The Basketball Shot: Building the Bridge Between Physics and Mathematics

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Abstract

Inspiring Science Education (ISE) (http://www.inspiringscience.eu/) is an EU funded initiative that seeks to further the use of inquiry-based learning (IBSL) in science by providing digital resources for teachers to help them make science education more interesting and relevant to students' lives. The "Basketball Shot" is a lesson plan that involves the use of video-capture to help the student investigate the concepts of speed, velocity and acceleration. Using the LoggerPro® data collection and analysis program from Vernier Software and Technology, 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 demonstrated. 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. The lesson plan addresses the call for authenticity in science practical work and mathematics. [1-3], [4, 5]. Research suggests that real world data simulations promote problem solving amongst students, peer to peer active engagement and higher order thinking [6]. The many advantages derived from such approaches are thus that they underpin inquiry-based learning, learner and knowledge-centred instruction [7, 8].

Background

Practical work creates great expectations in students and is one of the distinct features of science teaching [9]. The assumption that practical work is a "good thing", is largely because of the motivation and engagement a hands-on approach can facilitate [2]. This resonates with Thomas & Banks [10], who stress that experimentation is often singled out as a key determinant in "doing science" and the essential means to testing hypotheses. However, this new approach has its many critics, with concerns that science practical lessons can be too short. Moreover a single teacher with a large class is may not be the best environment to convey a true appreciation of science [5, 11]. Modern criticisms of practical work centre on its lack of "authenticity", therefore the role of practical work in science instruction needs to be clearly defined in terms of its purpose and potential. Woolnough & Allsop [12] discuss the historical approach to practical science where it should address four primary aims: motivate students; develop experimental skills and techniques; simulate the work of the "real" scientist; and, support theory. In a similar vein, Wellington & Ireson [13] refer to the importance of science practical work to answer the questions of "what" and "how" of science. 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 LoggerPro. 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 LoggerPro®. Hence it provides an excellent and cost efficient tool to analyse real world data in an authentic way and help build a bridge between concepts of physics and mathematics.

Inquiry based learning

It is clear from the literature that there is no universal agreement on what the appropriate aims and objectives actually are for practical work in science, and moreover little agreement on what the best approaches should be in teaching practical science [1, 14, 15]. According to Hodson [1], students often assume that practical work will reinforce their learning, or develop problem solving skills [16], but it does not happen in practice. In response to this dilemma, Russell & Weaver [17] 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 [18]. A radical shift from a deductive to an inductive approach to teaching science has been recommended by many Western countries' reports [for example, 19, 20, 21] and reaffirm a new conviction that inquiry is central to the achievement of scientific literacy.

Capturing real world data with accuracy, speed and simultaneity

Data-logging products have been traditionally deployed in science laboratories [4], for recording and handling experimental data as part of the National Curriculum for England, amongst others [22]. When students use dataloggers they avoid the "drudgery of data collection and processing to enable progression to higher order skills" [23]. Early studies [for example, 24, 25-29] indicate that dataloggers were seen to be useful in supporting experimentation and collaborative group learning because they freed up more time dispensing with the need to manually collect data, draw graphs and process results [22]. In particular, dataloggers provide an "immediate link between the investigation and the result" [29] which is consistent with more recent studies [30]. The immediacy of the data appearing on the screen helps make a better connection between the experiment and the graph and leads to an increase in student motivation [13, 29, 31-35]. Moreover, Warwick & Siraj-Blatchford [36] found that students who collected data themselves stimulated their desire to provide explanations for their data, and were more likely to discuss their findings with other students, thereby supporting a socio-constructivism pedagogy. Murphy [37] comments that the potential afforded by datalogging in primary science is also considerable in terms of prediction, real time data capture, observational skills, space-time cognition, measurement skills and interpretation of data.

Bridging the divide between maths and science using LoggerPro

The lesson plan begins by posing a question: "In throwing a ball, what forces would you expect to act on it if you throw a ball against a wall, or throw it so it bounces off the ground?" 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 in two components (x and y).

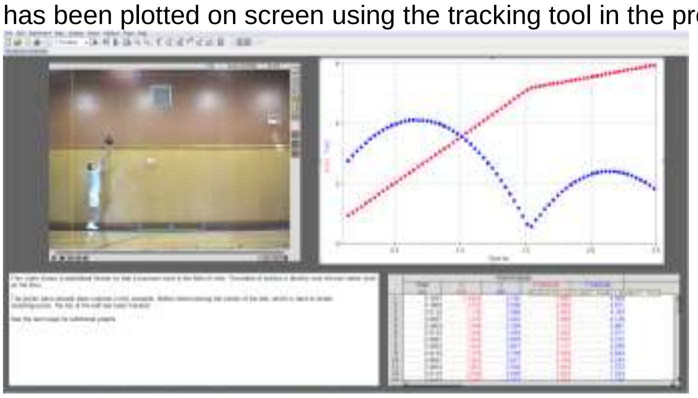

Figure 1 – Basketball experiment screen shot

The motion of the ball can then be tracked, frame-by-frame, using an embedded tracking tool icon in the program. The built in features of the programme allow for easy manipulation of the graphs, in that mathematic curve fits can be quickly and efficiently. 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 $Ax^2 + Bx + C$. 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. Figure 1 shows that the bounce of the ball (blue trace) is not 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 2.

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

Figure 2 – 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 3). Therefore our equation approximates $y = 5x^2-22x+21$, of which the solution is approximately $x = 1.4$, and $x = 3$.

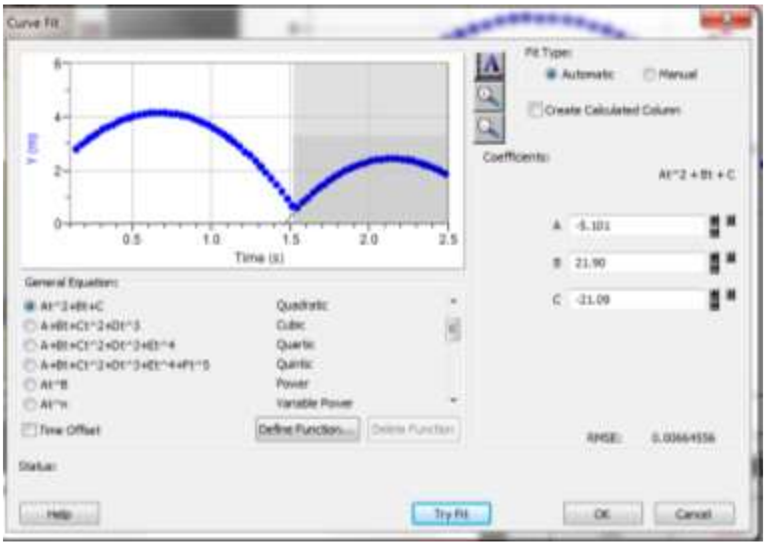

Figure 3 – Solution to the quadratic equation

Conclusion

Using digital technologies, with or without the use of datalogging sensors, can support inquiry-based learning. Connections between the mathematics underpinning many of the physics phenomena are not so obvious to the student who studies maths in isolation to physics. Another key aspect of using a program such as LoggerPro® is that it allows the student to use and work on real world data, therefore making a connection with real world applications.

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