Exploring Kepler's laws using an interactive whiteboard and Algodoo

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Abstract

Combining an interactive whiteboard with the right software, and with an appropriate instructional approach, is crucial for its productive use in physics classrooms. We describe how the interactive whiteboard can be used in combination with a physics-based sandbox software program (Algodoo) to address the topic of Kepler's laws. The proposed activity engages students in collaborative inquiry and draws on students' experience in using touch-screen technology. Students engage in the manipulation of virtual objects on the interactive whiteboard and investigate Kepler's laws by actively participating in the creation of planets, sending them into orbit, and representing their motion using a wide variety of virtual tools.

Introduction

There are many different ways of using an interactive whiteboard (IWB) in physics instruction [1–3]. Combining the technical advantages of IWBs with appropriate pedagogical approaches and student engagement is crucial to the productive use of an IWB in a physics classroom. However, using it in a way that benefits students and that avoids unnecessary use can be a challenge.

We describe an activity that takes advantage of the IWB's large touch-screen and uses it in a way that engages students in collaborative inquiry. The activity takes advantage of students' everyday experience and familiarity with touch-screen applications by allowing them to use their bodies to control the IWB and engage with the on-screen virtual environment.

Traditionally, Kepler's laws have been difficult to address experimentally, although there have been some attempts of mechanical classroom demonstrations on this topic [4]. Some approaches also use pre-made mechanical solar-system models [5] and computer-based resources [6–9].

We propose an activity that combines an IWB with Algodoo software (www.algodoo.com) to address the topic of Kepler's laws. Algodoo is a freely available two-dimensional physics-based sandbox software. It enables users to create objects that then interact in a virtual environment, which can be tweaked to a large degree. For example, gravity as well as air drag can be increased, reduced or turned off. Several parameters of user-created objects, such as the attraction parameter and density, can also be adjusted.

Investigating Kepler's laws

To address the topic of Kepler's laws in Algodoo, we must create a Sun that attracts other objects and turn off the uniform downward gravitational field and air drag. We can then start the activity by drawing new objects close to the Sun (figure 1).

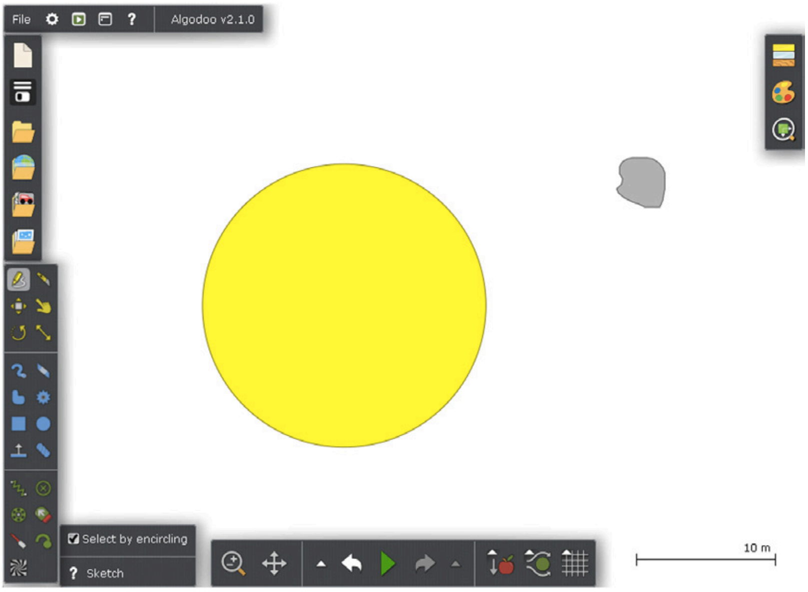

Figure 1. First, we create a massive central object with a positive 'attraction' parameter, around which user-created planets will orbit. The image above shows a yellow 'Sun' and a free-hand-drawn grey planet.

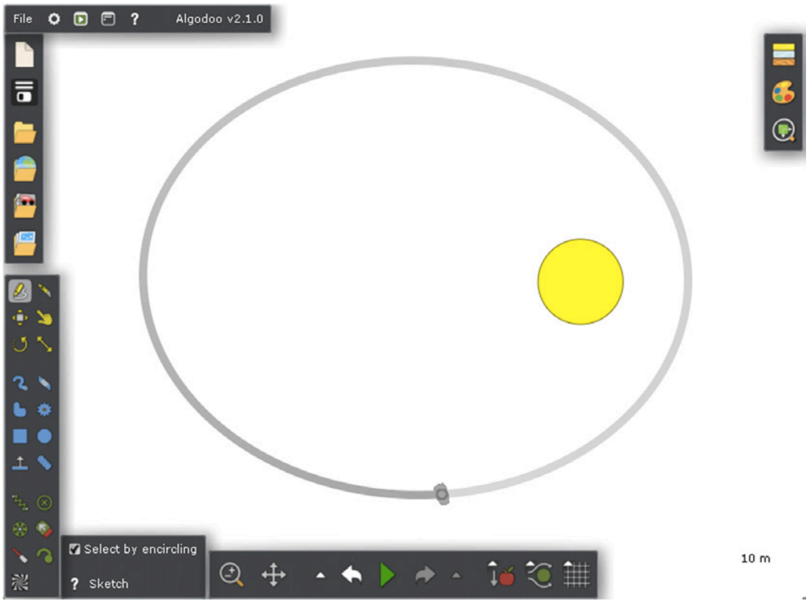

Figure 2. The tracer tool can be used to draw the orbit of the planet. Students can also use a piece of string to draw an ellipse that matches the one drawn by the tracer, by using the 'transparent' mode on the IWB and drawing across Algodoo.

First, the newly created object will fall to the Sun's surface and eventually stop there. Then, we can drag the planet outwards and throw it into orbit. In the planet throwing activity, where learners engage physically with the IWB, the input of the learner is directly connected to the relevant physical quantity—the velocity of the planet.

By throwing a planet in the vicinity of the Sun, the participants can discover three distinct categories of orbit (colliding with the Sun,

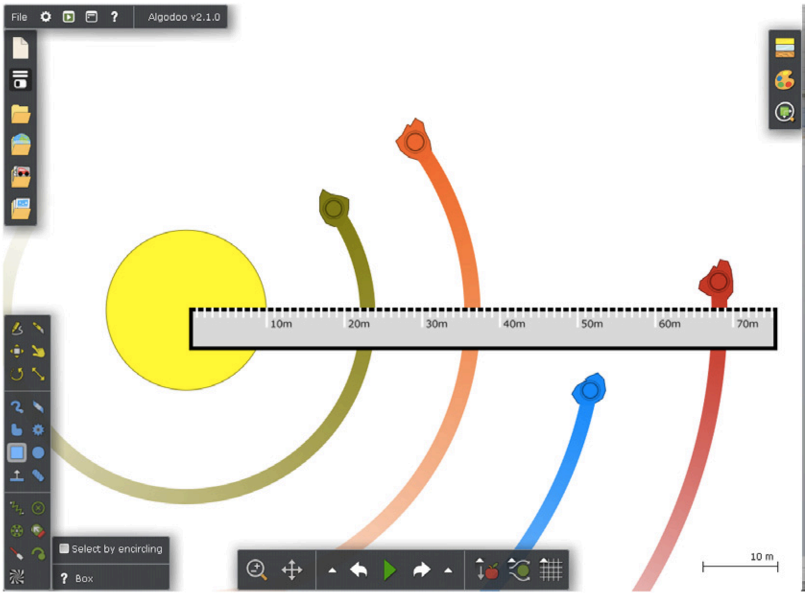

Figure 3. We create a ruler to help students investigate the relationship between the semimajor axis of a planet's orbit and its orbital period (which can be measured using a stopwatch). The problem can be simplified by sending planets into circular orbits using a built-in tool.

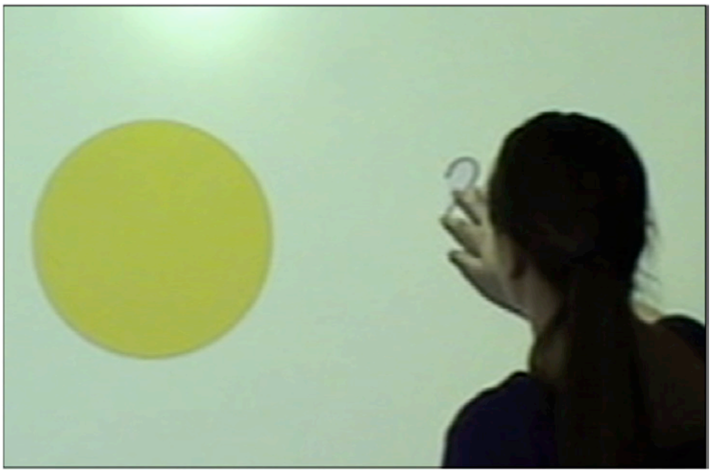

Figure 4. A student drawing a custom, heart-shaped planet in Algodoo on a touch-sensitive IWB.

periodic and unbound orbit). Framing the activity as 'observing while playing' can encourage students to participate, so that their confidence in using touch-based technology and related experience can be productively applied.

Algodoo has many possibilities for different representations. One of the most useful representations for the motion of planets is the tracer—a massless object that is attached to another object and leaves a trace of a pre-set duration on the background.

If the tracer's duration lasts for the whole orbital period, or longer, it draws the shape of the orbit (figure 2), allowing learners to explore its shape.

When the tracer's duration is shorter than in figure 2, we can use the trace length to indicate the speed of the planet qualitatively (longer means the planet moves faster). Learners can use observations of the planet's changing speed depending on its distance from the Sun to qualitatively formulate Kepler's second law.

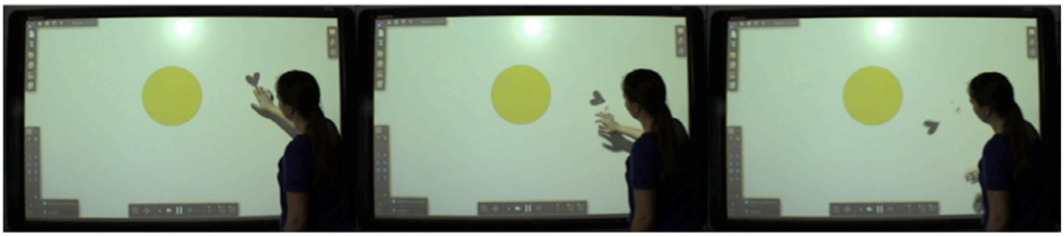

Figure 5. A sequence showing a throwing action. Grabbing, dragging with appropriate speed and releasing a planet sends it into orbit (hyperbolic or elliptic).

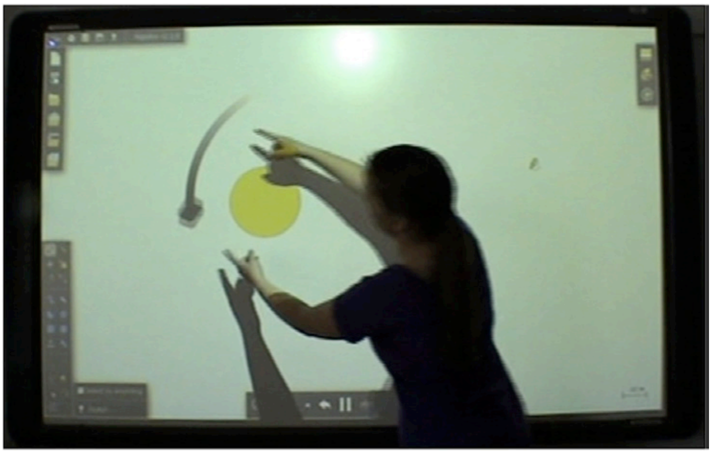

Figure 6. A student performing a gesture, pointing out a distance, the length of a trace left by a tracer attached to a planet moving through its orbit's perihelion.

Students can also observe that planets that orbit further away from the Sun have longer orbital periods. Algodoo also has a tool for sending planets into circular orbits. One possible way of investigating Kepler's third law is that students draw multiple planets at different distances from the Sun, send them into circular orbits using the built-in tool and observe how they move. Using a virtual distance measuring tool and a stopwatch, we can also investigate Kepler's third law quantitatively (figure 3).

Using Algodoo on an IWB

The described activities on the IWB encourage learners to communicate their ideas and observed patterns in new ways. In a study of ours [10], we have observed 15 and 16 year-old high-school students using gestures that directly reflected manipulation moves in Algodoo on the IWB, such as throwing. The IWB can therefore facilitate the use of alternative modes of communication and multiple representations of physical phenomena. In figures 4–6, we present, respectively, a typical sequence of student engagement in on-screen object creation and manipulation, followed by gesturing. Research has shown that gestures and physical engagement play an important role in learning [11, 12].

Concluding remarks

The described activity makes possible a hands-on approach to an otherwise experimentally inaccessible topic. The presented activity should be taken as an example of an activity where a piece of technology is supporting active and hands-on learning. We strongly believe that encouraging student physical engagement and collaborative investigation are the most important aspects in the implementation of the presented activity.

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