Full Length Research

Design and implementation of a simple apparatus for teaching dynamics in physics

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Identifying the best teaching method remains a challenge for contemporary educationists. The desire to seek out more effective and efficient ways of teaching continues to drive researchers towards finding ways of integrating engineering design techniques with productive teaching methods. In particular, the teaching of certain topics in physics has been identified to require teaching techniques that would so deal with the subject as to make it both interesting and instructive for students. Generally, students tend to be scared of science subjects because these appear somewhat abstract to the learner. There is, therefore, need to design tools that will make some of these subjects less abstract and easily comprehensible to students. In this paper, we present the design and construction of a Dynamics Teaching Aid that makes teaching and learning of dynamics in secondary schools rather easy and interesting for both teacher and student by exploring the advantage of visual learning. This apparatus presents certain advantages in our local teaching environment as it does not require rigorous training to be used by teachers; can be easily mass-produced for local use at highly reduced cost and does not depend only on public electric power supply for its operation. Its precision in explaining the physical concept of certain quantities in dynamics such as velocity and acceleration marks the hallmark of our design concept.

Key words: Engineering design techniques, teaching, dynamics, apparatus, environment, velocity, acceleration

INTRODUCTION

Teaching is defined as the systematic presentation of facts, ideas, skills and techniques to students (Ryan 2009). Societies that have and must make advances in diverse areas of life must develop efficient and successful methods of teaching or imparting knowledge. This fact is made obvious along historical lines of developed societies. The ancient Greeks, whose respect for learning is evident in their art, politics, and philosophy, saw the value in educating children. Wealthy Greeks added teachers to their households, often slaves from conquered states. At the height of the Roman Empire, citizens also followed the practice of having teacher-slaves, usually Greeks. By the middle Ages in Europe, the Roman Catholic Church had taken responsibility for teaching which was evident in established monasteries and other learning centres. These centres often later evolved gradually into Universities such as the University of Paris in France and the University of Bologna in Italy. (Ryan 2009).

The indispensable importance of teaching in both developed and developing societies cannot be overemphasized. In recent times, efforts are geared towards improving our ability to render teaching more efficiently and productively. This is obvious in the numerous techniques developed to make teaching effective and productive. Some teaching techniques include computer-aided instructions, conversation as a teaching method, the law of effect (trial and error), Montessori Method, propaganda and reading to learn, and so on.

Educationists continue to identify subjects that prove rather difficult to grasp by students and try to develop and adapt certain teaching techniques to ease its understanding. Physics, a major science has the potential to prove rather difficult to understand by students. (Reddish 1994) explained that students consider physics a difficult subject because Physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other –
words, tables of numbers, graphs, equations, diagrams, maps. Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly difficult for many students. (Ornek, Robinson, and Haugan 2008) concluded after their survey on “what makes physics difficult?” that faculty members should learn how to reach their students and how to make physics concepts be understood by their students even if they are really sophisticated in their field. The structure of physics as a physical and natural science indicates a need for experimental ways of teaching and dealing with its subject matter. In this respect, we present the design and construction of a simple dynamics teaching aid. It is aimed at rendering experimentally and vividly to students the concept and relationship between certain quantities like velocity, distance and time. This work originates after a careful study of teaching techniques and an effort to apply engineering designs to further enhance teaching and learning of physics in secondary schools.

MATERIALS AND METHODS

Literature review

In this section, we sampled certain works in literature on teaching techniques. We examined these works in order to identify those techniques that have produced remarkable results on the performance of students. There are numerous works on various teaching techniques in literature. The most popular is the constructivist technique. Constructivism is a theory of knowledge that argues that humans generate knowledge and meaning from their experiences (Wikipedia 2010). Students are not a blank slate and knowledge cannot be imparted without the child making sense of it according to his or her current conceptions. Therefore children learn best when they are allowed to construct a personal understanding based on experiencing things and reflecting on those experiences (Liepolt 2004). Furthermore, this theory reveals that certain activities are primarily encouraged in a constructivist classroom; these are:

Experimentation: Students are exposed to experiments and made to discuss together as a class
Research Projects: students research a topic and can present their findings to the class.
Field trips: this allows students to put the concepts and ideas discussed in class in a real-world context.
Films: these provide visual context and thus bring another sense into the learning experience.
Class discussions: this technique is used in all of the methods described above. It is one of the most important distinctions of constructivist teaching.

In a research work on the effects of constructivist teaching (Kim 2005), approach concluded after series of experiments that constructivist teaching is more effective in terms of academic achievements of students and also, students have some preference for a constructivist teaching classroom environment. On the other hand, critics have voiced certain arguments against the constructivist based teaching method with claims that they are either misleading or contradict known findings (Anderson, Reder and Simon 2000). Supporters of constructivism rather argue that students’ especially elementary school-aged children are naturally curious about the world, and giving them the tools to explore it in a guided manner will serve to give them a stronger understanding of it (Liepolt 2004).

Mayer (2004) developed a literature review spanning fifty years and concluded that the constructivism pertaining to hands-on activity is a formula for educational disaster. His argument is that active learning is often suggested by those subscribing to this philosophy. Mayer recommended using guided discovery, a mix of direct instruction and hands-on activity, rather than pure discovery. (Kirschner, Sweller, and Clark 2006) agreed with the idea of constructivism by arguing that learners construct knowledge but their work further supports instructional design recommendations of this theoretical framework. They claim that the constructivist description of learning is accurate, but the consequences of giving instructions as suggested by constructivists do not necessarily follow. The potential benefits/limitations of constructivist teaching approach is to a large extent based upon the large number of varied personal characteristics and opinions as well as the prevalence of different learning problems in children today.

Other teaching techniques like the Montessori method stresses the development of initiative and self-reliance by permitting children to do things by themselves. Design that intended in him within is one advantage to the teacher and to the students. Use of Teaching Aids reduces the talk and chalk method of teaching. Also, it identifies that teachers are compelled to improvise teaching aids for their teaching due to its unavailability.

In general, it is particularly accepted that Human beings unlike other animals try to be sure of anything they do. They therefore try to get a datum to which every other thing can be compared or identified with. It is therefore on this argument, and having identified a need for improved teaching aids, that visualization has been identified as a long lasting means of learning. For example, in linear motion, the speedometer has been the means by which speed is measured and visualized. Designs identified in him within literature regarding speed measurement like the invention of Josp Belu in 1888, Nikola Tesla in 1916 have on the other hand revealed that engineers over the ages have employed locally sourced materials though sometimes crude, to implement the design of certain devices. With advancements in engineering designs, several modern teaching aids especially visual aids have revealed how engineering design concepts have found relevance in enhancing teaching and learning in schools and universities. Undoubtedly, many of these engineering teaching aids have greatly advanced man’s ability to easily understand but most times, insufficient financial investments in purchasing these aids predominantly in developing societies has been identified as a significant drawback to productive learning. The cost of acquiring these modern teaching aids has constituted a disadvantage particularly in Nigerian secondary schools. There is therefore a need for engineering
designs to cut down on both design complexities and financial cost by using locally sourced materials. Having identified physics as a subject particularly inclined to the use of teaching aids for its understanding, and dynamics as a key subject matter, we carried out a light survey to identify the availability of this teaching aid in our local secondary school environments in Minna, Niger state, Nigeria. We identified the lack of such a teaching aid and hence the motivation for this work. We were motivated to make designs for our local environment that comfortably integrates a drastic reduction in financial cost with a strong inclination towards visual teaching to improve the learning of dynamics in senior secondary schools.

**Dynamics teaching apparatus**

This Section presents the design and operation of the apparatus for the teaching of dynamics in physics.

**Design**

The power supply unit draws from the a.c mains to the step down transformer, which steps the voltage down from 240V to 12V. The power unit incorporates the step down transformer, a bridge rectifier and an LM 7805 for voltage regulation. The value of each power component was chosen to ensure optimum performance. The mathematical design calculations resulted in the choice of a 1000µF filter capacitor that gives a ripple free d.c output voltage. A supplementary d.c battery source provides power supply in the absence of the a.c mains. Figure 1.

The sensor block consists of two sensors namely sensor A and B. They are similar in physical and electrical characteristics. They are Light Dependent Resistors (LDR) that respond when a laser beam falls on them resulting in a reduction in their internal resistance value. Laser beam was chosen because of its ability to produce a monochromatic light. The user input keys consist of 10 normally open toggle switches, among which 5 are used to select predefined distances of 20, 40, 60, 80, and 100 cm respectively. A dedicated switch is provided for any distance of choice but preferably within the stipulated range of 1m because of physical design constraints. There are 3 other switches used to display any of the three parameters: time, velocity, and acceleration and lastly, a switch to serve as a reset button.

The microcontroller is a single chip microprocessor used for computation and display of the various parameters. The AT89C51 was incorporated with a 12MHz crystal oscillator whose function is to generate the system clock pulse, thus making the system operate at approximately 1 Million instructions per second (1MIPS). The controller was programmed to execute the following:

(i). Ensure that the keypad scan routine continues until a key representing a distance of interest is pressed which determines the value the microcontroller will use in its calculation.

(ii). Ensure that once the device is switched on, the controller is kept waiting for a distance to be chosen.

The display unit consists of a common anode seven-segment display. It is powered appropriately to ensure correct display of digits. This display could be to four significant figures because the display is made up of four digits. To make and break the current reaching the different segments of the seven segment display, four PnP transistors (2N3906) were used to effectively drive the display. The common anode was chosen in preference to the common cathode type in order to be sure that the system runs as a current sink and not as a current source. This is to avoid heating up of the microcontroller. The four seven-segment displays were all multiplexed to reduce the number of input-output pins required to interface the different displays with the microcontroller. By energizing the proper pins with a proper d.c voltage level subsequent LEDs can be energized to achieve the desired number to be displayed.

A smooth rail of about 1.2 m is attached to the entire system. The rail is the pathway designed to provide a channel of movement for a roller (a small ball) that will be used to simulate a moving object. It is graduated for a maximum distance of 1 m. Sensor A is fixed at zero mark (origin) on the rail, while sensor B is made

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**Figure 1:** Block diagram of the system
incorporate simple experimental structures as teaching techniques was presented to show the need to present in this paper. A brief literature review of some and implementation of the Dynamics Teaching Apparatus Nigerian secondary schools. This necessitated the design go a long way in improving the standard of education in Employing effective and productive teaching methods will

RESULTS
Here we present the results obtained after careful testing of the implemented apparatus for teaching dynamics. The results shown in table 1 reveal the precision level of the device when compared to theoretical values. The experiment was conducted by setting the roller in motion along the rail between the sensors. Readings were taken for different rail lengths and timers were used to make comparative measurements with the digital values obtained by the device. The results show a close relationship in approximation between our device’s measurement and theoretical values. The considerable level of precision of this device guaranteed from experimental results makes it a reliable tool in enhancing teaching of simple concepts in dynamics in secondary schools.

Table 1: Readings Taken from the Device

<table>
<thead>
<tr>
<th>Distance (cm)</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (s)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Velocity (cms⁻¹) (approx.)</td>
<td>20</td>
<td>40</td>
<td>30</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Acceleration (cms⁻²) (approx.)</td>
<td>20</td>
<td>40</td>
<td>15</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

Operation
The operation of this apparatus is controlled by the System Controller, which is a microprocessor unit (AT 89C51) as described earlier. At the start of an experiment, the device is switched on; a distance of interest is selected on the key pad, which is automatically recorded by the system controller; sensor B is moved on the rail to the position of the selected distance; then, a roller is gently dropped in the rail before the position of sensor A (the origin of the calibrated distance), to move between the sensors thus blocking the signal generated by the transmitter from reaching the receiver. This process actuates the system by sending a signal through predefined ports and triggering the start of the timer (for example, the crossing of sensor A starts the timer). The timer keeps incrementing after every second until another signal is received through another predefined port, which signals the end of the timing sequence (this happens when sensor B is crossed by the roller). Note that the time is captured and stored by the system controller, for use in necessary computations. The system controller then uses the stored values of distance and time to compute and store, the velocity and acceleration of the roller. The user makes a choice regarding the output result desired. It could be either the display of time taken to cover the selected distance, the velocity or acceleration of the roller. Once this is done, the reset button is pushed to clear the display for a new experiment.

CONCLUSION
Employing effective and productive teaching methods will go a long way in improving the standard of education in Nigerian secondary schools. This necessitated the design and implementation of the Dynamics Teaching Apparatus presented in this paper. A brief literature review of some teaching techniques was presented to show the need to incorporate simple experimental structures as teaching aids alongside these techniques to improve quality of teaching. The technical design structure of the device was presented and the test results were shown. This design presents certain advantages that ensure ease of adaptability to the Nigerian local schools. These advantages are: it does not require rigorous training for teachers to be able to use it; it can be easily mass produced for local use at highly reduced cost, and does not depend only on public electric power supply for its function. Finally, its level of precision makes it rather reliable to be used in learning environments. This device has limitations in terms of calibrations. The time and distance calibrations are somewhat coarse. The authors however think that this is not adverse considering the level at which the apparatus will be used. The aim will still be achieved.

REFERENCES
method.html.