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Development of Multifunctional Mobile Teaching Aid for Basic and Secondary schools in Nigeria.

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Abstract
The inadequate supply of educational teaching aids and truly functional laboratories to aid teaching and learning in the basic, science, secondary and virtual schools across Nigeria and in fact globally due to high cost incurred in acquiring them has necessitated the invention of a multifunctional mobile teaching aid and intervention laboratory for schools. The invention relates to educational demonstrations, experimentations, display and instructional materials as home-grown, purpose-built game changer to positively disrupt the educational sector to enhance quality and effective Science, Technology. Engineering and Mathematics (STEM) education in Nigeria translating into reduced situation of mass failures in NECO, WAEC, NABTEB, IJMB, UTME, quality impactful teachers' delivery, students' participatory interests in studies, value for money and reduced capital flights from importation of apparatus. This innovation which has been adopted and deployed by the Kaduna and Niger state Governments with other Federal Ministries of Education, Science, Technology and Innovation provides multifunctional interfaces for variety of experiments on single equipment and its auxiliaries has made experimentation and teaching easier, more captivating its mobility around for appropriate purposes and it equally fits into existing conventional laboratories. The results obtained in basic science, physics, chemistry, biology and mathematics were conclusively effective and efficient using the innovation. The 170cm height of the equipment was experimentally obtained like it was being done in the conventional laboratory to measure the height of the ceiling using simple pendulum and the results of 165cm was gotten within +2.9% minimum experimental error with recommendation for height automation and collapsibility.
Keywords: Invention, Multifunctional, Mobile, teaching-aid, laboratory

Introduction
In Nigeria, the use of practical supports for theoretical teachings of science had always been through the conventional laboratories which contain auxiliaries like retort stands, clamps, beakers, burettes, ray boxes, pulley system and other experimental functionaries usually in small confinement that is not only conducive and convenient enough for effective participatory teaching and learning, but is also very expensive and expansive in space utilization (Lawal,2008).There have been several challenges facing the educational system of Nigeria; one of these challenges is the lack of proper equipment and teaching aids for the teachers to properly demonstrate the theoretically acquired knowledge for more understanding. These challenges were identified and finding lasting solutions propelled Lawal to build in his 2008 efforts to invent and patented (RP:NG/P/2014/398) science educational mobile intervention laboratory that is multifunctional mobile teaching aid that also serves as intervention laboratory for basic, science and secondary schools (Lawal,2016). It could equally be deployed virtually and through other information and technology means and social media platform especially in the case of any lockdown and shut down of schools. The overwhelming feedbacks from the teachers, schools and educational stakeholders especially Kaduna state government that has adopted the invention in her schools has been a strong endorsement of its utility and versatility as reported in leadership newspaper,2019, Engineering Forum News, 2019 and sunnewsonline,2021.To leverage on emerging technology culminating in further improvement, upgrade and automation from researchers and innovators on one hand and

market interests from educational managers on the other hand, the need for the automation of the lifting mechanism of the equipment for appropriate height adjustment was carried out and reported by Alkali,2019, Inyang,2019, Paul,2019, Awoyemi, 2019 and Momoh,2021 with the original patent owner and inventor (Lawal,2016).

This paper therefore presents the potentials exploration of the multifunctional teaching aid which also serves as interventional laboratory to positively disrupt the educational improvement and standards in the country.

Objective of the Study

The main objective of this project was to develop a multifunctional mobile teaching aid and intervention laboratory for schools.

Research Question

How viable is

Methodology

Some major factors like cost, availability of raw materials and weight among others were put into consideration during the design of the project. Selection of the right materials during construction is a vital decision to make as it is a major factor that determines the success of project as the design engineer's understanding of engineering materials and their properties is critical. The impact of production methods and heat treatment on the properties of materials must be understood by a construction engineer. The following are the key categories of engineering materials namely metals and their alloys, such as Iron, steel, copper, aluminum and Non-metals, such as glass, polymers, elastomers, ceramics etc. The parts and materials used in this work are presented in Table 1 below: -

Table 1 Parts and Materials used in the development of a multifunctional mobile teaching aids

PART NO	PART DESCRIPTION	QUANTITY REQUIRED	MATERIALS
1	Square pipe	418 feet, 1x1	**Mild steel**
2	Square pipe	18 feet, $^{3}/_{4}$x$^{3}/_{4}$	Mild Steel
3	Rectangular pipe	118 feet, 2x1	Mild Steel
4	Laminated plywood	1 4ft by 8ft	MDF Wood
5	Hinges	2	Mild steel
6	Angle brackets	28	Mild steel
7	Rollers	4	Steel and plastic
8	Contact adhesive	1	Wood adhesive
9	Bolts and nuts	28M4,	Mild steel
10	Screws	8 $\frac{3"}{4}$,	mild steel
11	Spur gears	2	Mild steel
12	Microcontrollers		
13	Edges tape		Plastic

Fabrication of Metal Frame

1. The pipes were marked out to the various lengths of the improved science educational mobile intervention laboratory metal frame using scriber, tape rule, and tri-square.
2. The marked-out lengths on the pipes were clamped on bench vice one after the other and were cut into the marked out dimensions using a hacksaw. Straightness of the hand during cutting was strictly ensured in order to obtain a straight cut-edge of the pipes.
3. The cut pipes were joined together in an orderly manner to obtain the exact shape of the designed metal frame of the work using the electric arc-welding machine at 120A, and E6013 electrode.
4. The angle brackets were welded to the metal frame on the right positions of the frame where the plywood is to be bolted to.
5. Four rollers, two with a stopper and two without stopper, were welded to the four legs of the frame.
6. All the welded joints on the metal frame were grinded to a fine surface using the hand-held grinding machine.

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7. Potty filler was applied to the grinded welded joints after been mixed with a hardener, and was scrubbed with a san-paper to give it a fine-finished look.
8. The plywood was then marked out to the various dimensions using a tape rule and a pencil.
9. The marked-out dimensions on the plywood were cut out using the circular wood saw.
10. The 105cm by 100cm size board's edges was covered with edges tape, held firmly to the edges of the board using the wood adhesive.
11. The welded metal frame was sprayed with a white paint using a compressor spraying machine and left for a day to dry.
12. The cut plywood was attached to the metal frame using bolts, nuts, and a screwing machine.
13. 10mm holes were drilled on the 110cm by 100cm board with 1cm equidistance apart using a drill bit, and a hand-held drilling machine.
14. The perforated board was attached to the two arms of $\frac{3"}{4}$pipes which protruded from the two sides of the table top using a U-shaped clamp.

Lifting Device Mechanism and Assembly

The lifting device made up of the components such as Scissor screw jack, Spur gears,12v D.C motor, Transformer, Switch, Rectifier, Arduino, Keypad, LCD display and Microcontroller (Faraday,2013, Rout *et al*, 2014 and Chaudhary *et al*,2016) are required for the automation of the height adjustment as recommended by users. A jack is a mechanical lifting system that can be used to apply massive forces or raises large loads. For lifting heavy machinery, a mechanical jack used a screw loop. Hydraulic control is used by a hydraulic jack. 1st A car jack, floor jack, or garage jack is the most common type, which raises vehicles so that maintenance can be performed. Jacks are usually rated for a maximum lifting capacity (1.5 tons or more). A jack screw also known as a screw jack, is a jack that works by spinning a leadscrew. It is often used to lift moderately heavy weights, such as vehicles; to raise and lower the horizontal stabilizers of aircraft; and to provide flexible supports for heavy loads, such as house foundations (Rout *et al*, 2014).

Automation of Lifting Device

This automation of the lifting device could be handled by a device (microcontroller) used is an Arduino board which attached with wireless remote controls the upward and downward movement of the experimental board mounted on the lifting device. To lift the experimental board, the suited microcontroller (Bogdan,2018).

Results

The invented multifunctional mobile teaching aid with multiple experimental set up on display are shown in Figures 2
.

Figure 2: The Invented and automated Multifunctional Teaching aid with the switch and remote control system.

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Experimentations

One of the experiments carried out was to determine the Height of the Equipment using the Simple Pendulum principle as shown schematically in Figure 3 below and pictorially in Figure 4.

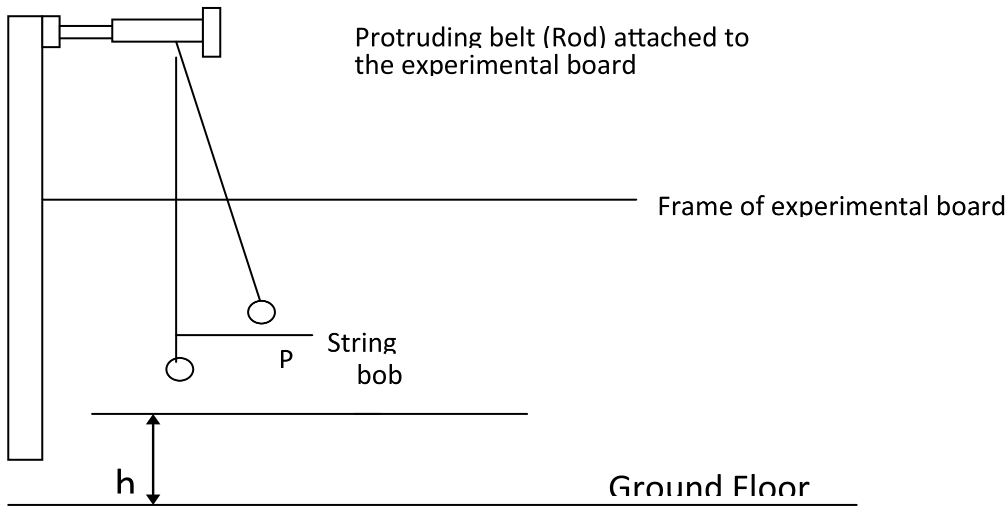

Figure 3: Diagram of simple pendulum experiment to determine height of the equipment

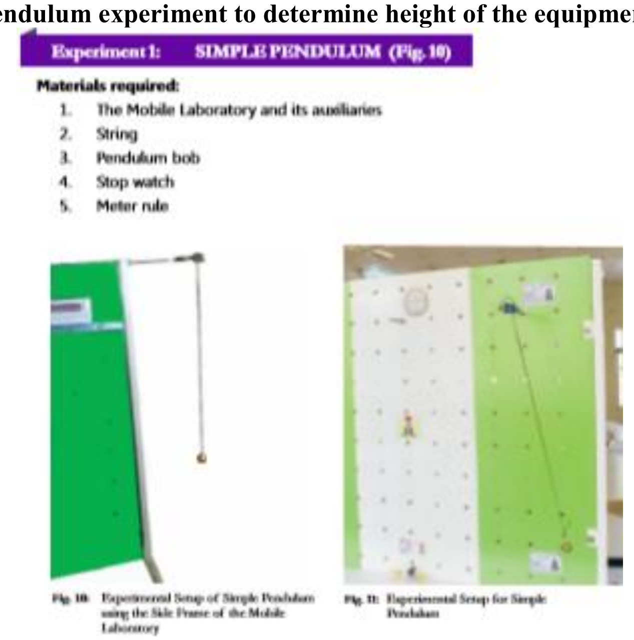

Figure 4: Screenshot of the Simple Pendulum experimentation set up on the equipment

APPARATUS

1. Pendulum
2. Stop watch
3. Meter rule
4. String
5. Protruding bolt (rod)
6. Multifunctional Mobile teaching aid and Intervention laboratory

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Procedure:
The protruding bolt (rod) is attached inserted on the welded nut at the highest side of the experimental board the simple pendulum is then hung on the protruding rod and the height of the bob above the floor is adjusted for the various height starting with 20km above the floor, the bob was set swinging through a small angle and the time for 20 oscillations was counted the experiment was repeated by adjusting the height above the floor for 30cm, 40cm, 50cm, 60cm.
The Table 2 below are the experimental readings from the multifunctional teaching aid and intervention laboratory.

Table 2 Values from the experimental readings

Height above floor (cm)	Time for 20 oscillation(s)			Period T(s)	T(S)	
1 2 average						
20 48	49	48.5		2.42 5.88		
30 46	46	46	2.3	5.29		
40 44	44	44	2.2	4.84		
50 42	42	42	2.1	4.41		
	60	40	40	40	2	4.00

Theory and Calculations
From the simple pendulum equation for periodic time (T)
T= 2
But L = H-h (1)
Where,
H = height of the experimental board
h = height of the bob above the floor
Therefore, T $= 2\pi = \frac{\sqrt{H-h}}{g}$(Abbot,1989, Nelkon and Parker,1995) (2)

Expanding $T^2 = 4\pi^2 \frac{H-h}{g}$ (3)

$\frac{gT^2}{4\pi^2} = H^- h$

When $T^2 = 0$,
H – h = 0
Which implies h = H at $T^2 = 0$

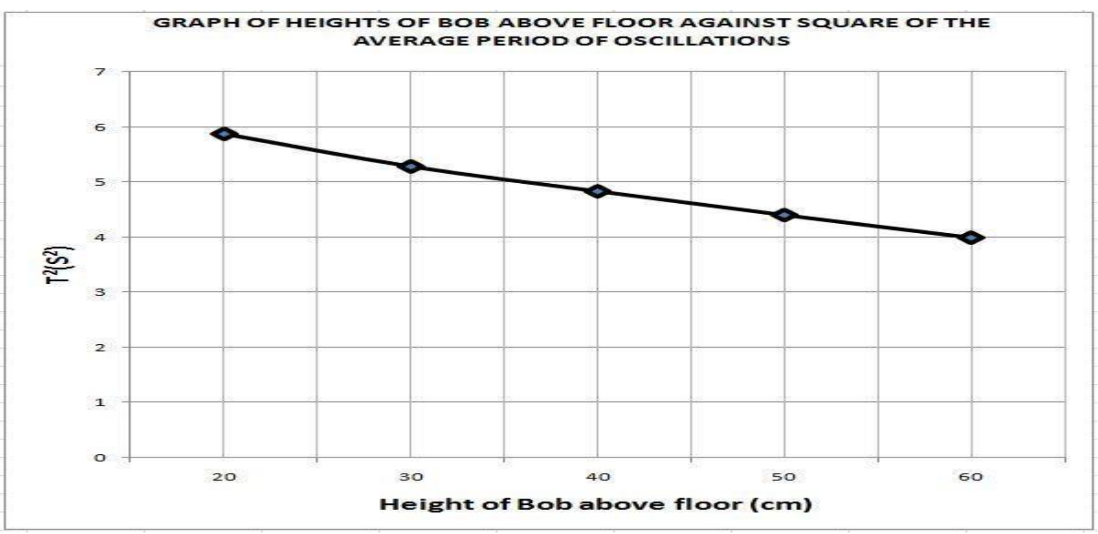

Figure 5:

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Graph of period of oscillation against height of bob above floor
Actual height of the experimental board is 170cm
From the graph in figure 5
When $T^2 = 0$, h = 165cm
This H – h = 0
H = 165cm
Error estimated= (165-170) cm = -5cm

$$\% \text{ error} = \frac{Difference\ in\ height}{Actual\ Heiight}\ x\ 100 \quad (4)$$

$$\frac{-5}{170} \text{ x } 100 = 2.9\ \%$$

This result shows another encouraging output of the multifunctional teaching aid and intervention with minimum experimental results and error of 165cm + 2.9%.

Screenshot from the Monograph of the equipment of some experimental set up and procedures for Physics, Chemistry and Biology are shown below:

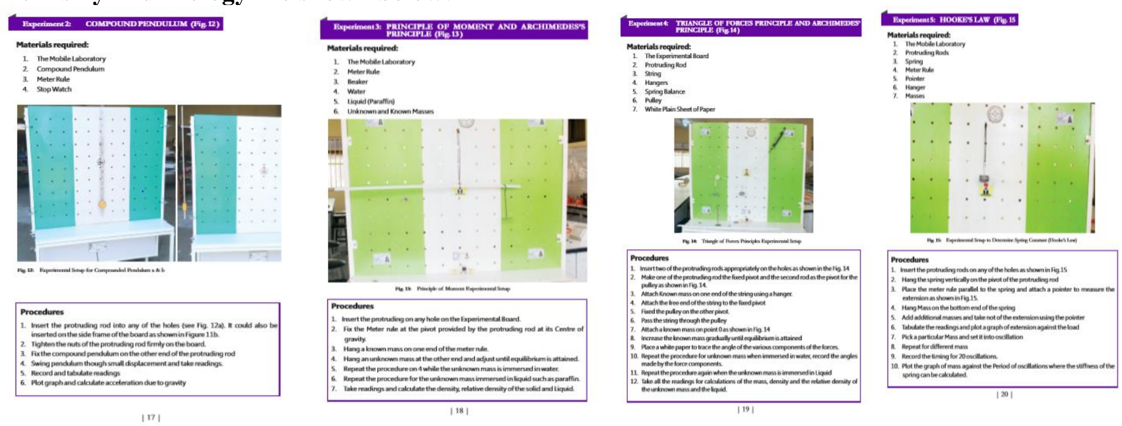

Figure 6: Screenshot for the Monograph for the Experimental setup and procedures for Compound Pendulum, Moment Principle, Triangle of Forces and Hooke's Law in Physics

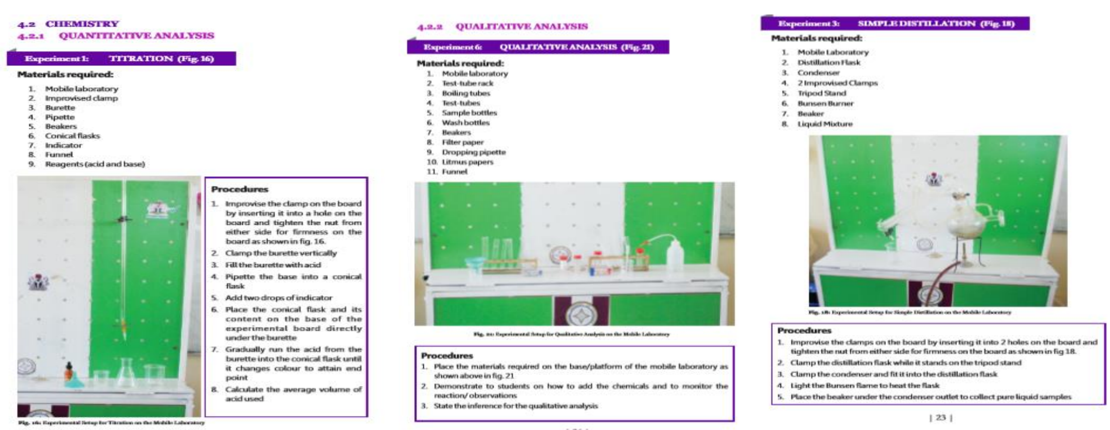

Figure 7**:** Screenshot from the Monograph of Experimental Setup and Procedures for Quantitative Analysis (Titration), Qualitative Analysis and Simple Distillation in Chemistry

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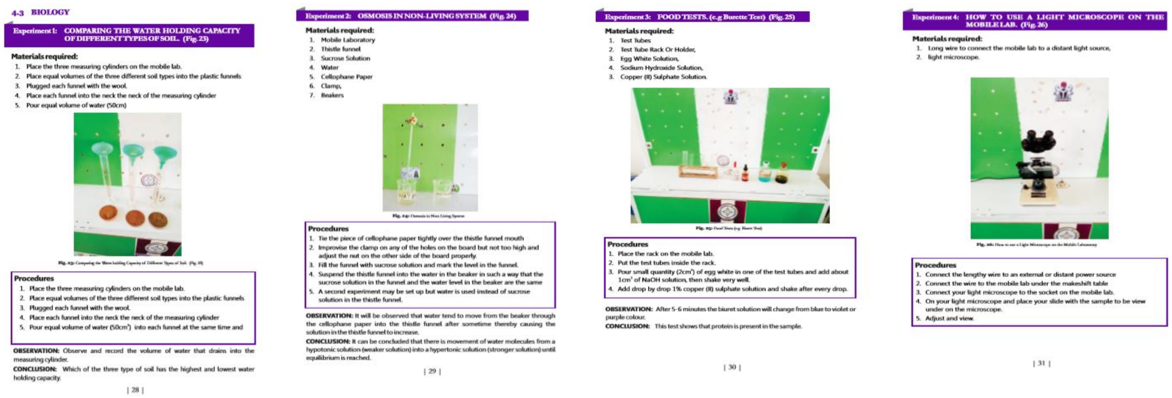

4-3 BIOLOGY

Experiment 1: COMPARING THE WATER HOLDING CAPACITY OF DIFFERENT TYPES OF SOIL. (Fig. 23)

Materials required:
1. Place the three measuring cylinders on the mobile lab.
2. Place equal volumes of the three different soil types into the plastic funnels
3. Plugged each funnel with the wool.
4. Place each funnel into the neck the neck of the measuring cylinder
5. Pour equal volume of water (50cm)

Procedures
1. Place the three measuring cylinders on the mobile lab.
2. Place equal volumes of the three different soil types into the plastic funnels
3. Plugged each funnel with the wool.
4. Place each funnel into the neck the neck of the measuring cylinder
5. Pour equal volume of water (50cm^3) into each funnel at the same time and

OBSERVATION: Observe and record the volume of water that drains into the measuring cylinder.
CONCLUSION: Which of the three type of soil has the highest and lowest water holding capacity.

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Experiment 2: OSMOSIS IN NON-LIVING SYSTEM (Fig. 24)

Materials required:
1. Mobile Laboratory
2. Thistle funnel
3. Sucrose Solution
4. Water
5. Cellophane Paper
6. Clamp,
7. Beakers

Procedures
1. Tie the piece of cellophane paper tightly over the thistle funnel mouth
2. Improvise the clamp on any of the holes on the board but not too high and adjust the nut on the other side of the board properly.
3. Fill the funnel with sucrose solution and mark the level in the funnel.
4. Suspend the thistle funnel into the water in the beaker in such a way that the sucrose solution in the funnel and the water level in the beaker are the same
5. A second experiment may be set up but water is used instead of sucrose solution in the thistle funnel.

OBSERVATION: It will be observed that water tend to move from the beaker through the cellophane paper into the thistle funnel after sometime thereby causing the solution in the thistle funnel to increase.
CONCLUSION: It can be concluded that there is movement of water molecules from a hypotonic solution (weaker solution) into a hypertonic solution (stronger solution) until equilibrium is reached.

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Experiment 3: FOOD TESTS. (e.g Burette Test) (Fig. 25)

Materials required:
1. Test Tubes
2. Test Tube Rack Or Holder,
3. Egg White Solution,
4. Sodium Hydroxide Solution,
3. Copper (II) Sulphate Solution.

Procedures
1. Place the rack on the mobile lab.
2. Put the test tubes inside the rack.
3. Pour small quantity (2cm^3) of egg white in one of the test tubes and add about 1cm^3 of NaOH solution, then shake very well.
4. Add drop by drop 1% copper (II) sulphate solution and shake after every drop.

OBSERVATION: After 5-6 minutes the biuret solution will change from blue to violet or purple colour.
CONCLUSION: This test shows that protein is present in the sample.

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Experiment 4: HOW TO USE A LIGHT MICROSCOPE ON THE MOBILE LAB. (Fig. 26)

Materials required:
1. Long wire to connect the mobile lab to a distant light source,
2. light microscope.

Procedures
1. Connect the lengthy wire to an external or distant power source
2. Connect the wire to the mobile lab under the makeshift table
3. Connect your light microscope to the socket on the mobile lab.
4. On your light microscope and place your slide with the sample to be view under on the microscope.
5. Adjust and view.

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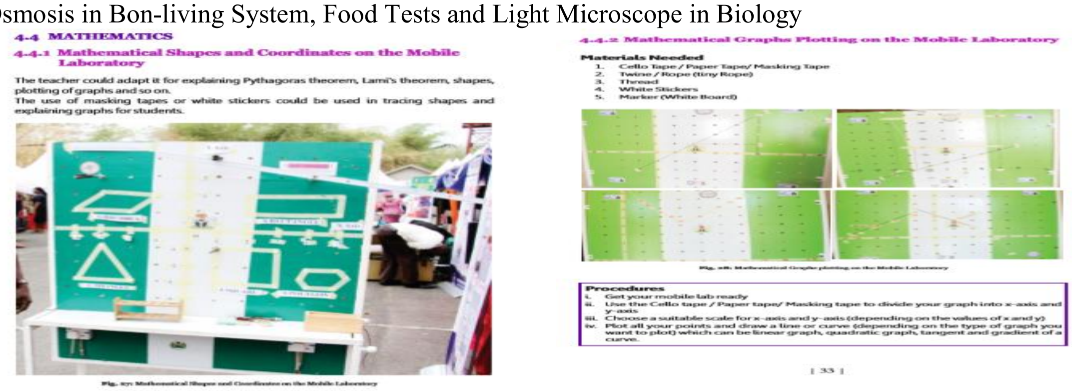
Figure 8:

Figure 8: Screenshot from the Monograph of Experimental Setup and Procedures for Water holding Capacity of Soils, Osmosis in Bon-living System, Food Tests and Light Microscope in Biology



4-4 MATHEMATICS

4-4.1 Mathematical Shapes and Coordinates on the Mobile Laboratory

The teacher could adapt it for explaining Pythagoras theorem, Lami's theorem, shapes, plotting of graphs and so on.
The use of masking tapes or white stickers could be used in tracing shapes and explaining graphs for students.

4-4.2 Mathematical Graphs Plotting on the Mobile Laboratory

Materials Needed
1. Cello Tape / Paper Tape/ Masking Tape
2. Twine / Rope (tiny Rope)
3. Thread
4. White Stickers
5. Marker (White Board)

Procedures
i. Get your mobile lab ready
ii. Use the Cello tape / Paper tape/ Masking tape to divide your graph into x-axis and y-axis
iii. Choose a suitable scale for x-axis and y-axis (depending on the values of x and y)
iv. Plot all your points and draw a line or curve (depending on the type of graph you want to plot) which can be linear graph, quadratic graph, tangent and gradient of a curve.

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Figure 9: Screenshot from the Monograph of Experimental Setup and Procedures for Mathematical Shapes, Coordinates and Graph Plotting in Mathematics.

Conclusion

The multifunctional Mobile Teaching Aid and Intervention Laboratory invented and furthered automated was tested to perform some experiments in Physics, Biology, Chemistry, Mathematics and some basic technologies has shown its utility and versatility with promising status as a positive disruptive game changer in teaching, demonstrations and conduct of practical in science classes effectively for the improvement of the basic, science, secondary and technical educational standard in the country.The Simple pendulum experimental determination of the height of the equipment as 165cm against the actual height of 170cm with 2.9% minimum error is testament on the effectiveness of the multifunctional teaching aid and intervention laboratory.

Recommendation

Government at all levels, Educational Mangers and stakeholders and Non-governmental, local and international educational support organizations are urged to take advantage of this home-grown and purpose-built invention to enhance quality educational delivery, scientific and technological ripples so as to address effectively the often pervading dearth of equipment that is the usual narrative in our educational system.

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