Understanding of Physics Concepts in Context of Real World Experience using Simulations

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ABSTRACT

Information and Communication Technologies (ICT) pose tremendous challenges to Physics teaching and learning. Computers, multimedia and the world-wide-web have provided some new tools for illustrating and explaining dynamic concepts of Physics. Among the various ICT applications, computer simulations are of special importance in Physics teaching and learning because they can support powerful modeling environments involving Physics concepts and processes. Simulations provide a bridge between students' prior knowledge and the learning of new physical concepts, helping students develop scientific understanding through an active reformulation of their mis-conceptions. This paper describes a family of simulators that have been developed to teach several topics in Physics like Kepler's laws, interference and collisions. These simulators provide students with laboratories for experimenting with the phenomena in the context of real world situations. Students working with simulations exhibited significantly higher scores in their learning levels. Our findings strongly support that computer simulations may be used as an alternative instructional tool, in order to help students confront their cognitive constraints and develop functional understanding of Physics concepts like Kepler's laws, Interference etc. in an effective manner.

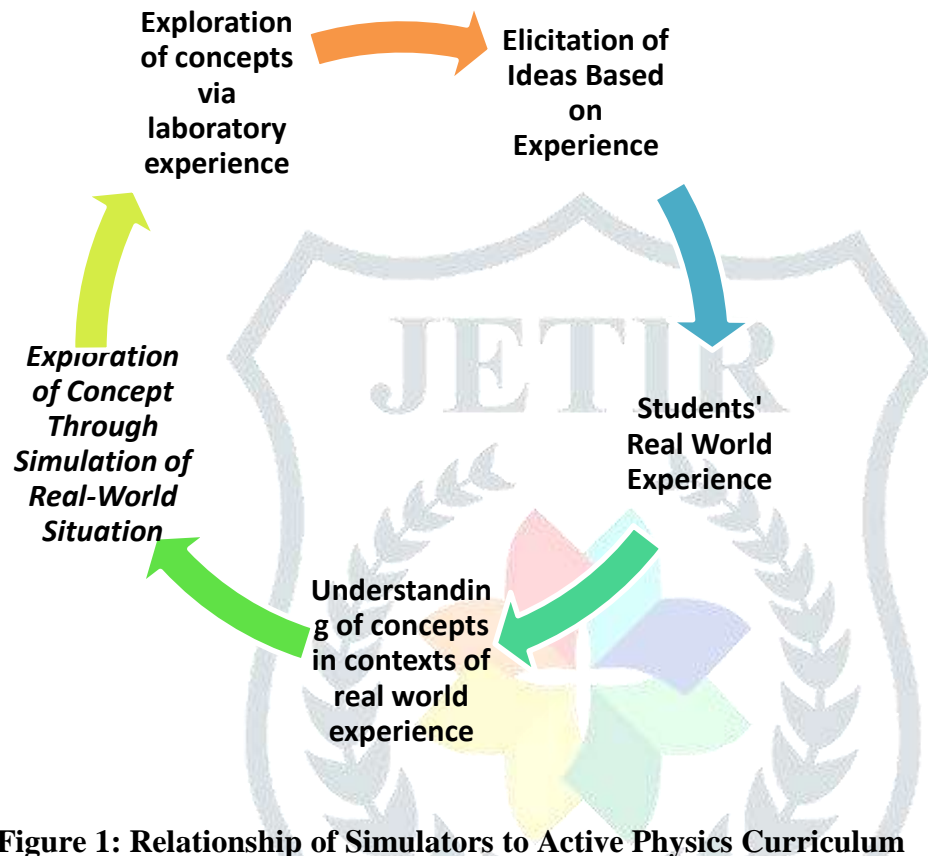**Keywords:** Simulations, multimedia, interference, Kepler's laws, collisions.

Introduction

Simulations have an extensive history in science education and have been found to support learners' understanding of scientific ideas and the ability to engage in scientific practices [1–7]. As Honey and Hilton report, simulations "enable learners to see and interact with representations of natural phenomena that would otherwise be impossible to observe" [8]. This paper describes a family of simulators that have been developed to teach several topics in physics including Kepler's laws, interference and collisions and how each phenomenon was modeled as a dynamic system of elements working together to produce the behavior students are trying to understand. Interfaces are also presented for each simulator to illustrate the kind of parameters students can manipulate to do experiments and the information they receive to interpret simulation results.

Dynamic Simulation vs. "Traditional" Approaches

Many of the phenomena Physics students learn about are dynamic in nature. However, traditional methods of teaching have been static and do not help students develop intuition about the dynamic aspects. Textbooks emphasize using formulae to get particular answers. Computers, multimedia, and the world-wide-web have

provided some new tools for illustrating and explaining these dynamic phenomena[9,10]. Many of the animations and videos that are available serve as demonstrations, but don't allow students to manipulate and experiment with them. It is this engagement that is essential for really understanding scientific concepts rather than just memorizing formulae. The simulators described in this paper attempt to "close the loop", as shown in Figure 1, by providing a virtual laboratory using real-world examples, but without the attendant risks and difficulties.

Figure 1: Relationship of Simulators to Active Physics Curriculum

Collisions:

The Java applet deals with the extreme cases of a collision process illustrated by two wagons: For an elastic collision it is characteristic that the sum of the kinetic energies of the involved bodies is constant. After a perfectly inelastic collision, however, both bodies have the same velocity; the sum of their kinetic energies is reduced, compared with the initial value, because a part of it has changed into internal energy (warming up).

The total momentum of the involved bodies is conserved, regardless whether the collision is elastic or inelastic. We can choose the simulation of an elastic or an inelastic collision by using the appropriate radio button. The "Reset" button brings the wagons to their initial positions; the animation is started by a mouse click on the "Start" button. If we select the option "Slow motion", the movement will be ten times slower. We can write the values of mass and initial velocity into the text fields. Positive (negative) values of velocity mean a motion to the right (left) side. Extreme inputs are automatically changed. The applet will illustrate the velocities, the momenta or the kinetic energies of the wagons.

Traditional physics texts do not generally treat collisions as a dynamic phenomenon. They concentrate on using formulae that apply conservation of momentum to calculate post-collision speeds and directions of objects that collide. The simulator deals with both the traditional emphases on post-collision velocity and direction and the dynamic aspects that are especially important for understanding how occupants will fare in a crash. Figure 2 shows the one of the setup screens that let students choose the type (and therefore the mass), velocity, and direction of the other vehicle they will be colliding with. Figure 3 shows the results of a pair of crashes.
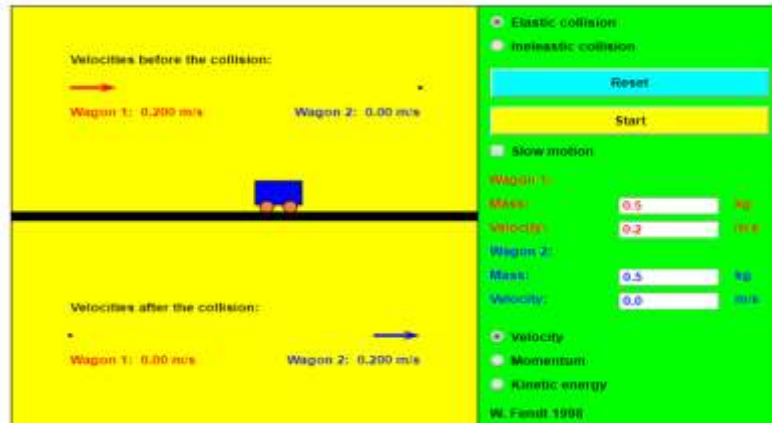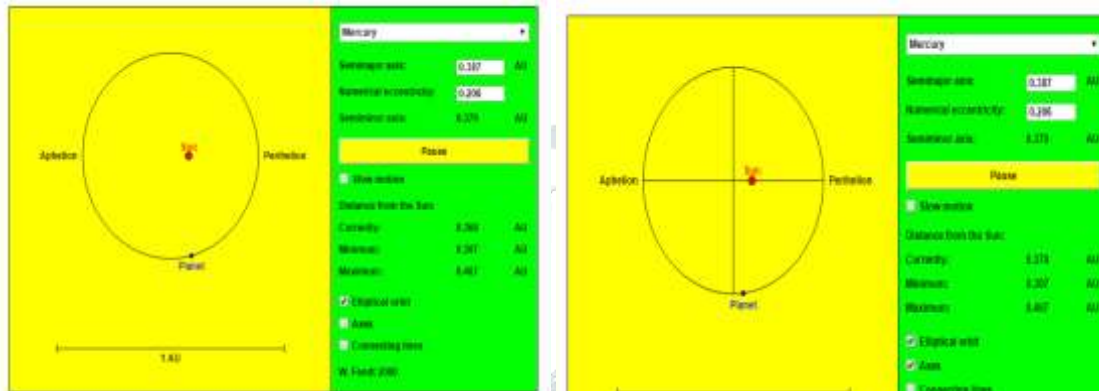

Figure 2: Input Screen for Setting Up Collision Experiments

Figure 3: Results of Collisions

Kepler's Laws:

The Java applet illustrates this law shown in figure 4. A planet can be displaced with pressed mouse button on its orbit around the Sun. It is possible to investigate the orbit of an imaginary celestial body by entering its semi major axis and numerical eccentrity (less than 1). The program will calculate the length of the semi minor axis and the current, the minimal and the maximal distance from the Sun. These lengths are given in astronomical units (AU). 1 AU = 1.49597870 x 10^{11} m is defined as the average distance between Earth and Sun.

Figure 4: Input Screen for verification of Kepler's laws
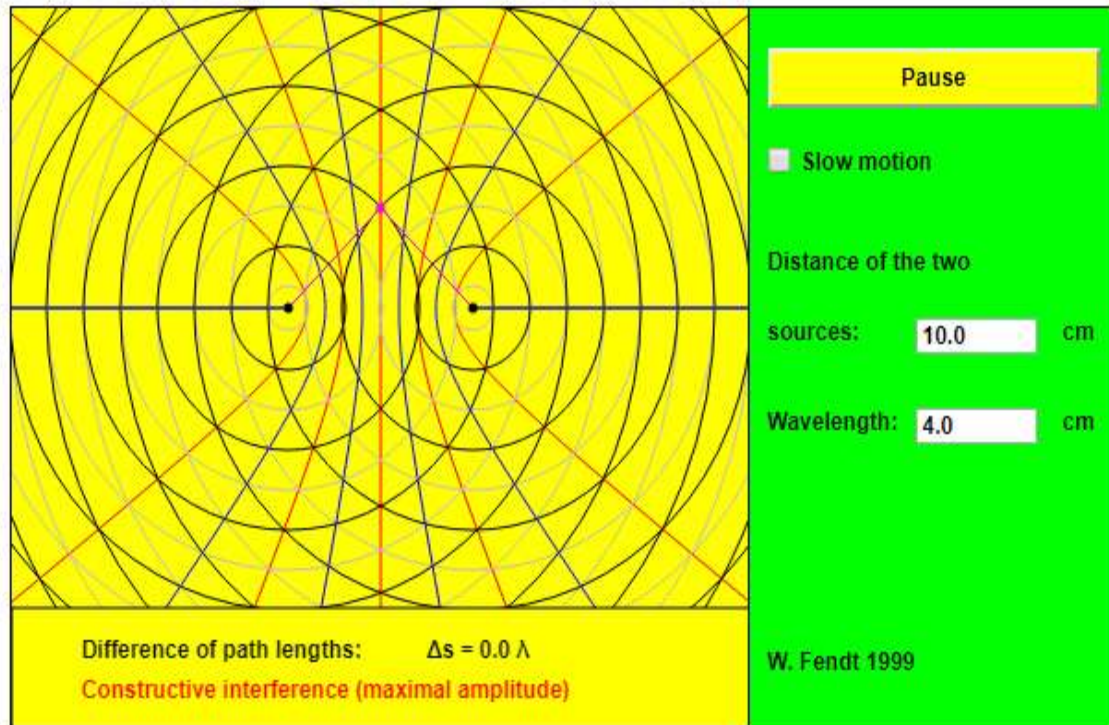
Interference:

The interference of two waves shown in figure 5 (e.g. of water or sound waves). The waves spread out from two sources oscillating with the same phase. For the interference of the waves the principle is valid that the elongations are added, considering their signs. We can observe the following two extreme cases:

At those points, where the difference of the path lengths (the difference of the distances from the two sources) is an integer multiple of the wavelength, the waves arrive with the same phase. This means that maxima (black circles) respectively minima (gray circles) always arrive at the same time, so that the interference is constructive (maximal amplitude). Points with this property are situated on the red marked curves respectively surfaces.

At those points, where the difference of the path lengths is an odd half-integer multiple of the wavelength, there are opposite conditions: At those points which are situated on the blue painted curves respectively surfaces a maximum of one wave always arrives simultaneously with a minimum of the other one, so that the resulting wave is diminished (destructive interference, minimal amplitude).

The button "Pause / Resume" of the applet makes it possible to stop or continue the simulation. If we choose the option "Slow motion", the animation will be five times slower. We can vary the distance of the two sources

and the wavelength by using the corresponding text fields. At the bottom the program indicates the difference of the path lengths for the violet coloured point. We can move this point with pressed mouse button.

Figure 5: Input Screen for studying the phenomena of Intereference

These kinds of insights are not available to students with the traditional approach. In addition to a wide range of experiments and tutorials, the simulator also has some built-in challenges that can serve as assessment tools and help to determine how well students have understood the material.

Conclusions

Although Teaching Physics is the toughest task for the teacher, it can be made simple through latest ICT technique – simulation which creates a lot of excitement and creative problem solving. This also creates a platform for learning environment of building self confidence, ability to solve challenging problems and empowering them to build a better future for themselves and society .

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