

Martin Soegaard · Damjan Štrus

C

# Science in Sports



## INTRODUCTION

This teaching unit goes well with information and communications technology (ICT) and classical mechanics. Almost everything in terms of theories in classical mechanics is suitable for usage of ICT. The software Tracker (see annex) is very useful for studies of position and its derivatives (velocity, speed and acceleration), forces (e.g. Newton's 2nd law), and work and energy (gravity, Hooke's law, potential and kinetic energy). Students can easily do the analysis as early as age 13. The analytical complexity of the experiments can increase with students' age.

Working with video analysis is ideal for hands-on, inquiry-based learning and working with the Scientific Method. The Scientific Method is a great way to make students think about the experiment before conducting it. Not only will they reproduce results, they will also be involved in the experiment. ①

## RESOURCES

You need a computer with the free video analysis and modelling tool Tracker installed, and any type of digital camera or mobile phone that can record video. If your school already has another video analysis software, you may prefer to use that instead. In all cases, the first step must be to record physical phenomena with a video camera. Then the recording is imported into the video-analysis software, which allows us to process images and analyse relations between physical quantities.

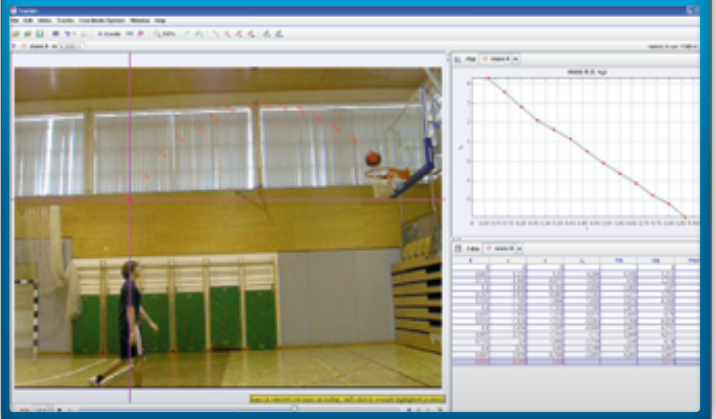
## CORE

### Input

For our teaching unit, students are required to record a specific movement of the sport they are analysing, e.g. a moving bicycle, a runner, a basketball thrown into the basket, etc. Then they analyse the physical laws of the chosen type of motion. When all is completed, they may present their project to other fellow students, using presentation tools, e.g. Prezi, PowerPoint, Glogster, or some other software suitable for presenting a project. The presentation could lead to a subsequent discussion of the results.

In this teaching unit, we analysed the movement of a bicycle. We conducted the experiment at a school in Slovenia and Denmark, respectively. Afterwards, students from both countries compared their results.

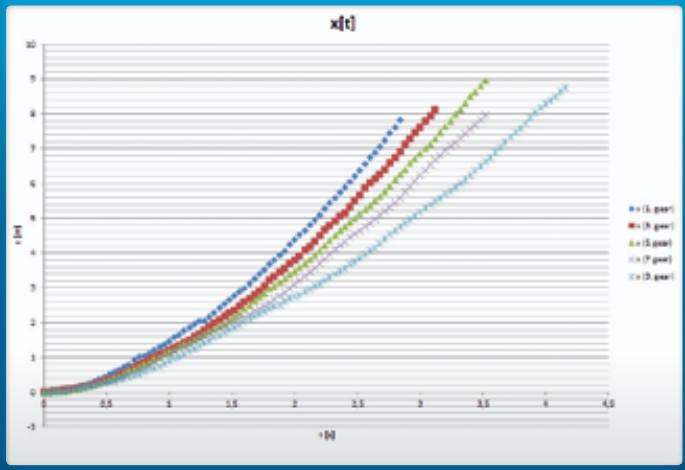
### ① Analysis of a flying basketball with Tracker



- Students record a few videos. The person rides the bicycle on a horizontal surface for 10 metres (the camera must not move during the experiment). In the first video, the person rides the bicycle at maximum power in first gear. Then the experiment is repeated with a second video in the third gear, etc. If the bicycle has many gears, the latter should be divided into multiple intervals (e.g. five).
- Then students will measure the length of the bicycle to establish an average length of bicycles for their analysing videos.
- They use Tracker to make a Table using time ( $t$ ), distance ( $x$ ), velocity ( $v$ ) and acceleration ( $a$ ) for each video.
- Tracker cannot compare graphs from several videos, so all data must be transferred to an OpenOffice, LibreOffice, Excel, or other spreadsheet. The main idea is that students draw just one graph in which they compare the velocity  $v(t)$  of the bike in all videos. There should be another graph to compare the acceleration  $a(t)$ .



## ② Comparison of the velocity of the bike in different videos



- Finally, the students can analyse graphs and make a physical conclusion. If they set up a hypothesis at the beginning, using the Scientific Method, they can compare the outcome with their hypothesis. This way, students can see if the hypothesis was correct, partially correct, or wrong. Having students reflect on the experiment once more, will enable them to think about it long after its completion.

The bicycle example, and other examples mentioned here, are well-suited for independent homework projects which are presented in the classroom. The examples are also suited for class experiments, especially when you want to include ICT in your teaching. Students have at least two options: They can record a specific movement from the sport they have chosen, e.g. a moving bicycle, a runner, a basketball thrown into the basket, etc., or they can use

pre-produced sports clips from online-video communities such as YouTube or Vimeo. The chosen clip must contain some data (measurable data such as the length of the bicycle, mass of the observed body, as shown in the pictures, etc.).

All this information can be entered in the notes section of Tracker, located on the extreme right side of the main command-order line. You'll find them displayed when you launch the program. We are now presenting a few useful steps for using the Tracker video analysis with the help of our bicycle experiment:

- Import the first video you wish to analyse into the program;
- Determine the Start and End frames of the video to isolate the section you will be analysing (black arrows on the video slider);
- Calibrate your video with a known length, e.g. the length of the bicycle using Calibration stick. If you're working with a length in centimetres, you get the velocity in cm/s and the acceleration in cm/s<sup>2</sup>. If you put the length in metres, the velocity is in m/s and the acceleration in m/s<sup>2</sup>;
- Determine the coordinate system that indicates to the software which section of the clip is considered to be a unit in the horizontal and vertical direction.

You'll find the buttons for all these settings in the main command-order line of the Tracker software.

The main part of the video analysis is where you denote the position of a moving bicycle as a function of time – we denoted a position for every single frame. You do that by clicking "Create Point Mass", then hold the CTRL-button down, and click the moving body on every single frame. Be careful to mark the same position on the bicycle in every frame. Thus, the software receives information about the bicycle position as a function of time.

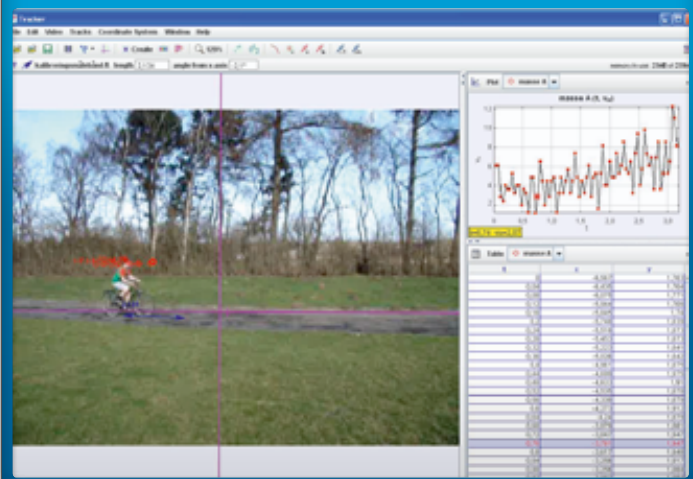
These are some of the things the students must know when they start using Tracker. If they want to know more, great support can be found in the Tracker help section. ③

### Analysis

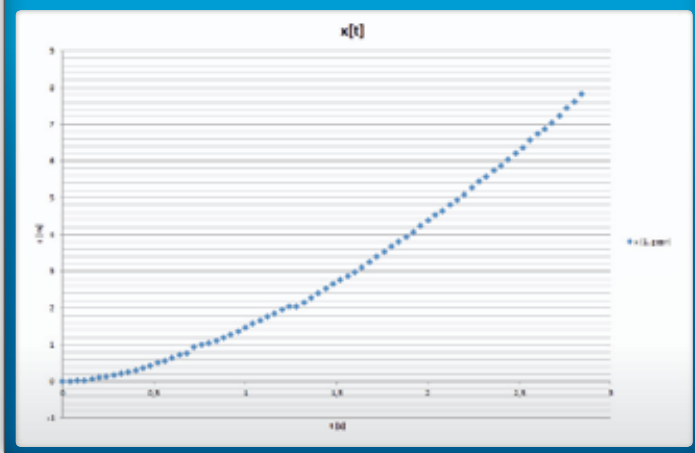
Based on the data, the software is ready to graphically demonstrate the time dependence of many quantities (position and speed in horizontal and vertical dimensions, actual velocity, acceleration and kinetic energy).

In our bicycle experiment we plotted the two graphs:  $x(t)$  and  $v(t)$ . The picture shows the graph  $x(t)$ . ④

## ③ Analysis of bike velocity with Tracker



### Graphical analysis of the velocity



From those two graphs, students can observe velocity and acceleration of the bicycle and compare acceleration in different gears.

For analysing relations between physical quantities, it is a good idea to enlarge windows with graphs (click the arrow on the right side of the main line of the graph window). Students can change the selected physical quantity by clicking the name of the quantity on the axis. The software opens a window in which you can choose another physical quantity. By clicking the same arrow on the right side, which is now facing down, students restore the previous view.

When teaching students aged 16–19, it is necessary to analyse graphs in greater depth. To do so, students must click the right mouse button on the graph they want to analyse. From the resulting pop-up window, they then select the option Analyse. Tracker opens a new window with a graph. For the bicycle experiment, we recommend that students find an adjustment curve for the graph  $x(t)$  and from the matching equation they can read out the acceleration. Then they do the same with the graph  $v(t)$  and read out the acceleration from the inclination of the graph, and compare the results.

### Output

It is very educational to graphically observe these quantities:  $x(t)$ ,  $v(t)$ ,  $a(t)$  and  $E_{\text{kin}}(t)$ . Students first imagine what the graph would look like. Then they draw it, compare their results with classmates, and finally check all solutions together in Tracker.

Looking at the graph  $v(t)$ , students then can discern the average acceleration of the bicycle by using the curve fitter in the Data Tool.

### CONCLUSION

Students can set up hypotheses for the problems that they have to solve and for the varying ways in which different types of objects or persons react when they are part of an experiment. Video-analysis software such as Tracker can be very helpful in understanding many of the physical laws. It's a great tool for visualising the experiment the students are performing. During physical lectures students get the physical theory, for instance, they hear that all bodies (if they are solely affected by gravity) fall down to earth with the same acceleration, regardless of weight. They are able to write and use equations for path, speed and acceleration of movement with constant acceleration. They can draw graphs for path, speed and acceleration versus time. Additionally, this curriculum should be cross-linked with mathematics, so students are able to recognise the connection between  $y=kx+n$  and  $v=v_0+at$  etc. Tracker allows students to be very active: conducting and handling their own experiments, observing the relationships between quantities, and analysing experiments in detail. Finally they compare the theory with the results of their experiment and effectively are "learning by doing".

