The paper presents a lesson plan for processing real world data for physics and mathematical concepts learning

L'articolo presenta un progetto didattico per l'elaborazione di dati del mondo reale per l'apprendimento di concetti della fisica e della matematica

Using video to promote Inquiry-based Learning in science: the case of Logger Pro®

STRUMENTI TOOLS

USARE IL VIDEO PER PROMUOVERE L'APPRENDIMENTO SCIENTIFICO BASATO SULL'ESPLORAZIONE: IL CASO DI LOGGER PRO®

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INTRODUCTION

Research suggests that real world data simulations promote problem solving amongst students, peer-to-peer active engagement and higher order thinking (Smetana & Bell, 2012). According to Hodson (1993), students often assume that practical work will reinforce their learning, or develop problem solving skills (Hofstein & Lunetta, 1982), but it does not happen in practice. In response to this dilemma, Russell and Weaver (2011) suggests that «*new approaches to the laboratory may be appropriate, in addition to efforts to improve instructor-student communication*» (p. 57). Both the content and the pedagogy of science learning and teaching are being investigated internationally, and new standards are emerging which are designed to rejuvenate interest and attainment in science (Hofstein & Mamlok-Naaman, 2007). A radical shift from a deductive to an inductive approach to teaching science has been recommended by many Western countries' reports (see, Minstrell & van Zee, 2000; NRC, 2000; Rocard et al., 2006) and reaffirm a new conviction that inquiry is central to the achievement of scientific literacy.
This paper describes the "Basketball Shot" lesson plan, which leverages a video analysis software for processing real world data such as the motion of a basketball in terms of physics and mathematical concepts. The lesson plan was written for the Inspiring Science Education project (ISE) (http://www.inspiringscience.eu/) which seeks to further the use of inquiry-based learning (IBL) in science through the use of ICT in the classroom. Moreover, the lesson plan looks at the commonality of concepts that exists between mathematics and physics and how such concepts can be effectively communicated to students using real world data.
The lesson plan demonstrates how a video of a player throwing a basketball is used as the pedagogic tool to measure concepts of vectors, speed, velocity and acceleration together with their relative meanings with regard to linear and quadratic equations. The program used for the analysis is Logger Pro® from Vernier Software & Technology (www.vernier.com). The lesson plan challenges the student to make and subsequently test their predictions using mathematical formulae. The lesson plan addresses the call for authenticity in science practical work and mathematics (Cleaves & Toplis, 2012; Hodson, 1993; 1998; 2014; Toplis & Allen, 2012). The many advantages derived from such approaches are thus that they underpin IBL, learner and knowledge-centred instruction (Berlin & White, 1986; Hargrave & Kenton, 2000; Lee, 1999).

SOFTWARE BACKGROUND

Practical work creates great expectations in students and is one of the distinct features of science teaching (Abrahams, Reiss, & Sharpe, 2013; Fotou & Abrahams, 2015; Hodson, 2014; Millar & Abrahams, 2009). The assumption that practical work is a “good thing” is largely because of the motivation and engagement a hands-on approach can facilitate (Hodson, 1998).

The aim of the “Basketball Shot” lesson plan is to use real and authentic data, taken using a digital camera Mpeg file, of a player throwing a basketball in a school gym. The movie file is then imported into a Vernier Software and Technology datalogging package called Logger Pro®. The movie is easily inserted into the program and seamlessly integrates with the data capture analysis functions inherent in the program’s capability. The useful feature is that, once the movie is inserted, it is automatically synchronised with the table of data and the graphing functions of Logger Pro®.

The “Basketball Shot” lesson plan involves the use of video capture to help the student investigate the concepts of speed, velocity and acceleration. Using the Logger Pro® program, video is captured of a player throwing a ball towards the basket. The ball does not reach the basket, but instead bounces on the floor and continues its motion. The concept of constant velocity, vectors, acceleration in two dimensions is therefore shown. Moreover, a connection with mathematics is established where the relevancy of linear and quadratic equations, together with the concept of vectors, are clearly demonstrated in the context of the motion of the ball with the curve fitting features of the program. The lesson plan challenges the student to make and subsequently test their predictions using mathematical formulae.

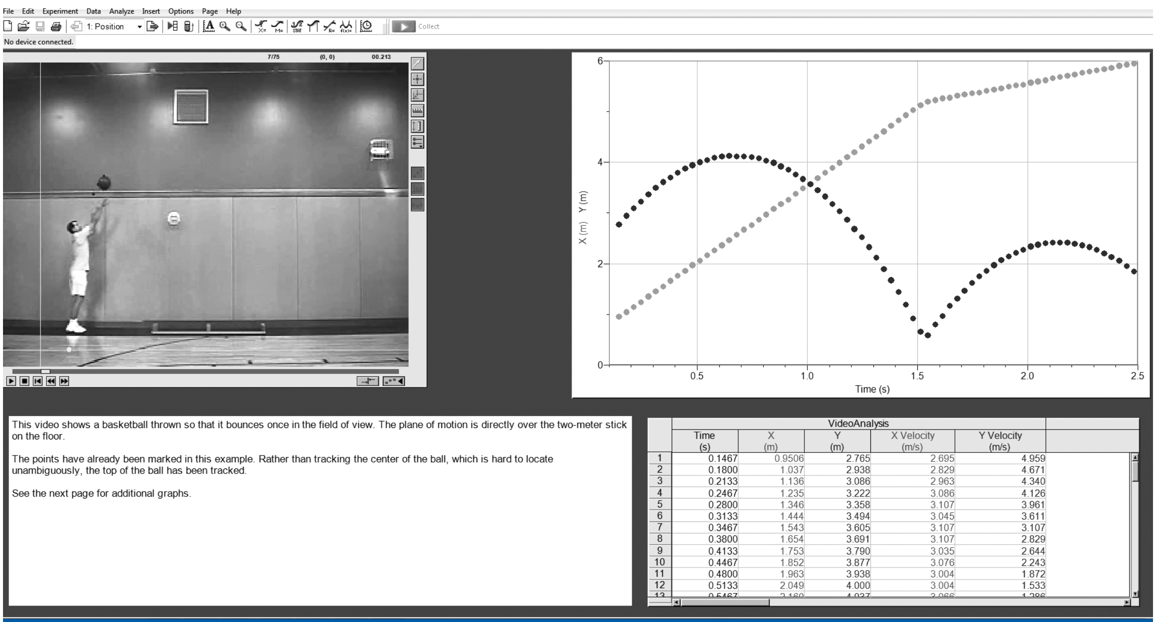
BRIDGING THE DIVIDE BETWEEN MATHS AND SCIENCE USING LOGGER PRO®

As any teacher will know, there is a considerable amount of physics and mathematics concepts involved here in this short action. Figure 1 shows the screen shot after the basketball has been thrown and the motion of the ball has been plotted on screen using the tracking tool in the program.

The motion of the ball is shown by two traces, one in read and one in blue. This represents the two components of motion, that of the x-component and that of the y-component. You will notice that, in front of the thrower, there is a measuring rod. In this case its length is 2 meters, and it is in the same plane as the player. This is necessary, of course, to reduce errors of parallax and therefore to give an accurate measurement of the true distance the balls travels along both axes. Once that measurement has been entered, the origin is then set. The user can set this anywhere they want, but in order to aid in the IBL approach, the origin is set lower than the floor limit on the screen. In opting for this setting, it brings some interesting aspects of quadratic equations into play later in the lesson (Figure 2).

The motion of the ball can then be tracked, frame by frame, using an embedded tracking tool icon in the program. After tracking the ball through its entire motion, the video screen will show a clear parabolic motion of the ball as it bounces (Figure 3).

The corresponding graph screen will show the motion of the ball in 2D; in the x and y planes. The plot shows how far the ball has travelled in a given time; the velocity of the ball. The red and blue traces are describing exactly the same motion, but they have much greater visual impact when it comes to



	Time (s)	X (m)	Y (m)	X Velocity (m/s)	Y Velocity (m/s)
1	0.1467	0.9506	2.765	2.695	4.959
2	0.1800	1.037	2.938	2.829	4.671
3	0.2133	1.136	3.086	2.963	4.340
4	0.2467	1.235	3.222	3.086	4.126
5	0.2800	1.346	3.358	3.107	3.961
6	0.3133	1.444	3.494	3.045	3.611
7	0.3467	1.543	3.605	3.107	3.107
8	0.3800	1.654	3.691	3.107	2.829
9	0.4133	1.753	3.790	3.035	2.644
10	0.4467	1.852	3.877	3.076	2.243
11	0.4800	1.963	3.938	3.004	1.872
12	0.5133	2.049	4.000	3.004	1.533

Figura 1. *Basketball experiment screen shot.*

explain what a constant velocity might be (Figure 4). From the blue trace (the y-axis) the uniformity of the ball's motion is not so obvious, but from the red trace (x -axis) the constant motion of the ball before the bounce and its constant motion again afterwards is easily described by the red trace.
The built-in features of the programme allow for easy manipulation of the graphs, in that mathematic curve fits can be quickly and efficiently accomplished. For example, the red x-axis trace can be measured in both its segment by using the linear equation, y = mx + b, whilst the blue y-axis trace uses instead a quadratic equation of the for $Ax^2 + Bx + C$. Figure 4 also shows a tangent tool that can also be added to the screen, so that when moving up across the graph, will give an instantaneous rate of change at that point. The slope of the tangent will give the value of the rate of change, and along the blue curve the changes are more dramatic, whilst on the red curve the slope only changes once.
In an earlier example the origin of the graph was set such that it appeared to be "under" the floor level of the thrower. The reason for that will now become clear. Figure 4 shows that the bounce of the ball (blue trace) is on x-axis, but instead above it. By having it this way, it allows the student to offer a prediction as to where the ball might have bounced if it were allowed to travel all the way to the x –axis. Since the blue trace is a quadratic equation, it must have two solutions for x; that is, it "cuts" the x-axis in two places. A familiar equation to all secondary school mathematic students is that which follows in Figure 5.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Figura 5. *Finding roots for quadratic equation.*

By using the "Curve Fit" function, we can see that on the smaller bounce the solutions for A, B and C are shown (Figure 6).
Therefore, our equation (of the second bounce of the ball) approximates y = 5x2- 22x+21, of which the solution is approximately x = 1.4 and x =3.

CONCLUSION

In schools where this lesson plan has been introduced, students have gained a better appreciation for the commonalities between physics and mathematics. For example, in a separate study conducted over a period of 12 weeks by the authors into the use of datalogging software in Tanzania (English, Crotty, Farren, & Hennessy, 2016), empirical data showed that students using datalogging Logger Pro® software were better able to engage with the experiments and showed a much

Figura 2. *Setting up the point of original (that is the position of the x and y axes).*

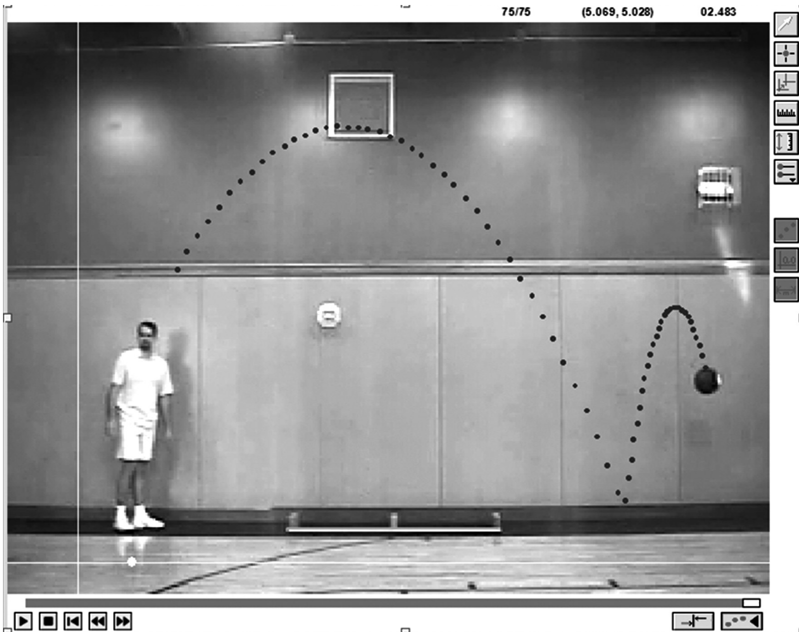


Figura 3. *Motion of the basketball tracked on screen.*

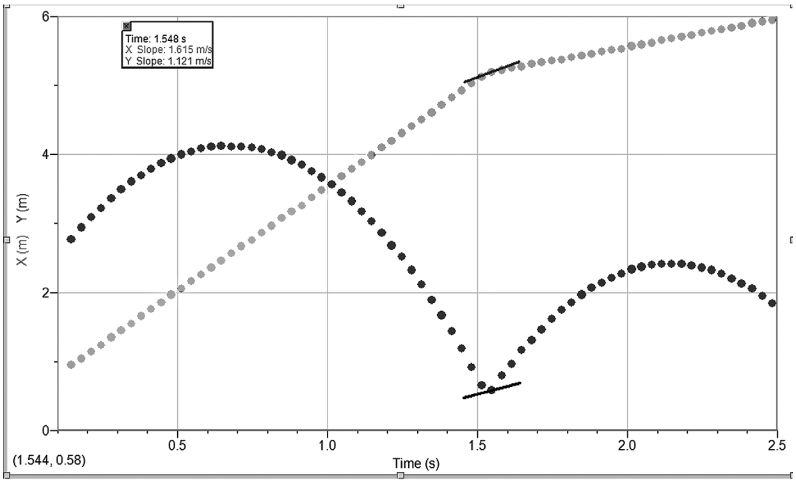


Figura 4. *The corresponding graph plot of the ball.*

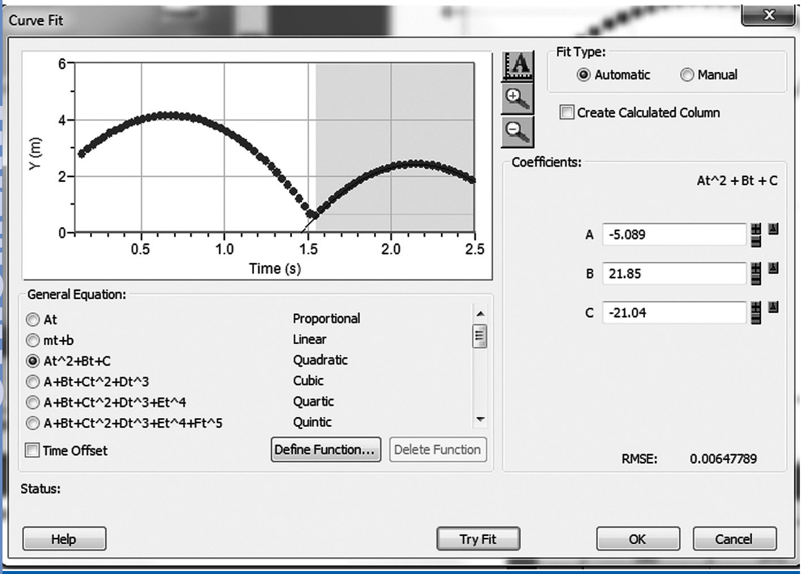


Figura 6. *Solution to the quadratic equation.*

improved ability to understand the concepts of velocity and acceleration compared to the control groups. Test scores of students increased by 11% for those who were instructed through Logger Pro® compared to those in the control group who were taught with the normal school teaching.

In other instances, students have chosen to devise their own videos relating to physics, for example, track the motion of a racing car. The facilitation of capturing real world adds a concrete connection with reality making it more engaging with students. Limitations of the approach mean that random video obtained on the Internet cannot be easily integrated because of the need for an accurate calibration of distance in the program. The program might also benefit if it were able to track two objects simultaneously, which would be idea for measurements of conservation of momentum. The Basketball Shot lesson plan presented in this paper shows the use of video capture to help the student investigate the concepts of speed, velocity and acceleration. Connections between the mathematics underpinning many of the physics phenomena are not so obvious to the student who studies maths in isolation to physics. This approach to unifying the constructs of building a bridge between concepts of mathematics and physics is also economical in terms of equipment required; all the teacher needs is a webcam, or digital camera and a computer to run Logger Pro®. The advantages are not only in a greater engagement and relevance for the student, but also the time needed for preparation is much less than a standard physics lab.

This paper would have benefited from a more in-depth study of improved levels of cognition of concepts and engagement by students with the experiment. A future research study is planned in this respect.

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