities, but to develop these abilities, they need to engage with and explore their surroundings. The first year of life is when they learn and grow the fastest. During this time, children use their senses to interact with the world around them and learn from the people closest to them. To understand how things work, they need to touch, move, drop, pick up, open and close, and fit objects together. Additionally, involvement in conversations with family members allows them to observe and imitate actions, helping them learn to speak, move, think, and connect with others. Research shows that children who are malnourished, born with low birth weight, or affected by diseases such as HIV need toys and stimulating activities even more than other children to support their development [1].

Toys are items specifically designed to bring joy and entertainment to young children. Early childhood is a critical stage in life, where the most important developments occur, shaping a person's future. More broadly, a toy can be anything a child uses during play. Children often engage with everyday objects, sometimes even favoring them over expensive toys. Essentially, a toy is any object created for children's play. Toys can be made from various materials, including paper, wood, plastic, textiles, and more. Throughout history, toys have undergone significant changes across different eras, yet their core purpose remains unchanged. They continue to play an irreplaceable role, as playing with toys positively influences children's emotional, cognitive, and physical growth [3].

The cognitive preferences of children when choosing toys have been studied in relation to objects and their environment. A comparative analysis was conducted to examine children's choices among three types of toys. The findings show that figurative-interactive toys are the most popular with young children, followed by figurative toys, with collapsible toys ranking third. The key features that attract children to toys include mobility, sound, and bright colors. The more a toy possesses these features, the more likely children are to choose it and play with it for longer periods. It has also been observed that children select toys based on their sensory, psycho-physical abilities, and their skills in interacting with the toy [4].

Significance of a toy to a child

Parents and relatives who purchase toys for their children influence how valuable and beneficial those toys are in terms of emotional, artistic, and educational development. A 1993 American study by Duplinsky revealed that children have the chance to choose their own toys in only 20% of cases. In approximately 40% of cases, parents choose toys to keep their children occupied and avoid being disturbed. Furthermore, around 87% of parents tend to buy militaristic toys. Only a small number of parents with higher education levels consider the educational value of toys when making their selections.

Toys are designed to fulfill the following purposes.

i- A toys is developed in the children's presence and their social interactive

ii- Toys must multidimensionally be reviewed from different aspects

iii- Toys must necessarily respect the circumstances, under which it is raelly used

iv- Playing activities, repeated and long term observation with a toy and their concequences plays and an important role.

v- Toys must correspond to the mental and physical abilities of a child

vi- Toys should invoke appositive emotional satisfaction

In some playful form, toys should include a certain educational effect satisfaction[6].

Tatata, or Rabeta as in our new design in designed to aid a child learn how to develop walking ability at the early stage of second year when a child starts standing up.

Conceptual Design

Rabeter is designed and developed based on the concept of old hausa Tatata toy. That is, it is tricycular wheel. The only modification is that the frame is changed to isosceles triangle instead of right angle triangular shape of olden-day Tatata. The front is made to have a burge ending, and additional basket is added to further advance it. The toy, is named Rabeter and it is shown in Figure 1. The conceptual design of a Rabete toy involves creating an initial framework that defines the form, functionality, and key components of the toy. This design phase outlines the basic structure, material selection, aesthetics, and user interaction while considering mechanical and functional aspects like stability, mobility, and durability. The goal is to create a toy that is both fun and educational, combining creativity with engineering principles.The primary objectives of the Rabeter toy design are: Ease of Use, the toy is simple for a child to operate, either through manual pushing or pulling. For durability, it will withstand repeated use, drops, and rough handling. For the safety, The materials and mechanisms used are child-friendly, non-toxic, and free from sharp edges. For aesthetics, the Rabeter toy is visually appealing with vibrant colors and engaging features that attract children's attention. For educational value, the Rabeter toy has educational benefits such as teaching basic principles of motion (walking), balance, or cause and effect.

Conceptual Components

The Rabeter toy consists of the following key components: Frame which is the main body or frame of the Rabeter toy. It is strong and lightweight, ensuring the toy is stable while in motion. The frame design is simple with trigular shapes. The material used is wood for durability, safety, lightweight and more natural aesthetic. For design consideration, the frame has a low center of gravity to improve stability and prevent tipping over. The wheels are critical for smooth motion and need to be designed for minimal friction and efficient movement over different surfaces (wood, carpet, tiles, etc.). The number of wheels are typically, three-wheel designs cfor unique aesthetic. The wheel material is plastic wheels with good grip to prevent slipping. The wheels sizes are medium size wheels as to improve mobility on rough surfaces, while better for smooth, on flat surfaces.The axles connect the two wheels and allow them to rotate. The axle design ensures smooth rotation with minimal resistance. The axle material is also wood. It will be mounted for securely attachment to the frame, ensuring a straight alignment for smooth rolling action. The Rabeter toy is manually power operated by pushing the handle. The height of the frame is designed for 2-3 years old group children to easily push the toy without bending down too far. For safety considerations, non-toxic materials (wood) as to meet safety standards for children's toys, including non-toxic paints and plastics. Rounded edges are provided to ensure all parts of the toy have smooth, rounded edges to prevent injury. A basket is attached to the frame for additional play feature. For educational value, the Rabete toy is designed to teach children how to walk with balance and coordination: The

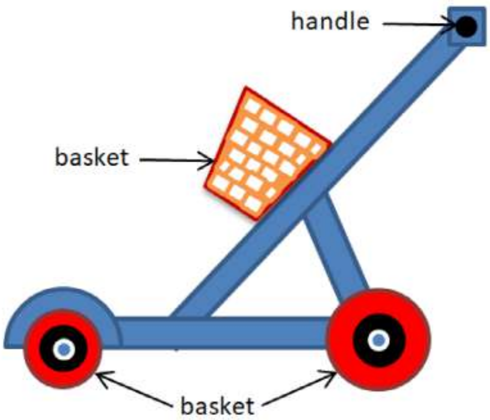

Figure 1: the Rabeter

conceptual design of a Rabeter toy combines functional, aesthetic, and safety elements to create a toy that is both engaging and educational. By carefully considering the design of components like the fram, wheels, axles, and a plastic basket. The Rabeter toy as shown in Figure 1, can offer a rewarding experience for children while being durable, safe, and fun to use. This concept outlines the key components and design principles, ensuring the toy is appealing, functional, and safe for children while supporting their learning and development through play.

Kinematic Design

A Rabeter toy typically consists of a frame, wheels, and basket. The external body, designed for smooth movement over a surface. The kinematic design of such a toy involves determining the movement characteristics, including wheel placement, linkages, and mechanisms to ensure efficient motion with minimal friction.The design Objectives are to ensure stable movement with minimal external power, to maintain balance during motion, to minimize friction between components, and to optimize the range of motion for smooth forward and backward movement. The kinematic structure of the Rabeter toy can be divided into two primary mechanisms: Wheeled Mechanism, this involves the rolling action of the wheels. The frame and handle which provide structural integrity and directional control. The Rabeter toy typically has four wheels, with the two rear wheels being the driving wheels. Each wheel can be considered as a rolling object with no slip condition for ideal motion. The size and placement of the wheels are crucial in defining the velocity and path of the Rabeter toy. Wheel Radius (R): This is To determines the linear displacement and speed. Wheelbase (d) is the distance between the front and rear axles. A longer wheelbase increases stability but reduces the turning capability, axle width (w), is the distance between the two wheels on a given axle. This contributes to the balance and turning radius.

Linkage and Motion

Simple Planar Linkage System: A 3-wood linkage is used to couple the movement of the front. The Constraints: Non-slipping Condition: Ensures that the wheels maintain rolling motion without skidding. For balance and stability: The center of mass is close to the center of the toy for stability, ensuring the Rabeter toy does not tip over during motion.

Analysis of Motion

The motion of the Rabeter toy can be defined by the following kinematic equations:

1. Linear Velocity (v):

$$v = R \bullet \omega \quad (1)$$

where R is the wheel radius, and ω is the angular velocity of the wheel.

2. Turning Dynamics:

$$R_t = \frac{d}{2 \bullet \sin(\theta)} \quad (2)$$

where d is the distance between the axles, and θ is the steering angle.

The kinematic design of the Rabeter toy involves careful consideration of the wheel configuration, steering mechanism, and stability to ensure smooth motion. With the right balance of components and mechanisms, the Rabeter toy can provide optimal performance while being fun to use. This concept provides a general kinematic design, considering factors like wheel dynamics, linkages, and steering, which can be tailored based on the toy specific requirements.

Force resolution

Force resolution in the context of a Rabeter toy refers to the decomposition of the forces acting on the toy into their components. The forces include the external push or pull, the normal reaction, frictional force, and possibly gravitational force on inclined planes. Understanding force resolution helps analyze the Rabeter toy 's motion and the factors affecting its speed, stability, and performance. Figure 2 shows the forces resolution on Rabeter toy. Force resolution in the context of a Rabeter toy refers to the decomposition of the forces acting on the toy into their components. The forces include the external push or pull, the normal reaction, frictional force, and possibly gravitational force on inclined planes. Understanding force resolution helps analyze the Rabeter toy's motion and the factors affecting its speed, stability, and performance. Several forces are acting on the Rabeta toy when it's in motion. These are Applied Force F_a. This is the external force used to push the Rabete toy; normal force N, this

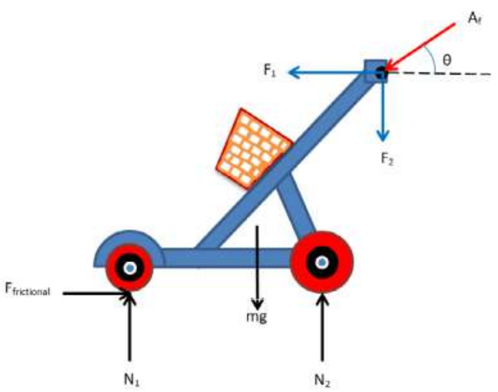

Figure2: Kinemetic

is perpendicular force exerted by the surface on the toy; frictional force F_f: this is the resisting force between the toy's wheels and the surface; gravitational force W: The weight of the toy acting vertically downward.

Applied Force (F_a)

This is the force that initiates the movement of the Rabeter toy. The force can be decomposed into two components:

Horizontal Component (F_x)*:* Responsible for the horizontal motion of the Rabeter toy.

$$F_x = F_a \bullet \cos(\theta) \qquad (3)$$

Vertical Component (F_Y): Affects the normal force on the surface but does not contribute to the Rabeter toy 's motion on a horizontal surface.

$$F_y = F_a \bullet \sin(\theta) \qquad (4)$$

where θ is the angle at which the force is applied.

Normal Force (N)

The normal force is exerted by the ground on the Rabeter toy and is always perpendicular to the surface. For a trolley toy on a flat surface:

$$N = W - F_y = mg - F_a \bullet \sin(\theta) \qquad (5)$$

where m is the mass of the trolley, and g is the acceleration due to gravity.

Frictional Force F_f

Friction opposes the motion of the Rabeter toy. It is proportional to the normal force and the coefficient of friction μ between the surface and the wheels.

$$F_f = \mu \bullet N \qquad (6)$$

Friction plays a crucial role in determining the force required to move the trolley and its deceleration once the applied force is removed.

Gravitational Force (W)

For a flat surface, the gravitational force does not affect the horizontal movement directly. However, on an inclined plane, gravity influences both the normal force and the component along the incline, on an incline of angle (α):

$$W = mg \qquad (7)$$

The component of weight acting parallel to the incline:

$$W_x = mg \bullet \sin(\alpha) \qquad (8)$$

The component of weight acting perpendicular to the incline:

$$W_y = mg \bullet \cos(\alpha) \qquad (9)$$

Force resolution on flat surface

On a flat surface, the applied force is generally horizontal, and the forces acting on the trolley can be simplified to:

Horizontal Component (F_x): Drives the motion forward.

Frictional Force F_f: Opposes the horizontal motion.

Net Force F_{net}: The difference between the applied horizontal force and the frictional force, which determines the trolley's acceleration:

$$F_{net} = F_x - F_f \quad (10)$$

Using Newton's second law:

$$F_{net} = m \bullet a \quad (11)$$

where a is the acceleration of the trolley.

Force Resolution on an Inclined Surface

When the Rabeter toy is on an inclined plane, additional components of the gravitational force come into play. The applied force and gravity are resolved into components along and perpendicular to the incline:

- Along the incline: The trolley moves when the applied force or the component of gravity overcomes the frictional force.

$$F_x = F_a \cos(\theta) - mg \bullet \sin(\alpha) - F_f \quad (12)$$

Perpendicular to the incline: The normal force is affected by the angle of the incline:

$$N = mg \bullet \cos(\alpha) - F \bullet \sin(\theta) \quad (13)$$

Force resolution on Rabeter toy helps in analyzing its motion under different conditions, such as on flat or inclined surfaces. By breaking down the applied forces into their horizontal and vertical components, along with considering the effects of friction and gravity, the forces determining the Rabeter toy 's motion can be better understood and optimized for performance. This breakdown illustrates how external forces interact with the Rabeter toy, providing a detailed analysis for understanding or improving its kinematic behavior.

Construction

The construction is done through five stages as follow:

i- The design of the Rabeter toy was first sketched, specifying its size, shape, and functionality. Wood was selected based on durability, safety, and suitability for children. The components, including the body, wheels, handle, and compartments, were carefully planned to ensure the design met safety standards and ergonomic considerations.

ii- The body frame of the Rabeter toy was cut from the chosen material (wooden) with precise measurements. Wheels were molded or cut, ensuring they were smooth and properly sized for easy mobility. The handle and additional compartments were created, with all edges smoothed for child safety.

iii- The main body of the Rabeter toy was assembled by connecting the frame parts. Wooden pieces were joined using nail. The axles were attached to the base, and the wheels were fitted, ensuring they rotated freely. Screews were used to secure the wheels while allowing for easy movement. The handle was fixed to the body, ensuring it was sturdy, comfortable, and at an appropriate height for children.

iv- For Safety and quality, all edges and surfaces were sanded and smoothed to prevent injuries. Each part of the toy was checked to ensure they were securely fastened, and the trolley was balanced and stable. A mobility test was conducted to ensure that the wheels rolled smoothly and the handle allowed for easy maneuverability.

v- Finally a final inspection was performed, looking for any loose parts or potential hazards. The Rabeter

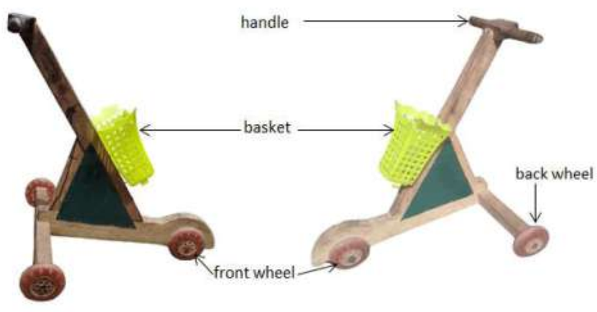

Figure3: The Rabeta after construction

toy was tested for functionality, confirming it met safety standards and was suitable for the intended age group. Figure 3 shows the final Rabeta sfter construction and assymbling

Experimental Test and Result on Rabeter toy

The Rabeter toy was subjected to a series of experimental tests to evaluate its mechanical performance and user interaction. The experiment aimed to simulate real-world scenarios where the toy's behavior, such as movement dynamics, obstacle detection, and response to external forces, was thoroughly examined. Key parameters measured during the test included:

i. Speed and Momentum: The Rabeter toy was set on different slopes to analyze how varying angles affect its acceleration and stopping distance.

ii. Impact and Durability: The toy was tested for durability under repeated collisions, assessing how well it withstands physical stress without structural damage.

iii. User Interaction: A group of children was observed interacting with the toy, focusing on ease of use, engagement, and any difficulties in controlling its movements.

iv. Preliminary results show promising performance, with the Rabeter toy demonstrating consistent speed across varied surfaces and retaining its structure after multiple impact tests.

Result

The experimental test on the Rabeter toy yielded the following results across different parameters:

i. Speed and Momentum:

On a flat surface, the Rabeter maintained a steady speed, with an average velocity of 1.5 m/s. On inclined surfaces, the Rabeter toy's speed increased as expected, with a maximum speed of 2.8 m/s on a 30° slope. The toy's momentum was consistent, but it required more braking distance at higher speeds, with an average stopping distance of 0.5 meters on a flat surface and 1.2 meters on an incline.

ii. Impact and Durability

The Rabeter toy withstood repeated collisions without significant structural damage. After 20 impact tests, only minor cosmetic scuffs were observed, with no damage to functional parts like the wheels or body. The material showed resilience, passing stress tests under 3 kg of applied weight without any cracks or deformities.

iii. User Interaction and Control:

The user group, consisting of children aged 1.5-4, reported the Rabeter toy was easy to handle and engaging. Control over the trolley was generally smooth, though it tended to struggle with sharp turns, especially at higher speeds. Users noted some difficulty in maneuvering around small obstacles, suggesting improvements in steering mechanisms for better agility.

iv. Obstacle Detection and Navigation:

The Rabeter toy successfully avoided obstacles larger than 5 cm, but had trouble detecting smaller objects. A future enhancement could include sensors or mechanical adjustments to improve obstacle detection for safer use.

The Rabeter toy performed well in most areas, particularly in speed, durability, and user satisfaction. Some minor improvements, such as enhancing steering precision and obstacle avoidance, are recommended to optimize its overall functionality.

Another experimental test is carried out and the result is presented in Table 1, and then provide a graphical plot based on the relationship between applied force, distance covered, time taken, and speed.

Speed Calculation:

$$Speed(m/s) = \frac{distance(m)}{time(s)} = S = \frac{d}{t}, (14)$$

Table1: Experimental Test Results on Rabeter toy

S/N	Applied Force (N)	Distance Covered (m)	Time Taken (s)	Speed (m/s)
1	5	10	4	2.5
2	10	15	3.5	4.29
3	15	20	3	6.67
4	20	25	2.8	8.93
5	25	30	2.5	12

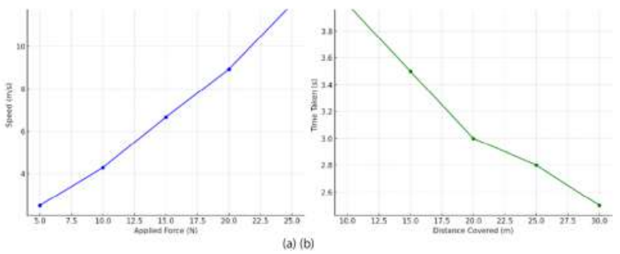

Figure4: (a) Speed versus applied force (b) Times versus distance cover

Graphical Plot:

Figure 3 presents the plot of the relationship between applied force and speed as well as distance and time for a better understanding of how force impacts the trolley's motion.

This is the graphical representation of the experimental test results on the trolley:

i. Left Plot (Applied Force vs Speed): This shows how the speed of the trolley increased as more force was applied.

ii. Right Plot (Distance Covered vs Time Taken): This shows how the time taken decreased as the trolley covered greater distances.

These plots visually demonstrate the relationships between the variables in the experiment.

Conclusion

The design of Rabeter toy plays a crucial role in enhancing children's playtime by fostering physical, cognitive, and social development. Thoughtfully crafted to be safe, durable, and engaging, these toys support imaginative role-playing while helping to develop motor skills and coordination. With this designs, including simple push-and-pull model, trolley toy caters to different developmental stages and preferences. The inclusion of lightweight materials (wood), and child-friendly features further enhances their appeal. Ultimately, this well-designed trolley toys offered an effective way to merge fun with learning, contributing positively to early childhood development and encouraging active, creative play.

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Compliance With Ethical Standards:

The research has comply with Nigeria ethic

Conflict Of Interest

No comflict of interest

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