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DESIGN AND CONSTRUCTION OF A SIMPLE MASS SCALE USING RECYCLED MATERIALS THROUGH TRANSLATIONAL–ROTATIONAL MOTION

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ABSTRACT

The development of simple measuring instruments provides an alternative approach to applying classical mechanics principles through the use of low-cost and readily available materials. This study aims to design and describe a simple mass scale prototype based on a translational–rotational motion mechanism constructed from recycled materials. The study adopts a prototype engineering approach with descriptive analysis, covering material selection, assembly procedures, operating principles, and functional demonstrations. The prototype was constructed using a jar, wood, cardboard, paper, and supporting components assembled into a load container, support structure, drive mechanism, and indicating system. The results demonstrate that placing a load in the upper container causes the support components to move downward. This displacement is transmitted through a gear-like mechanism and converted into rotational motion, causing the dial and indicator needle to move. The functional demonstration shows that the prototype produces a mechanical response to applied loads, including a visual indication labeled ½ kg. However, this indication cannot yet be considered a validated measurement because calibration data, repeated measurements, and comparisons with standard masses are unavailable. This study demonstrates the potential of integrating recycled materials with translational–rotational mechanical principles in developing simple measuring instruments. Further metrological testing is necessary to evaluate the prototype's accuracy, precision, sensitivity, and measurement range.

1. INTRODUCTION

Measurement is a fundamental activity in physics that enables the quantitative determination of physical quantities through comparison with established units or standards (Pratama et al., 2025). Measurement instruments facilitate the systematic, objective, and quantitative analysis of natural phenomena and the physical characteristics of objects. The reliability of measurement results depends not only on the availability of a measurement scale but also on the instrument's operating principle, mechanical stability, zero-point adjustment, calibration, and the user's ability to interpret

readings accurately (Rahmawati et al., 2026). Therefore, developing simple measurement instruments provides an effective means of understanding the relationship between fundamental physics concepts and their practical applications in everyday life.

Mass is a fundamental physical quantity in the International System of Units (SI), with the kilogram (kg) as its standard unit (Auliyah et al., 2023). In mechanical measurements, distinguishing between mass and weight is essential because they represent different physical quantities. Mass refers to the amount of matter in an object, whereas weight is the gravitational force acting on that object and is expressed in newtons (N) (Taufiq & Kaniawati, 2023). The relationship between these quantities is expressed in Equation (1), where W represents weight, m denotes mass, and g represents gravitational acceleration. Understanding this relationship provides a theoretical foundation for designing mechanical instruments that respond to applied loads and convert mechanical responses into mass measurements.

$$W = mg \tag{1}$$

Various instruments have been developed to measure mass, including equal-arm balances, Ohaus balances, spring scales, analog scales, and digital scales. Each instrument has distinct operating principles, structural designs, levels of precision, and operational requirements. Mechanical balances generally rely on force equilibrium or changes in component positions in response to applied loads, whereas digital scales employ sensors to convert physical responses into electrical signals. These differences demonstrate that mass measurement can be achieved through various mechanical and electronic approaches, depending on measurement requirements and resource availability.

The development of simple measuring instruments is relevant to physics education and practical applications, particularly in demonstrating mechanical principles through observable physical processes (Afia et al., 2026). Constructing instruments independently provides opportunities to understand the functions of individual components, the relationships between interconnected parts, and the effects of applied loads on mechanical displacement. This approach also facilitates the exploration of fundamental concepts, including force, equilibrium, displacement, and rotational motion, through instrument design and testing. Therefore, developing a simple mass scale extends beyond producing a measuring device; it also represents an engineering application of fundamental physics principles.

One mechanical principle that can be applied in the development of mass scales is the relationship between translational and rotational motion (Setiyarto, 2026). Translational motion refers to a change in the position of an object or component from one point to another, whereas rotational motion describes the movement of an object around a specific axis or pivot point. These two types of motion can be interconnected through mechanisms such as levers, hinges, shafts, and other mechanical linkages. Integrating translational and rotational motion allows displacement generated by an applied load to be converted into angular movement of an indicating component.

In mechanical weighing systems, applying a load can cause displacement in specific components of the instrument's structure (Cahyono et al., 2026). This displacement can subsequently be transmitted through a mechanical linkage, producing rotational movement in a pointer or indicator. The resulting angular displacement provides a visual response that can be used

to indicate the applied load. The relationship between linear displacement and angular rotation is therefore an important aspect in determining the instrument's mechanical response, particularly when the resulting movement is intended to be translated into a mass measurement scale.

The translational–rotational mechanism is also associated with the principle of torque, which describes the tendency of a force to produce rotational motion about a specific axis or pivot point. Torque depends on the magnitude of the applied force, the distance from the pivot point to the point of force application, and the angle between the force direction and the lever arm. In a mechanical mass scale, the force generated by an applied load can produce torque that contributes to the movement of the rotational components. This principle provides a theoretical basis for explaining how an applied load can generate mechanical movement and ultimately produce a visible response on the indicating system.

$$\tau = Fr \sin \theta \tag{2}$$

Beyond mechanical principles, material selection is an important consideration in the development of simple measuring instruments. The materials used do not necessarily have to consist of industrial components or specialized materials that are relatively expensive. Recycled materials, such as wood, cardboard, and plastic containers, can be incorporated into the instrument's structure, provided that their physical properties are suitable for the intended functions of each component. The use of such materials offers an alternative approach to developing measuring instruments with lower material costs and more accessible resources.

The use of recycled materials in instrument construction is also associated with efforts to reuse materials that retain functional value (Prihandono et al., 2026). Wood can serve as a structural frame or support, cardboard can be used for structural components and scale indicators, while jars can function as load containers. Material selection should consider mechanical strength, structural stability, ease of fabrication, and the ability to maintain component positioning during operation. These material characteristics influence the stability of the mechanical system and the consistency of the instrument's response. Therefore, selecting appropriate recycled materials is essential to ensuring that the components can perform their intended functions within the overall mechanical configuration.

Nevertheless, the use of recycled materials presents several technical challenges that must be considered during the design process. Variations in material thickness, strength, density, and surface quality can affect structural stability. Weak joints, friction between moving components, and inaccurate pivot positioning may also influence the mechanical response of the instrument. Therefore, the assembly process must consider dimensional compatibility, structural balance, and smooth component movement to ensure consistent operation of the translational–rotational mechanism.

The development of a mass scale based on a translational–rotational motion mechanism offers an alternative approach to integrating mechanical principles into simple measuring instruments. This design utilizes the mechanical response generated by an applied load to produce displacement in the driving components and angular movement in the indicating system. Unlike digital instruments, which require electronic components and signal-processing systems, a mechanical approach allows the relationship between the applied load and the instrument's response to be observed directly. These characteristics make the proposed design a relevant alternative for

developing simple measuring instruments with relatively straightforward construction and accessible materials.

An important aspect of mass scale development involves not only the ability to produce pointer movement but also the relationship between the mechanical response and the measured mass. The pointer displacement must be correlated with reference masses through a calibration process so that each pointer position can be interpreted quantitatively. Calibration is necessary to establish the relationship between the input, represented by the applied load, and the output, represented by the displacement or angular position of the indicator. Without this process, pointer movement merely demonstrates a mechanical response and cannot serve as a reliable basis for determining measurement accuracy.

Performance evaluation is an essential stage in determining the capabilities of a developed instrument. Several parameters can be considered, including accuracy, precision, sensitivity, linearity, measurement range, and measurement error. Accuracy refers to the closeness of a measured value to its reference value, whereas precision describes the consistency of results obtained through repeated measurements. Sensitivity indicates the change in instrument output in response to a change in the input, while linearity describes the degree to which the relationship between the applied load and the indicator response follows a linear pattern. Evaluating these parameters is necessary to assess the measurement performance and suitability of the proposed design as a mass-measuring instrument.

Despite the development of simple measuring instruments, further investigation is needed to integrate the use of recycled materials with the application of translational–rotational motion mechanisms in a single mass scale design. Instrument development should extend beyond describing the materials and assembly procedures to explaining the mechanical displacement principles that connect an applied load to the movement of the indicator. The relationship between structural characteristics, mechanical responses, and calibration results is an important aspect of establishing the scientific contribution of such research. This research focus provides an opportunity to develop a simple mechanical instrument that is not only easy to reproduce but can also be evaluated using measurable performance parameters.

This study aims to design and construct a simple mass scale based on a translational–rotational motion mechanism using readily available recycled materials. The design process involves material selection, mechanical component assembly, development of the driving mechanism, and installation of the indicator as part of the measurement system. The development process also focuses on identifying the relationship between applied loads, component displacement, and changes in the angular position of the indicator. The resulting design is expected to provide insight into the application of mechanical principles in developing low-cost mass-measuring instruments.

Specifically, this study aims to develop a simple mass scale prototype, explain the mechanism of converting translational motion into rotational motion, and evaluate the instrument's response to applied loads. The evaluation is intended to identify the instrument's operating characteristics based on testing and calibration using reference masses. The main contribution of this study lies in applying mechanical principles to the design of a measuring instrument that utilizes recycled materials as alternative construction materials. The findings are expected to provide a foundation for the further development of simple mechanical measuring instruments while offering an

alternative approach to utilizing recycled materials in engineering applications and physics education.

2. METHOD

2.1 Research Design and Data Sources

This study employed a simple experimental engineering approach focused on the design, construction, and functional observation of a mass scale prototype based on a translational–rotational motion mechanism. A descriptive approach was used to identify the relationships between the arrangement of mechanical components, applied loads, and changes in the movement of the indicator. The analysis involved identifying the function of each component, examining the relationships between interconnected parts, and interpreting the mechanical principles underlying the instrument's operation. The available documentation served as the basis for reconstructing the fabrication process and systematically explaining the operating mechanism of the prototype. This study was subject to limitations in the availability of metrological data. The source report did not provide information regarding the number of measurement repetitions, variations in reference masses, calibration procedures, scale resolution, or measurement uncertainty calculations. Consequently, the evaluation focused on describing the construction and observable mechanical responses of the prototype. Mass indications presented in the visual documentation were not considered evidence of measurement accuracy until verified through comparison with reference masses.

2.2 Materials and Equipment

The prototype was constructed using readily available materials, some of which were repurposed from previously used items. Material selection was based on ease of fabrication, availability, and suitability for the structural and mechanical functions of the instrument. The primary materials consisted of a jar, wood, cardboard, and paper, along with supporting components such as a pencil and valve stems, as presented in Table 1. Adhesives and cutting tools were used to shape, assemble, and reinforce the prototype structure.

Table 1. Materials and equipment used in the construction of the simple mass scale

Component	Function in the assembly process
Jar	Main housing of the weighing mechanism, with specific sections modified by drilling holes
Wood	Load support, moving components, and structural mounting elements
Cardboard	Material for constructing gear-like components and the indicating dial
Pencil and paper	Auxiliary materials for forming a rolled component or simple shaft
Valve stems	Supporting components attached to the upper and lower sections of the wooden structure

Hot glue, wood glue, and Alteco adhesive	Bonding and reinforcing component joints
Scissors, ruler, and saw	Cutting, measuring, and marking materials
Paint and brush	Finishing and improving the appearance of the prototype

These materials were assembled into an integrated structure consisting of a load container, support structure, mechanical linkage components, and an indicating system. The use of cardboard for the gear-like components and indicating dial enabled the construction of a simple mechanical mechanism without requiring specialized manufactured components. Meanwhile, wood served as the structural element connecting the load-receiving section to the indicating system. All component joints were reinforced using adhesives selected according to the characteristics of the materials being assembled.

2.3 Prototype Fabrication Procedures

The prototype fabrication process consisted of several stages arranged according to the sequence documented in the original laboratory report. The initial stage involved preparing all tools and materials, inspecting the condition of the materials, and identifying the structural components to be assembled. Several holes were then made in the jar body according to the designated positions for the mechanical components. These holes served as mounting points and passageways for connecting elements between the internal and external sections of the structure. The next stage involved fabricating a rolled component using adhesive-coated paper. The paper was rolled around a pencil to form a simple cylindrical structure. Subsequently, cardboard was cut and shaped into a circular component using a pencil as a forming guide. The joints were reinforced with adhesive to maintain the component's structural stability during installation.

The third stage involved fabricating the support structure and mechanical components using wood. The wood was cut into several sections of different lengths to obtain longer and shorter components. These pieces were then arranged and bonded together to form the supporting structure and connecting elements that allow positional changes in response to applied loads. The placement of each component was adjusted according to the mechanical configuration shown in the assembly documentation. This stage established the structural arrangement required to connect the load-receiving section with the internal drive mechanism.

The fourth stage involved fabricating gear-like components from cardboard according to the dimensions of the wooden elements. The cardboard components were cut to the required shapes and attached to the wooden elements using adhesive. The joints were reinforced to minimize the possibility of component detachment during mechanical operation. The installation of these gear-like components was an important part of the construction because they were intended to transmit movement from one mechanical component to another. The fifth stage involved integrating the mechanical components with the jar body. A pencil was positioned through the central hole of the jar, followed by the installation of the wooden elements through the previously prepared openings. The connections between the wooden components and the jar body were reinforced using adhesive. Valve stems were subsequently attached to the upper and lower sections of the wooden structure, following the arrangement shown in the documentation. At the top of the assembly, the jar lid was positioned and secured with adhesive to form the load-receiving container.

The final stage involved installing the circular components made from cardboard and paper. Both components were provided with central holes to accommodate their installation on the shaft or mechanical connecting element. The dial was then mounted on the side of the jar to serve as the indicating surface, while the pointer was positioned to display angular changes as the mechanism responded to applied loads. After all components had been assembled, a visual inspection was conducted to examine joint strength, component alignment, and the freedom of movement of the indicating mechanism. The fabrication process concluded with painting selected sections of the prototype to improve its overall appearance and finishing quality.

2.4 Functional Observation and Data Analysis

Observations were conducted by applying loads to the container located at the upper section of the prototype and examining changes in the positions of the mechanical components and the response of the indicating system. The observed aspects included displacement of the supporting elements, movement of the connecting components, rotation of the dial, and changes in the pointer position. These observations were used to identify the potential relationship between the translational motion occurring in the load-receiving components and the rotational motion displayed by the indicator pointer. The mechanical analysis was based on the principles governing the relationships among force, displacement, and torque. Applying a load generates gravitational force acting on the mechanical system. This force may produce torque about a pivot point, resulting in angular displacement of the indicating components. The theoretical relationship between force and torque is expressed in Equation (2). This equation was used as a basis for mechanical interpretation rather than as a representation of experimentally measured torque in the prototype.

The observation results were analyzed descriptively by categorizing the information into three aspects: structural characteristics, mechanical responses to applied loads, and measurement limitations. Structural characteristics describe the arrangement and functions of the individual components, whereas mechanical responses explain the observable movements during the functional demonstration. The visual documentation presents a demonstration with a load indication labeled ½ kg. This value was recorded as information displayed in the documentation rather than as an accuracy test result verified against a standard weighing instrument.

The analysis also considered limitations in the available data, particularly the absence of repeated measurements, calibration using reference masses, and quantitative measurements of the pointer's angular displacement. Consequently, the instrument's accuracy, precision, linearity, sensitivity, maximum capacity, and measurement uncertainty could not be determined. Distinguishing between direct observations and theoretical interpretations was essential to maintaining objectivity and preventing conclusions that exceeded the available empirical evidence.

3. RESULTS AND DISCUSSION

3.1 Construction Results of the Mass Scale Prototype

The design process resulted in a simple mass scale prototype constructed using a combination of recycled materials, including a jar, wood, cardboard, and paper as the primary

structural components. The prototype was developed by integrating several components with distinct functions, including the main housing, load-receiving container, support structure, mechanical connecting elements, and an indicating dial equipped with a pointer. Each component was assembled into an integrated system to ensure that positional changes resulting from applied loads could be transmitted to the indicating mechanism. The resulting construction demonstrates the application of mechanical engineering principles through the utilization of simple materials readily available in the surrounding environment. This prototype development also illustrates that measuring instruments do not necessarily require industrial components, as they can be constructed by selecting and integrating materials according to their respective mechanical functions.

Structurally, the jar serves as the main housing or mechanical enclosure, providing space for installing most of the internal components of the mass scale. The jar was selected because its shape allows mechanical components to be positioned internally while providing an external surface for mounting the indicating system. Several holes were made in the jar body to accommodate the installation of connecting and supporting components. The upper section of the structure was equipped with a container for holding the object to be measured, allowing the force generated by the applied load to be transmitted to the internal mechanism. This arrangement establishes a structural connection between the load-receiving section, the motion transmission system, and the indicating mechanism. Furthermore, using a jar as the main housing simplifies the assembly process because its shape and dimensions can be readily adapted to accommodate the required components.

Wood serves as both a structural element and a driving component in the construction of the mass scale. The material was cut into several sections of different lengths to form the supporting structure and connecting components involved in the mechanical response to applied loads. The wooden components were positioned according to the openings in the jar body to ensure proper installation and movement within the designed configuration. When an object is placed in the upper container, the gravitational force acting on the load is transmitted to the supporting structure, resulting in positional changes in the mechanical components. These changes serve as mechanical inputs that are subsequently transmitted to the indicating system. The use of wood offers advantages in terms of ease of cutting, shaping, and joining with adhesives. However, the dimensions and installation positions of the wooden components must be carefully considered because structural inaccuracies may affect movement stability and the consistency of the instrument's response.

The wooden and cardboard components form an essential part of the prototype's motion transmission system. Cardboard was cut and shaped into gear-like structures and subsequently attached to the wooden elements. These components were arranged so that displacement of the driving element could be transmitted through mechanical contact to a circular component. The interaction between the gear-like elements enables the conversion of linear displacement into rotational motion. Conceptually, this mechanism resembles the motion transmission principle of a rack-and-pinion system, although the exact configuration and geometric specifications of the prototype have not been documented in detail. This mechanism represents an important design feature because it allows positional changes resulting from applied loads to be displayed through the rotation of mechanical components. Thus, cardboard functions not only as a structural material but also as part of the motion transmission system of the mass scale.

The indicating system was constructed using cardboard and paper components arranged into a circular dial and an indicator pointer. The dial was mounted on the side of the jar body in a position that allows the pointer to move and indicate angular changes as the mechanism responds to applied loads. This indicating system is an essential component because internal mechanical movements must be translated into visual information that can be observed by the user. When the circular component rotates, the attached pointer changes its angular position relative to the indicating surface. Functionally, this system serves as a mechanical interface between the internal response of the mass scale and the reading process performed by the user. However, translating pointer displacement into mass values requires zero-point adjustment and calibration using reference masses. Without these procedures, the dial and pointer can only indicate mechanical positional changes and cannot guarantee that the displayed values correspond to the actual mass.

The use of recycled materials in prototype construction provides an alternative approach to developing measuring instruments with relatively simple material requirements. Wood, cardboard, paper, and jars can be shaped using basic tools such as scissors, rulers, saws, and adhesives. The ease of material fabrication provides flexibility in adjusting component dimensions and configurations during the assembly process. Beyond their technical advantages, recycled materials also support the reuse of resources that retain functional value, thereby reducing dependence on newly manufactured materials. In mechanical instrument engineering, this approach offers an alternative for developing low-cost prototypes. Nevertheless, the use of recycled materials requires careful consideration of mechanical strength, stiffness, dimensional stability, and material suitability for the intended function of each component to ensure adequate structural performance.

The prototype construction also reveals several technical aspects that require further consideration in subsequent development. Wood may undergo dimensional changes due to moisture exposure and repeated loading, whereas cardboard has limited resistance to pressure, friction, and deformation. Adhesive joints may also weaken when subjected to continuous mechanical forces. These conditions can affect component alignment, motion transmission, and pointer stability. Furthermore, inaccurate shaft or connecting-element installation may introduce friction and mechanical clearance, potentially influencing the instrument's response. Therefore, further structural improvements should focus on reinforcing the supporting elements, improving the alignment of the gear-like components, and employing more stable joining techniques. Since this study did not include quantitative testing of material strength, load-bearing durability, or dimensional accuracy, these factors are considered potential structural limitations that require further investigation.

3.2 Analysis of the Translational–Rotational Motion Mechanism

The operating mechanism of the prototype begins when a load is placed in the container located at the upper section of the mass scale. The object placed in the container generates a gravitational force that acts on the container and is transmitted to the supporting structure inside the instrument. This force causes a positional change in the wooden component, which functions as the mechanical driving element. Based on the fabrication description and assembly documentation, the supporting component moves downward when a load is applied. This displacement indicates a mechanical response to the external force acting on the system. From a mechanics perspective, this phenomenon is related to Newton's second law, which describes the

relationship between the net force, mass, and acceleration of an object, as expressed in Equation (3). Under loading conditions, the component response is influenced not only by gravitational force but also by the reaction force of the supporting structure, friction, and the mechanical characteristics of the construction. If the mechanism incorporates a restraining or restoring element, the driving component may undergo displacement until a new equilibrium position is reached. This displacement serves as the initial input to the motion transmission system, which connects the load-receiving section to the indicating component. Thus, applying a load to the prototype does not merely change the position of the container but also initiates a sequence of mechanical movements that forms the basis of the indicating system's operation.

$$\sum F = ma \tag{3}$$

The movement of the wooden component can be interpreted as translational motion, which is subsequently transmitted to the gear-like mechanism. Translational motion refers to a change in the position of an object without rotation being its primary characteristic. In this prototype, the downward displacement of the wooden component serves as the input motion that interacts with a circular gear-like component. Contact between these two components enables motion transmission from linear displacement to angular motion. Conceptually, this mechanism resembles the operating principle of a rack-and-pinion system, in which the linear movement of a toothed element is converted into rotational movement of a gear. This motion conversion represents a key feature that distinguishes the proposed weighing mechanism from indicating systems that rely solely on direct positional changes. The effectiveness of motion transmission depends on the compatibility of the shapes and spacing of the gear-like components, the stability of their mounting positions, and the smooth movement of the connecting elements. When the components maintain appropriate mechanical contact, linear displacement can be transmitted to the rotational component more consistently. Conversely, improper alignment or excessive clearance between components may prevent some of the movement from being transmitted effectively. Therefore, the configuration of the mechanical linkage is an important factor influencing the response of the indicating system to changes in applied loads.

The circular gear-like component functions as the motion-receiving element that produces rotation in the indicating system. As the wooden component moves, its mechanical contact with the circular component causes an angular displacement. This rotational movement is subsequently transmitted to the pointer attached to the indicating dial, causing it to move from its initial position to a particular angular position. The resulting angular displacement serves as a mechanical output that can be directly observed by the user. In a measurement system, this component plays an important role in converting the instrument's internal mechanical response into readable visual information. The relationship between translational and rotational motion can theoretically be explained through the relationship between linear displacement and angular displacement. For a gear mechanism with an effective radius (r), the ideal kinematic relationship between linear displacement (s) and angular displacement (θ) can be expressed as Equation (4), where the angle is measured in radians:

$$s = r\theta \tag{4}$$

This relationship indicates that changes in the displacement of the driving element can produce corresponding angular changes in the rotational component. In the prototype, the resulting angular displacement is displayed through the movement of the pointer across the dial. However, this relationship remains a theoretical explanation because the component dimensions, effective radius, and actual displacement have not been quantitatively measured. Consequently, the observed pointer movement during the demonstration can be used to explain the mechanical response of the instrument but is insufficient to establish a quantitative relationship between increasing mass and changes in the pointer's angular position.

Theoretically, the rotational response of the mechanism can also be explained through the concept of torque. A force acting on a component at a certain distance from a pivot point can generate a tendency to produce rotational motion. The magnitude of torque depends on the applied force, the length of the lever arm, and the angle between the force direction and the lever arm. This relationship is expressed in Equation (2). In the proposed mass scale, the force generated by the applied load may produce torque around a specific mechanical pivot, thereby influencing component displacement and the rotational response of the indicating system. When the force acts perpendicular to the lever arm, the magnitude of torque can be expressed as shown in Equation (5). This principle explains how changes in the applied force or the distance from the pivot point can influence the resulting rotational response. Nevertheless, the actual torque generated in the prototype cannot yet be determined because the lever arm dimensions, pivot position, force distribution, and mechanical characteristics have not been quantitatively measured. Therefore, the torque equations are used as a theoretical foundation for explaining the underlying mechanical principles rather than as the results of experimental torque calculations.

$$\tau = Fr \tag{5}$$

The relationship between translational and rotational motion provides a basis for understanding how changes in applied loads can be converted into changes in the pointer position. Ideally, an increase in load produces a corresponding change in the force acting on the supporting structure, which is subsequently transmitted as linear displacement of the driving component and angular displacement of the rotational component. If the mechanical characteristics and structural conditions remain constant, these input changes may produce a consistent relationship between the applied mass and the pointer's angular position. However, this relationship is not necessarily linear because it is influenced by geometric configurations, material properties, and mechanical operating conditions. Friction between moving components may reduce the transmitted displacement, while clearance between gear-like components may cause delayed responses or movements that are not directly proportional to the initial displacement. Furthermore, deformation of the wooden and cardboard components under loading may alter contact positions and motion transmission characteristics. Other factors, including inaccurate zero-point positioning, shaft instability, and variations in pointer alignment, may also affect reading consistency. These considerations demonstrate that the ability of a mechanism to produce pointer movement must be distinguished from the ability of an instrument to provide accurate mass measurements. Therefore, the relationship between mass and pointer angle should be established through calibration using reference masses at different loading levels and repeated measurements. The resulting calibration

data can subsequently be used to evaluate the response characteristics, linearity, sensitivity, and measurement deviations of the prototype mass scale.

3.3 Demonstration Results and Instrument Response Characteristics

The usage documentation shows that the prototype was successfully assembled and demonstrated a mechanical response to applied loads. When an object was placed in the upper container, the supporting components underwent positional changes that were transmitted through the driving mechanism, causing the pointer to move across the indicating dial. One of the visual records shows a demonstration with a mass indication labeled ½ kg. This finding indicates that the interaction between the mechanical components can produce a visual output in response to an applied load. However, this indication cannot yet be considered a validated measurement because it is not accompanied by information regarding reference masses, calibration procedures, or comparisons with a standard weighing instrument. Therefore, the demonstration results only confirm the functional mechanical response of the prototype rather than its mass measurement accuracy.

The performance evaluation of a mass-measuring instrument ideally involves several parameters, including accuracy, precision, sensitivity, linearity, resolution, and measurement range. Pointer movement indicates that mechanical displacement can be transmitted into a visual output, but it does not establish a linear relationship between increasing mass and angular displacement. The absence of calibration data, variations in reference masses, and repeated measurements prevents the quantitative analysis of measurement deviations and reading consistency. Therefore, further testing involving the incremental application of reference masses, repeated measurements, and comparisons with a standard weighing instrument is necessary to determine the metrological characteristics and assess the suitability of the prototype as a mass-measuring instrument.

3.4 Evaluation of Construction, Limitations, and Development Implications

One of the main advantages of the proposed design lies in its use of simple and readily available materials. The use of a jar, wood, cardboard, and paper enables prototype construction without relying on electronic components or complex manufacturing equipment. The simplicity of the construction also provides opportunities to modify component dimensions, mechanical configurations, and indicator designs according to further development requirements. These characteristics make the design a potential alternative for developing simple mechanical instruments with relatively low material costs. Nevertheless, structural stability requires particular attention because recycled materials do not always exhibit uniform physical properties. Variations in cardboard thickness, wood quality, and adhesive joint strength may affect the mechanical response when loads are applied repeatedly. Friction between moving components may also cause delayed or inconsistent pointer movement. Therefore, material selection and assembly precision must be carefully considered to ensure more stable motion transmission.

Another limitation concerns the absence of information regarding the maximum load capacity and safe operating conditions of the prototype. The strength of the container, wooden supports, adhesive joints, and cardboard components must be evaluated before the instrument is used with larger load variations. Loading beyond the structural capacity may cause permanent

deformation or mechanical failure. Determining the maximum load capacity through incremental testing is necessary to ensure that prototype operati

4. CONCLUSION

This study successfully developed a simple mass scale prototype based on a translational–rotational motion mechanism using recycled materials, including a jar, wood, cardboard, and paper. The design demonstrates that applying a load to the upper container produces displacement in the supporting components, which is transmitted through a gear-like mechanism and converted into rotational motion of the dial and indicator pointer. The application of these mechanical principles highlights the potential of utilizing simple materials in the development of mechanical measuring instruments. However, limitations in the testing documentation, the absence of calibration procedures, and the lack of repeated measurement data mean that the prototype's accuracy, precision, sensitivity, and measurement range cannot yet be determined. Therefore, further development should focus on improving the structural design, conducting tests using reference masses, calibrating the measurement scale, and evaluating metrological performance to develop a more reliable mass-measuring instrument.

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