Abstract

The main reason why teaching engineering and science subjects are more difficult and also more expensive is because of the requirements of laboratories. Experimental analysis teaches the practical aspects of a course and also gives students experience of observing and collecting data in real time. In contrary to science subjects, for example, topics such as history or geography can be taught totally in a classroom environment. Currently, many institutions tend to use computer simulations wherever possible instead of laboratories. For example, the readily available Excel spreadsheet can be programmed to simulate the behaviour and movement of many dynamical systems such as a simple pendulum. This paper presents the requirements of engineering and science teaching and describes how the Excel spreadsheet can be used dynamically in the teaching of science subjects.

Keywords: Engineering teaching; science teaching; simulation; Excel; spreadsheet

1. Introduction

Software simulation techniques are currently used by many educational institutions in the teaching of engineering, science, and mathematics subjects. Simulation is usually in the form of a computer program with graphical interface, developed to mimic the operation of a real physical system. For example, the behaviour of an electric motor can be modelled on a computer using a simulation package and students can learn the operation of such a motor on a computer, away from the actual physical laboratory.

Although simulation can not replace a real physical experiment carried out in a laboratory environment, it has several advantages as outlined below:

Physical experimental laboratory kits are usually too expensive and many institutions can not afford to purchase such kits. Especially, in a laboratory environment usually more than one kit of the same type may be required and this increases the cost considerably. Simulation on the other hand is simply a computer program and is much cheaper to purchase and use. In addition, more than one copy of the simulation program can be obtained at reduced cost under special educational licenses and discounts offered by many organizations.

Physical kits require maintenance and in many cases it can be too expensive to replace faulty components, or to maintain a large number of kits. Simulation on the other hand does not become faulty, and does not require any
maintenance, except for occasional software updates, which are usually either free of charge or are supplied at low
cost to existing users with maintenance contracts.

Physical kits may become obsolete in very short time as the technology is advancing very rapidly. It then
becomes rather expensive to upgrade or replace these kits. As mentioned earlier, it is very easy and usually a low
cost process to apply updates to a simulation program.

Physical kits can be damaged very easily if they are not used properly. For example, a power supply kit can be
damaged beyond repair if the output pins are shorted together. On the other hand, it is not generally possible to
damage a simulation program by making wrong selections. The only problem may be the accidental deletion of the
simulation program or some of its components. Accidental deletion does not normally happen since most software is
protected for deletion. If the simulation software happens to be deleted by mistake, it can be re-installed easily at no
cost.

The purchase of a physical kit or a physical component may take long time as it may have to be approved by the
finance departments. With software simulation however, any type of component can be modelled and simulated
with no purchasing or waiting time.

One important disadvantage of simulation compared to real physical experiments is that the simulation can
sometimes hide the reality from the users. For example, it is very easy in a simulation program to pass a 100A
current through a small resistor. But in practise, in a laboratory environment this is very unlikely to happen as the
resistor would probably be damaged as a result of excessive heat dissipation.

There are many commercially available simulation packages in the market, developed for engineering, science,
and mathematics teaching. Perhaps the most popular one and the most comprehensive one is the MATLAB (2008).
Although extremely powerful, MATLAB is a rather expensive simulation package, formed of a base system with
many additional toolboxes for modelling and simulating various engineering, scientific, and mathematical
applications. For example, students can use MATLAB to model and then simulate the behaviour of a complex
system, or they can for example solve a simultaneous equation and then compare the results with manual methods.
MATLAB package offers toolboxes for control engineering, signal processing, image processing, fuzzy control,
mathematics, and many more. ANSYS (2008) is another commercially available simulation package similar to
MATLAB and developed for engineering, scientific, and mathematics applications. Some of the simulation
packages are developed for specific applications. For example, SPICE (2008), Multisim (2003), EasySim (2007),
B2Logic (2008) are commercial packages and have been developed to simulate electronic analog and digital circuits.
Users can model complex electronic circuits using electronic devices (e.g. transistors, resistors, capacitors,
operational amplifiers and so on), and then the operation of the circuit can be simulated under various input
conditions, with the outputs either observed on virtual instruments (e.g. a virtual oscilloscope or a virtual
multimeter), or plotted as graphics.

This paper describes how the Excel spreadsheet can be used as a low-cost and also an easily available tool for the
simulation of mathematical equations, and physical systems.

2. Example Application Of Excel In Physics

This section shows how the Excel spreadsheet program can be used to simulate a well known physics problem.
Here, the equations of motion of a projectile are used to simulate the behaviour of a projectile. If a projectile is fired
with an initial velocity of $V_0$, at an angle of $\theta$ with the horizontal, it is well known that the three basic equations
describing the range, height, and the flight time of the projectile are given by:

$$\text{Range} = \frac{V_0^2 \sin 2\theta}{g}$$  \hspace{1cm} (1)

$$\text{Height} = \frac{V_0^2 \sin^2 \theta}{2g}$$  \hspace{1cm} (2)
Figure 1 shows the Excel simulation setup. Here, on the left hand side of the form the picture of a typical projectile path is given with the basic equations of motion. Students can enter the initial velocity $V_o$, and firing angle $\theta$ of the projectile using a “spin” form control of Excel. As these parameters are entered, the range, height, time of flight, maximum range, and the maximum height attained by the projectile are all calculated and displayed dynamically and automatically. In addition, these outputs are also shown in graphical form so that students can see the changes visually and easily.

The example given in this paper is rather simple, but the basic principles for the simulation of more complex systems are the same. All that is required is the equations describing the behaviour of the system, and in addition Excel form tools such as spin control, text-box, list-box and so forth. One beauty of simulating with spreadsheets is that no programming skills are required and the simulator can easily be developed by students.

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\text{Time} = \frac{2V_o \sin \theta}{g} \tag{3}
\]

3. Conclusions

The paper has described how the Excel spreadsheet program can be used as a useful tool in science, mathematics, and engineering education. The experimental parts of most science subjects are nowadays carried out away from laboratories, using computer based software simulation packages. Commercially available simulation packages are very powerful, but at the same time their cost is considerably high and can not be afforded easily. Most of the
engineering, science, and mathematics experiments can easily be simulated by developing low-cost spreadsheet (e.g. Excel) based simulators as described in this paper.

References


