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MULTIPLE REPRESENTATIONS IN DISPELLING SOME COMMON MISUNDERSTANDINGS AND INCREASING THE CLARITY OF PRINCIPLES OF PHYSICS TAUGHT AT SECONDARY SCHOOL LEVEL

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ABSTRACT

In this study, it is expected to highlight some common illusions that can interfere with classroom teaching of physics at secondary school. Cases cited here surfaced as useful by-products while some experimental teaching sessions were being conducted with grades 10 and 11 students in three government schools in a suburb of Western province in Sri Lanka. The main purpose of that exercise was to test the efficacy of visual-perceptual approach to teaching on some physics lessons, namely, kinematics, Newton's laws of motion and equilibrium of forces, turning effect of forces etc. It has become necessary to keep an open dialog with students and to get their active participation in the teaching / learning process in order to prepare a suitable visual-perpetual assessment tool to measure their performance at the end of the teaching exercise. This teaching sessions spans for about 15 hours after school and spread over three months (each period being 40 minutes duration). These classes were held with the help of the respective science teachers of the school. The problematic cases for the students that will be discussed in detail later were successfully tackled by employing appropriate lesson specific visualization objects in conjunction with existing traditional methods of teaching. Sometimes more than one visualization mode (external representations) had to be used to facilitate better understanding of the same principle. End result seemed satisfactory in terms of marks scored for the visual-perceptual assessment tool and, student and teacher interviews.

Contribution/ Originality: This study document aims at encouraging curriculum developers and teachers to use multiple representations to supplement the textual (or verbal) mode in the same sequential order in which the text is presented. Student centered interactive teaching can guide the teacher on selecting suitable visualization objects appropriate to student and lesson.

1. INTRODUCTION

Certain topics categorized under the subject 'physics' today have been in association with mankind since time immemorial. In their day-to-day work, they had to experience force, energy, speed and different types of motion, friction, pressure, etc. Up to the present day, manual workers capable of doing marvelous jobs involving the principles underlying these phenomena are not uncommon. For example, in villages, one can see tree cutters, removing unwieldy branches with surprising accuracy and dexterity in dropping the cut pieces of logs in narrow spaces. Unification of these not-much-educated people's souls with such things as equilibrium of forces, the resultant of more than one force - very often the gravity and a pull exerted with a rope -, etc. are marvelous things to behold. Cycling, driving and carpentry are abundant with such maneuvers.

All these manual workers get their training in traditional ways and they lack proper scientific training. Therefore, these workers themselves and the society they live in can have certain amount of imperfections in their knowledge regarding certain aspects of these works. Such errors can cast shadows into the classroom mostly at secondary levels. Students depending on their background sometimes have to struggle hard to absorb the correct principles and therefore, the teacher has a great responsibility to elicit from the student such problems by adopting novel teaching methods deviating from didactical ways followed in the past. Children should be heard to a greater degree. A dialogue to discuss their preconceived ideas including misconceptions should be accommodated paving the way to critical thinking and emerging inquiries. This gives the students a sort of ownership of the things they learn.

Some common misbelieves have been cited below. The fact that application of a constant force on a moving body in the direction of its motion gives rise to continuous acceleration can be alien to many students and they think that the constant force is a must for maintaining the movement. Another classic example is the misbelief regarding the falling of light and heavy objects under the gravity. Inability to use the knowledge of classroom circuit diagrams to do simple home wiring work with understanding and confidence is another example. Here, it is the unsuitability of the line diagram of the circuit (a visualization object) for practical purposes and therefore, replacing or supplementing it with an alternative representation mode would overcome the problem.

2. LITERATURE REVIEW

Science education involves the use of various representations such as diagrams, graphs, symbols, computer-aided visualization tools such as video clips, animations and simulations. Wong and Chu (2017) mentioned that though physics teachers do use multiple representations in classroom teaching they may not sufficiently pay their attention to step by step development of concepts through the use of these representations (with relevance to teaching electric current). Further, Wong and Chu (2017) pointed out the importance of multiple representations in teaching about forces for upper secondary students.

The relevance of these representations for this study is that designing teaching and learning activities by including multiple representations spanning through three levels of representations: macro, micro and symbolic (Hill *et al.*, 2014) which can be used to represent various simplified models of complex natural phenomena in physics can be made use of building necessary mental images found in physics. These modes of representations can consist of the concrete (material) mode, the verbal mode, the symbolic mode, the visual mode and the gestural mode (Gilbert, 2005; Gilbert, 2010; Cheng and Gilbert, 2017).

The concrete mode is where various physical models or practical setups are used to explain the physics subject matter. The verbal mode involves written and spoken language used to explain the subject. Further, the verbal mode includes the use of analogies also. The symbolic mode primarily involves the use of mathematical relationships of physical quantities in physics. The visual mode contains the use of diagrams, graphics, graphs, videos, animations, simulations, etc. The gestural mode is the teacher's gestural expressions used to explain the subject. Also, the dramatized demonstrations may be considered under the gestural mode. Further, each of these modes may contain sub-modes.

The teacher has to use the above mentioned external representation modes appropriately in classroom teaching. Corresponding to the external representations, the learner builds internal representations. Gilbert (2005) mentioned that these internal representations can be called mental images, visualizations or visual-perceptions in science education. In learning physics, these internal representations can be related to still objects, changes in properties of moving objects, mathematical equations, some hypothetical model, etc. It is the teacher's duty to do necessary elaborations using the external representations to strengthen building necessary internal representations in the learner to promote the visualization of the necessary areas in physics.

As representations are closely linked with visualization (Rundgren and Yao, 2014) it is worth of mentioning something on theories of visual learning. Piaget's ideas on developmental psychology gave a pioneering scientific insight into how a child develops visual learning parallel to the development of the child's spatial cognition (Piaget and Inhelder, 1956). The schema theory presented by him also related with building necessary internal representations. Further, the Dual Coding Theory (Paivio, 1986; Sadoski and Paivio, 2012) and the Visual Imagery Hypothesis (Hochberg, 1998; Pylyshyn, 2003) can be treated as providing a good theoretical framework for developing computer based visualization tools for teaching science (Vavra *et al.*, 2011). The dual coding theory emphasizes the importance of using a combination of both the verbal and visual modes, and the visual imagery hypothesis highlights the use of graphical representations as means of reducing the learner's load of working memory. Use of some of the computer based visualization tools such as video clips, animations, simulations, etc., as external representations are suggested in the following discussion in correcting the misunderstandings.

3. COMMON MISUNDERSTANDINGS AMONG THE STUDENTS

The misunderstandings discussed below were identified by the interactions with the students made for identifying visualization related areas in physics for developing a visual-perceptual assessment tool, in an experimental study conducted in the year 2017 (March-June) with a sample of 184, grades10 and 11 students (aged 15-16 years) in Sri Lankan government school system following the national curriculum implemented from the year 2015.

Case 1: The common misbelief that continuous application of a fixed horizontal (unbalanced) force on an object in rectilinear motion) causes the object to maintain a constant velocity rather than accelerating it.

Many students cannot visualize the fact that continuous application of a fixed horizontal (unbalanced) force on an object moving on a horizontal path causes the object to uniformly increase its speed (causes to accelerate). What they observe in day-to-day experiences is that constant application of force is the thing that maintains the speed of the object on a level ground. To speed up, they think this force should be constantly increasing. The frictional force exerted by the surface and by the air, without their knowing slows down the object and only to overcome such opposite forces (working in the direction opposite to the movement), the constant application of force in the direction of movement is necessary and not for maintaining the speed. These difficulties have to be practically illustrated using suitable modes of representation for the students to correct their internal image.

Newton's second law of motion is presently represented in many introductory secondary school physics textbooks as $F = ma$ where 'F' is the unbalanced force applied to an object, 'm' is the mass of the object and 'a' is the acceleration of the object. As a first step in visualizing the Newton's second law, how the acceleration of an object moving in a straight-line changes when a constant unbalanced force is applied to it provided its mass is constant must be clearly clarified. In classroom teaching the teacher may use some practical setup (Figure 1) or/and may select suitable section from currently available computer aided tools in the internet such as video clips, Interactive simulations, animations, etc.[1]in such a way that it helps the students build their basic visual-perceptions regarding the nature of movement of an object in this theoretical situation. In using the set up in Figure 1, employing a very smooth horizontal table surface and wheels of trolley would give some convincing results.

[1] e.g. https://www.youtube.com/watch?v=B7_oU3HrnBI

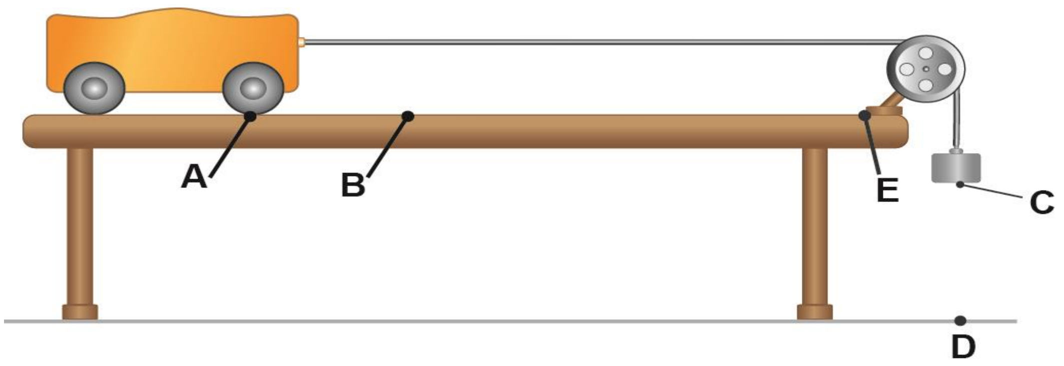


Figure-1. Practical set up to demonstrate the effect of constant force

In the above setup, an unstreachable light string is attached to a trolley kept on a horizontal table and the string goes through a smooth pulley fixed to the table, at E as shown in Figure 1. A known fixed weight is attached to the other end of the string. When the weight is released from the rest (from C), it moves under a constant force until it reaches the ground. This constant force is the net force of gravitational force applied on the weight (downwards) and the tension of the string acting on the weight (upwards). Here also, as revealed by the discussions held with the students, most of the students think that the gravitation force on the weight is the only force acting on the weight and they were not aware of the tension of the string. The students can observe an acceleration (increasing speed) of the trolley until the weight hits the ground by using this kind of practical setup. The trolley accelerates only in its AB motion, and movement beyond B is with constant velocity (AB = CD). Here what can be observed is the increasing speed. The distances AB and CD should be sufficiently long enough to see the correct type of movement.

In order to further elaborate this, the teacher can use the algebraic equation for Newton's second law, that is, $F = ma$, as another form of representation to support foregoing explanation. Here the '*a*' relates to changing of velocity only and the velocity can exist without being changed (that is, constant velocity). Therefore, from the equation $F = ma$, it can be visualized that if F exists (F is non-zero), there should be an acceleration.

To convey the effect of application of a constant force to an object an interactive simulation (*PhET*) called 'Force and Motion Basics'[2] another representation mode is highly recommended. Under 'Force and Motion', 'Motion' sub module, the student can decide the force applied by the man and keep the force at a constant value by holding the mouse, and then how the speed increases can be seen on top of the screen form the speedometer (Figure 2).

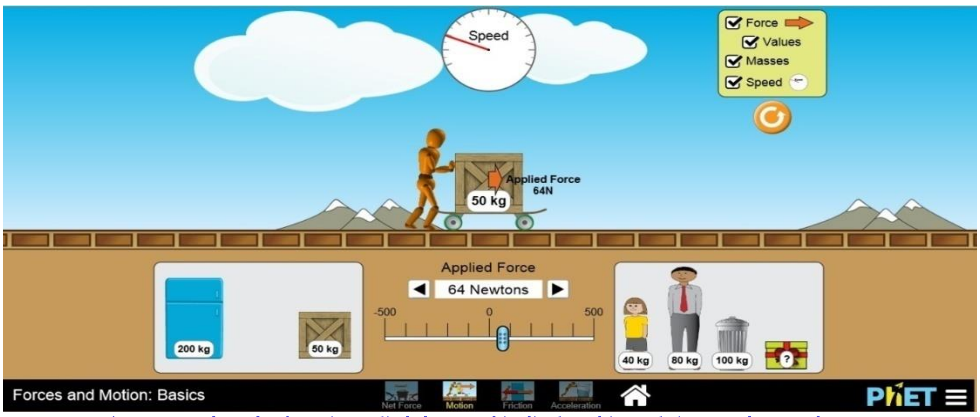


Figure-2. When the force is applied the speed is displayed in real time on the speedometer
(Source: https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html)

[2] https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html

Then the student can change the weight of the object by dragging the objects given in the bottom of the screen on to the cart (Figure 2). Here, the student can see that the reading of the speedometer is constant when keeping on continuous application of a constant force to the cart. This kind of interactive simulation can be considered as helping the students to strengthen further the images formed by going through the practical setup mentioned in Figure 1.

Case 2: Belief that when two objects (e.g. two heavy balls) of which one is heavier than the other are released from the rest at about a height of 10 m (when the air resistance is negligible) from the Earth, the heavier object will come to the ground first rather than both the objects come to the Earth at the same time. Most of the students have the misconception that the heavier object will come to ground level earlier than the lighter one (Figure 3).

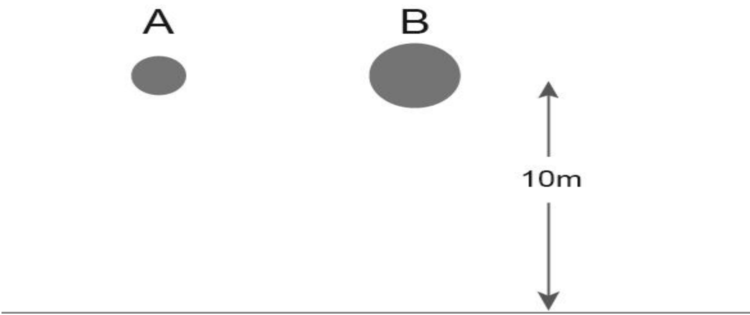


Figure-3. Comparison of motion of two objects one is heavier than the other

In Figure 3, A and B are two objects where A is heavier than B. If they were allowed to fall down from the rest at a height of 'say' 10 m from the ground, predicting which object will reach the ground first may seem confusing for many students. Most of the students had the pre-conception that the heavier one will come first to the ground. According to Newton's second law, both the object must come to the ground at the same time when ignoring the air resistance (which is negligible for a short distance of 10 m).

This kind of uncertainty in the students' mind can be easily eliminated by making use of a practical setup like the one given below (Figure 4) or using a video clip demonstrating the practical activity[3].

Figure-4. Comparison of free fall of a feather and a coin demonstrated by a physical setup

[3] e.g. https://www.you---tube.com/watch?v=clom4DdnFfM

In the above setup in Figure 4, a feather and a coin are placed inside a glass tube. The air can be removed from the glass tube by connecting the tube to a vacuum machine. When the tube is filled with air in atmospheric pressure, the coin reaches its lower base earlier than the feather if the two objects were allowed to fall down from the upper base of the tube. This is because the air resistance causes the feather to fall slowly mainly depending on the nature of the surface of the feather. When the experiment is repeated with vacuum inside the tube, both the objects come to the lower base at the same time.

The situation can be further elaborated by invoking the algebraic equations, another representational mode (the symbolic mode), making use of the Newton's second law as,

$$F = ma$$

$$a = \frac{F}{m}$$

In this example, *'a'* is equal to the gravitational acceleration, *g*;
g is constant for both objects;

The gravitational force (not the gravitational acceleration) on the object, *F* changes so that the ratio of $\frac{F}{m}$ is equal to *g* (*m* represents the mass of the respective object);
That is,

$$g = \frac{F_{feather}}{m_{feather}} = \frac{F_{coin}}{m_{coin}}$$

As both the objects start from the rest at the same time and travel the same distance, they should take the same time since *g* is the same.

(The fact that the higher the mass the higher is the force due to gravity can also be physically felt by comparing the pressure felt by the hand when two objects of which one is heavier than the other are allowed to fall to the palm from the same height).

Further, this can be clarified using the equation of motion, $s = ut + \frac{1}{2}at^2$.

As the acceleration of the two objects are the same, that is, $a = g$, it can be shown that time taken by the coin and the feather to reach the ground are equal using the formula,

$s = ut + \frac{1}{2}at^2$, which is another mode of symbolic representation.

The initial velocity, $u = 0$ for both the objects.
The distance traveled is the same for both the objects.
Since there are no other variables involving the equation, time should be the same for both the cases.
g is the same for both objects.
Therefore, when the values are substituted in the equation, durations of time taken by the objects are equal as shown below.

$$s = ut + \frac{1}{2}at^2$$

$$s_{coin} = \frac{1}{2} g t_{coin}^2$$

$$s_{feather} = \frac{1}{2} g t_{feather}^2$$

$$s_{coin} = s_{feather}$$

Therefore, $t_{coin} = t_{feather}$; $(t > 0)$

The same thing was further elaborated by using a CAL material downloaded from[4] another mode of representation (the visual mode). There an idealized set up was shown to the students using a feather and a hammer (Figure 5a and Figure 5b).

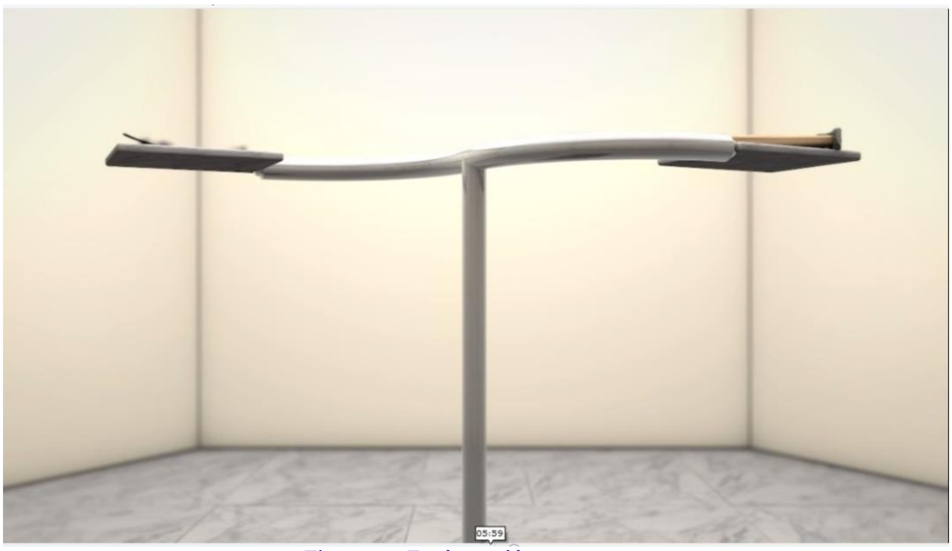


Figure-5a. Feather and hammer at rest
(**Source:** https://www.youtube.com/watch?v=NYVMlmL0BPQ)

Figure-5b. Feather and hammer released simultaneously
(**Source:** https://www.youtube.com/watch?v=NYVMlmL0BPQ)

4 https://www.youtube.com/watch?v=NYVMlmL0BPQ produced by www.tiros.ca

Both the objects come to ground at the same time. This program further elaborates this using Newton's second law of motion as given in the following screen (Figure 6).

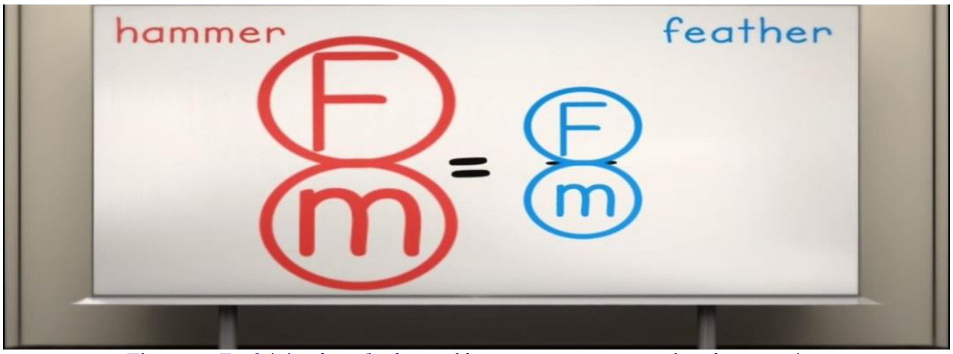


Figure-6. Explaining how feather and hammer come to ground at the same time
(**Source:** https://www.youtube.com/watch?v=NYVMlmL0BPQ)

It can be considered that the above screen helps students visualizing how the ratio between *F* and *m* held constant of the two objects. It indicates that when *m* is large *F* should also be large and vice versa so that the ratio is equal to *g*, the gravitational acceleration.

When some interesting stories are available regarding the history of science, they can be included in the lesson and that also can be used in dispelling misconceptions. Introducing a historical evolution of a particular topic, if it is available, in a manner of telling story can also help the student to correct the misbelief. Further the student may also develop the ability to see the beauty of the subject (which is generally considered as boring). It will further help the student to think as a scientist. For example, the teacher may explain the famous Galileao's experiment as a story to the students. Galileo performed an experiment from the top of the leaning tower of Pisa to refute the Aristotelian notion that heavier objects fall faster than lighter ones. He dropped two spheres of different weight from top of the tower and showed that both hit the ground at the same time.

Case 3: When marking the forces acting on an object kept on a flat horizontal table in a 2-D diagram, the weight of the object, *W*, and the normal reaction on the object by the table, *R*, are the '*action and reaction pair of forces referred to in Newton's third law of motion*' is another misconception.

(Newton's third law of motion can be defined as, when an object A exerts a force on object B, then object B must exert a force of equal magnitude and opposite direction back on object A).

This can be overcome by introducing a hypothetical diagram in which the two bodies are not touching each other though the forces are shown as they are touching which is called a free-body diagram (Figure 7).

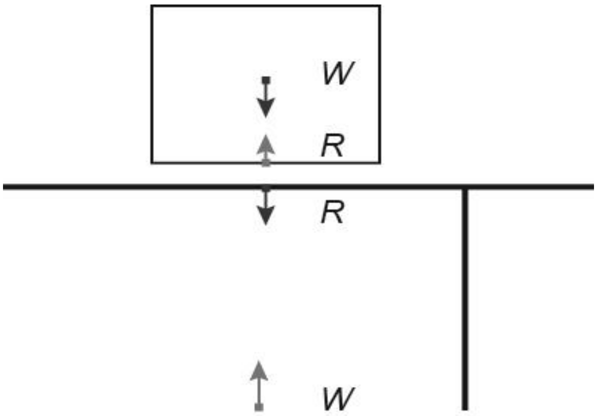


Figure-7. A free body diagram to depict action and reaction forces

In Figure 7, *R* acting downward on the table surface is the reaction and *R* acting upward in the object is the reaction (which is called normal reaction). Incidentally, in this case the weight of the object also works in the direction of action. Therefore, in the diagram, two *R*'s are one pair of action and reaction forces and two *W*'s are to be taken as another pair of action and reaction forces (the lower *W* is assumed to act at the centre of the Earth). The diagram in Figure 7 can be taken to supplement the usual diagram shown in the textbooks.

Case 4

There is another misconception regarding the same action and reaction forces, as explained below.

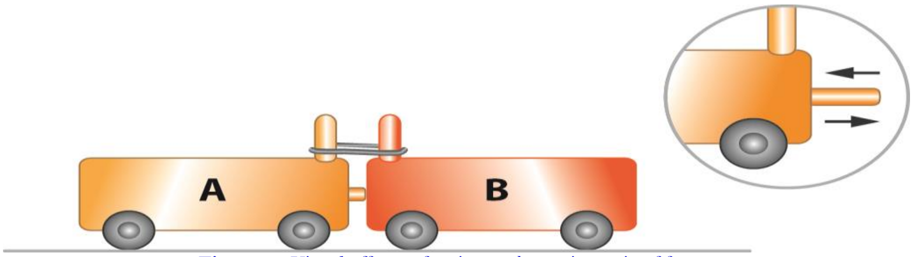


Figure-8. Visual effects of action and reaction pair of forces

Here, one trolley, trolley A, has a spring which is thrusting upon a similar trolley B, by tying the two trolleys together by a rope which can be instantly cut (Figure 8). Once the rope is instantly cut, the two trolleys will move apart. The trolley with the inbuilt spring will impose the action force on the other trolley. Then the reaction force will be imposed on the first trolley by the second trolley in opposite direction (before the rope is cut each trolley is under the force equilibrium). If the surface on which the trolleys are placed is uniform, the two trolleys travel the same distance to opposite directions and then come to rest (the surface is not frictionless). The equal distances so travelled by the two trolley to opposite directions is an indication that the magnitude of the action force imposed by one trolley on the other and the corresponding reaction force imposed by the second trolley on the first are equal in magnitude and acting on two distinct objects in opposite directions. It was revealed that most of the students were not aware of the fact that the friction force acting on a trolley from the surface causes the trolley to come to the rest and they have the misunderstanding that the action and reaction forces acted on the two trolleys when the rope had been cut still exist. This kind of misconception can be eliminated by the clear explanations of the teacher directing the student what to visualize through interaction of the visual effects. Another practical activity frequently used in classroom teaching to depict the above situation of action and reaction is shown in Figure 9 (it is a screen from a video clip).

Figure-9. Ready to demonstrate the action and reaction pair of forces.
(**Source:** https://www.youtube.com/watch?v=IRtBnhrEe94)

The representation shown in Figure 9 taken from a video clip[5] can be taken as a supplementary representation to those described above.

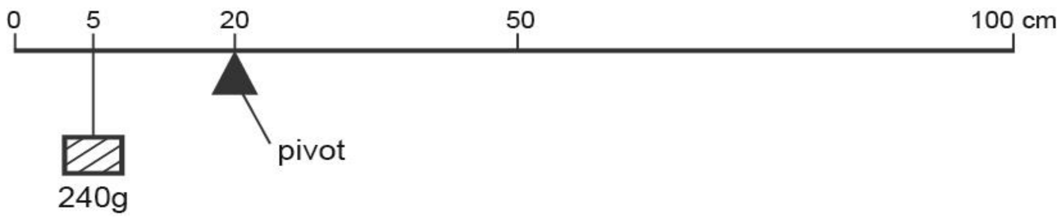
Case 5: Increasing the clarity of turning effect of forces

The moment of force is defined as the product of the magnitude of that force and the shortest distance (perpendicular distance) it has to the axis around which the rotation of the object takes place. It can be either clockwise or anticlockwise. If the system is at force equilibrium, the total clockwise moments are equal to the total anti-clockwise moments. This is called the principle of moments.

Given below is a type of question frequently found in secondary school textbooks regarding the numerical calculations involved in applying this principle.

Example:

The diagram shows a metre ruler pivoted off-centre but kept in equilibrium by a suspended mass of 240 g.



The centre of mass of the ruler is at the 50 cm mark. What is the mass of the ruler?

(a) 12 g (b) 24 g (c) 45 g (d) 120 g

Source: O Level Physics MCQ Hot Spots 1000 Frequently Examined Questions written by C.S. Lim in 2015, Red Spot Publications, Q9 on p.50

However, this phenomenon, 'moment of force' has been introduced in most of the textbooks through the following like diagrams which seems very satisfying (Figure 10a and Figure 10b).

Figure-10a. Moment of push on the door

[5] https://www.youtube.com/watch?v=IRtBnhrEe94

Figure-10b. Door under equilibrium of two pushes from either side
(**Source:** Physics for you by Keith Johnson published by Nelson Thrones Ltd, UK in 2001, page 100)

However, a clear functional relationship is lacking between the drawing for numerical problem and the two seemingly good pictures. This was the need for a third representation (Figure 11) which should show how the door is in equilibrium under the two thrusts exerted on it by the child and the man.

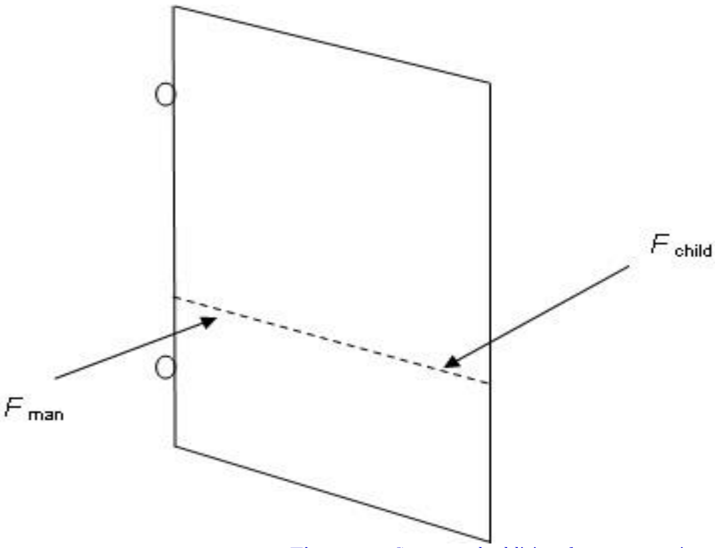


Figure-11. Suggested additional representation

In Figure 11, it is assumed that the child and man exert the forces on the same line on the door from the two sides of the door, and the two forces are perpendicular to the plane of the door. Then case of the door in equilibrium too can be brought into a type of numerical problem as given below.

Question:

When the force exerted by the man is 100 N, what is the magnitude of the force the child should exert on the door if it is to be in equilibrium? (Assume that the distances to the forces applied by the man and the child from vertical axis of the door where the hinges are fixed are 20 cm and 75 cm respectively.)

As a further effort of helping the students to visualize the application of the principle of moments, an interactive *PhET* simulation called 'Balancing Act' downloaded from[6] is a visualization tool which can be highly recommended. It gives only a 2-D view related with the situation of balancing a seesaw. The simulation consists of three modules 'Intro', Balance Lab', and 'Game' where it takes the student from simple tasks to little bit complicated tasks. Figure 12 shows a screen from 'Intro'.

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[6] https://phet.colorado.edu/sims/html/balancing-act/latest/balancing-act_en.html

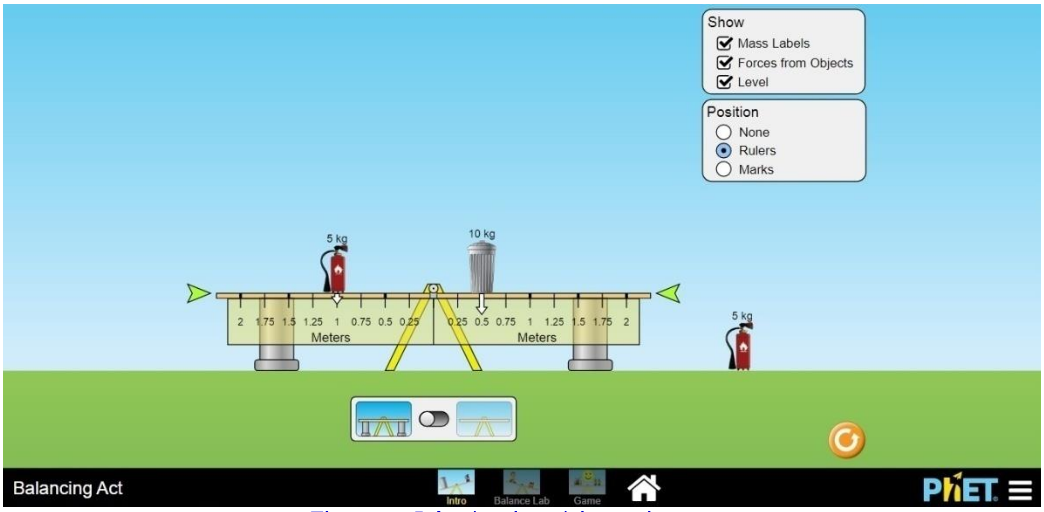

Figure-12. Balancing the weights on the seesaw
(**Source:** https://phet.colorado.edu/sim s/html/balancing-act/latest/balancing-act_en.html)

In Figure 12, the student can move the weight here and there on the seesaw and by removing the two side supporters whether the seesaw is balanced or not can be seen. By repeating the same thing using different weights the student can derive the principle of moments, that is, total clockwise moments is equal to the total anti-clockwise moment if the system is at the force equilibrium. In 'Balance Lab', the student can experience the same thing by using several masses. 'Game' module presents some interesting problem-solving tasks. This simulation leads the student to visually understand the principle of moment.

4. DISCUSSION

Certain common difficulties faced by the students in understanding some of the areas coming under mechanics section of physics were discussed above with suggested remedies to overcome them by strengthening the visual-perception on those areas through appropriate use of external representations. Gilbert (2005) summarized these external representations into five modes, namely, the material mode (physical setups), the verbal mode (spoken/written language), the symbolic mode (standard notations and algebraic equations), the visual mode (diagrams, graphs, video clips, animations, simulation, etc.) and the gestural mode (teacher's gestures). When understanding a particular subject matter, the student may need to go through several of the modes. For example, when learning Newton's second law of motion using physical set ups containing trolleys and weights (that is the material mode), using the equation, $F = ma$ (the symbolic mode), going through an animation explaining the law (the visual mode), understanding the second law written in verbal form (the verbal mode), etc. Elaborating the visual-perceptual aspect has to be done with relevance to the above mentioned external representation modes as appropriate to the lessons and to the background of the student.

In the case of visualizing the cross-section of which the forces acting on an object are marked, if the student has a higher spatial ability to do mental cross-sectioning, it will be easier for him to understand the situation. In visualizing the action of rotation mentioned under the moments also, spatial ability can matter to a certain extent. Lesson specific identification of such components of spatial ability related with visualizing the necessary physics subject matter is worth-while because it will pave the way to incorporate those skills in a subject specific, lesson specific or content specific way to classroom teaching and learning process.

It may be mentioned here that in the cases of visualizing the situation of application of constant force continuously for a certain time, and comparison of falling times of a heavier object and a lighter object, use of the algebraic equation, $F = ma$ (another kind of visual object / external representation mode) also helps students to visualize the situation. In physics education, the teachers need to identify the role of equations as a visualization tool. This is emphasized here because the most of the students generally have a fear on the equations and seem not understanding the importance of equation beyond mechanically solving them.

5. CONCLUSION

Teachers can make the subject 'physics' more contextual like economics, history, commerce and even biology by changing the teaching approach to a considerable extent. The old assumption that the students know nothing about most of the lesson topics until they are instructed has to be kept aside. In actuality, at the school level, they know something about very basic topics of physics such as force and motion, etc. though there can be few illusions here and there. Therefore, the teacher should be skillful enough to identify such shortcomings and remedy them by choosing alternate representational methods to supplement his current teaching. The students should be very patiently heard and teaching process should be interactive and students' participation should be very high if this end is to be achieved.

The term 'representation' is used to mean two types of it. One is external visible representations and the other is internal representations which are mental models. Many research studies are mainly concerned with multiple representations and they explicitly refer to external types mainly consisting of multimedia learning materials which are used simultaneously. Internal representations basically dealing with human psyche is not at all easy to experiment with. Since most of the representations are visual, the term 'visual representation' or 'visual aid' is also commonly used to refer to the external representation.

Teachers should bear in mind that these visual representations are combined with verbal or textual mode (print text) in such a way that students can fit them together for better understanding of concepts. Specialists suggest that the words and visualization objects should be presented in close proximity and simultaneously which means the sequence of presenting visual aids and presenting verbal or print text in building a concept should be more or less the same and visual aids should supplement the text and not replace it. Students should have access to both with equal ease.

In the case 1 and the case 2 of this article, the use of more than one visual aid to go with the text in respect of Newton's second law of motion has been discussed. Here physical set ups, equations and an interactive simulation (a computer aided learning material) have been used to explain the same principle. In addition to them, one animation too has been discussed. This type of variety affords the students a chance to toggle between them. They help the student to reduce overloading his working memory with too much verbal information. However, a word of caution needs to be mentioned about using animations and computer based learning materials, even though they can be encouraging and interesting to the student, there can be a tendency to use them in a way similar to cartoons on a television. Therefore, the teacher should intervene to choose the most suitable computer aided learning material specially animation and to guide the student to use them only when it is necessary for understanding concepts involving movements and requiring 3-D understandings.

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