How good was Bob Beamon?

Level
Middle and upper secondary

Mathematical ideas
Linear functions, informal data analysis, gradient

Description and Rationale
Mathematical applications and problems found in school textbooks sometimes lack realism and may reinforce the message that mathematics is divorced from real world concerns. Graphics calculators make it easier for students to represent, analyse and interpret data from real life situations, for example through the use of statistical and graphing procedures. This lesson allows secondary students to apply their knowledge of linear functions in the gradient-intercept form $y = mx + c$ to investigate published data on long jump world records. Bob Beamon's astonishing performance in the 1968 Mexico City Olympics provides the context for the task. The calculator is used to draw scatter plots of distance jumped versus the year in which the world record was set. Students then estimate and plot a line of good fit through the data in order to answer the question: *How good was Bob Beamon?*

This lesson also demonstrates how existing resource materials can be given a new lease of life by introducing technology as a means of investigating problems. The task is based on material published by the Spode Group in 1982, before the advent of graphing calculators and the Internet, but makes use of both these technologies to simplify the graphing procedure and place the initial data gathering in the hands of the students themselves.

Background
The task can be introduced by showing an overhead transparency of Beamon in the act of breaking the long jump record (see above), and asking students if they know the identity of the athlete. When trailing this activity with pre-service and practising teachers common responses include Jesse Owens and Carl Lewis, although Beamon is usually recognised as soon as the Mexico City Olympic Games are mentioned. Students can be introduced to the story of Bob Beamon through the newspaper article reproduced on the following page, by kind permission of the *St Petersburg Times*.
(Source: http://www.sptimes.com/News/121699/Sports/Beamon_jumps_into_rec.shtml)

Task
Many studies were published searching for explanations for Beamon's amazing jump, one popular theory attributing his performance to the altitude and rarified air of Mexico City (2250 metres above sea level). It could be said that Beamon was a man ahead of his time ... but how far ahead? In other words – *How good was Bob Beamon?*
Students can analyse long jump world record trends over the course of the 20th century to investigate this question.

Beamon jumps into record book

By BRUCE LOWITT

© *St. Petersburg Times*, published December 16, 1999.

As with most events in track and field, the long jump is measured -- and records are broken -- by fractions of an inch, by centimeters, which is what made Bob Beamon's feat (and, yes, feet) at the 1968 Mexico City Olympics that much more remarkable.

Beamon was, in effect, the No. 2 long-jumper on the U.S. team. Ralph Boston had won gold at the 1960 Rome Olympics and silver at the 1964 Games at Tokyo, and set or tied the world record five times. The record of 27 feet, 4 3/4 inches was Boston's when the 1968 Summer Games started.

Beamon had won 22 of 23 meets he had entered that year, but he was prone to fouling and was considered inconsistent. Furthermore, he had been suspended that June by the Texas-El Paso track team for protesting Brigham Young's Mormon racial policies by refusing to compete against BYU. That left him without a coach.

Boston, who had become Beamon's unofficial coach, and Soviet competitor Igor Ter-Ovanesyan were the favorites in Mexico City. Beamon and Boston were Olympic adversaries, but they were friends and teammates, too.

On Oct. 18, Beamon fouled on his first two qualifying attempts. One more and he would be eliminated.

Boston had a suggestion, something similar to what had happened at the 1936 Berlin Olympics when Jesse Owens had fouled in his first two qualifying attempts and Germany's Luz Long had told him how to avoid another foul. "Ralph Boston did the same for me," Beamon said later. "He told me, 'Bob, you won't foul if you take off a foot behind the foul line. You can't miss.' Basically, that's what Luz Long told Jesse (the German placed a towel at the spot for Owens to use as a takeoff marker), and I took Ralph's advice. I qualified."

With his opening jump in the final, Beamon effectively ended the competition for the gold medal. The 6-foot-3, 160-pound New Yorker sprinted down the runway and launched himself into Mexico City's thin air. When he came down, he was nearly out of the long-jump pit.

"I knew I made a great jump. ... I knew it was more than 27-4 3/4, which was the world record," Beamon said. He ran around excitedly, then fell to his knees, buried his face in his hands and, overcome by the moment, wept.

"I heard some of the guys saying things like 8.9 meters ... or something," he said. "Outside the United States, everything is in meters, so I wasn't sure how far I had jumped. "Then Ralph Boston came over and said, 'Bob, I think it's over 29 feet,' which was almost 2 feet farther than the world record."

From 1961-65, Boston and Ter-Ovanesyan had traded the world record back and forth, raising it from 27-1/2 to 27-2 to 27-3 1/2 to 27-4 3/4. Four and one-quarter inches in nearly five years. "I said to Ralph, 'What happened to 28 feet?'" Beamon said.

After what seemed like an eternity, the public-address announcer made it official: "Bob Beamon's leap, 8.90 meters -- 29 feet, 2 1/2 inches." In one leap he had raised the record by 21 3/4 inches.

"Compared to this jump, we are as children," Ter-Ovanesyan said afterward. And an angry English jumper Lynn Davies said to Beamon, "You have destroyed this event!"

The record would become track and field's oldest, standing for 23 years until Mike Powell leaped 2 inches farther at the 1991 World Championships in Tokyo.

"I've always been a very realistic person," Beamon said the day Powell eclipsed his mark. "I knew the day I set it that eventually someone would come along and surpass it. ... I knew it was inevitable. Now that it has finally happened, I don't feel any different. I don't feel as though something's been taken away from me or that people will think any less of me. "And don't forget," Beamon said with a hint of humor, "I still hold the Olympic record."

-- Information from Times files and 100 Greatest Moments in Olympic History by Bud Greenspan (General Publishing Group) was used in this report.

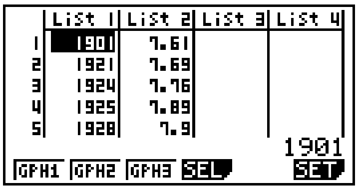
Possible solutions

Students can find data on men's long jump world records from the Internet. A good source is at the URL: http://www.sci.fi/~mapyy/tilastot.html. Here are the official data over the twentieth century:

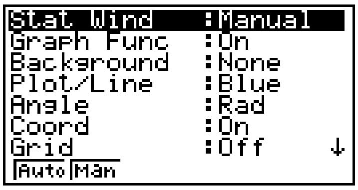
Distance (m)	Name	Country	Date	Place
7.61	Peter O'Connor	GBR	5.8.1901	Dublin
7.69	Edwin Gourdin	USA	23.7.1921	Cambridge, Mass.
7.76	Robert LeGendre	USA	7.7.1924	Paris
7.89	William de Hart Hubbard	USA	13.6.1925	Chicago
7.90	Edward Hamm	USA	7.7.1928	Cambridge, Mass.
7.93	Sylvio Cator	HAI	9.9.1928	Paris
7.98	Chuhei Nambu	JAP	27.10.1931	Tokyo
8.13	Jesse Owens	USA	25.5.1935	Ann Arbor, Mich.
8.21	Ralph Boston	USA	12.8.1960	Walnut, Calif.
8.24	Ralph Boston	USA	27.5.1961	Modesto, Calif.
8.28	Ralph Boston	USA	16.7.1961	Moscow
8.31	Igor Ter-Ovanesyan	URS	10.6.1962	Yerevan, USSR
8.31	Ralph Boston	USA	15.8.1964	Kingston, Jamaica
8.34	Ralph Boston	USA	12.9.1964	Los Angeles
8.35	Ralph Boston	USA	29.5.1965	Modesto, Calif.
8.35	Igor Ter-Ovanesyan	URS	19.10.1967	Mexico City
8.90	Bob Beamon	USA	18.10.1968	Mexico City
8.95	Mike Powell	USA	30.8.91	Tokyo

For an initial look at trends in the data, students may suggest a scatter plot of distance versus year.

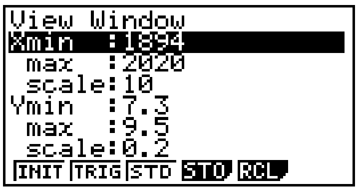
Select the STAT icon from the MENU screen and enter years in List 1 and distances in List 2.



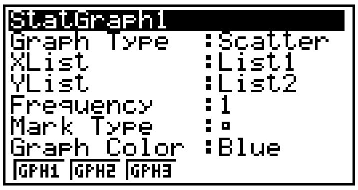
There are benefits in having students choose appropriate settings for the graph viewing window in order to make decisions about domain, range, and scale. Set the Stat Window to Manual (rather than Auto) by selecting SET UP (SHIFT-MENU) then Man (F2).



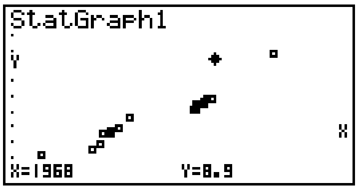
The view window is set via the function buttons below the screen (SHIFT F3) In this case, a good choice for the X-values is shown, with a span of 126 years, suiting the calculator screen dimensions.



The scatter plot is set up via the GRPH (F1) and SET (F6) commands. The set up shown produces a scatter plot of the distance jumped versus the year.

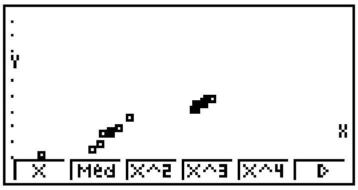


On EXITing the set up and returning to the List screen, selecting GPH1 (F1) produces the scatter plot shown. The TRACE (SHIFT-F1) command can be used to highlight the data point representing Beamon's extraordinary jump.



The scatter plot clearly shows that Beamon's (and Powell's) performance was substantially better than the trend established in previous years. Students may decide to investigate the question of "How good was Beamon?" by predicting the year in which his record jump of 8.90 metres *should* have been expected.

This trend can be more closely examined by deleting the final two data points from Lists 1 and 2, and repeating the procedure for drawing the scatter plot.

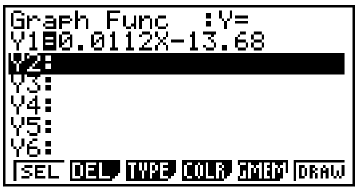


A linear model seems to be suitable for describing the relationship between distance and year. Students should be encouraged to estimate the gradient and find a line of best fit without recourse to the calculator's regression commands, in order to apply their knowledge of linear functions.

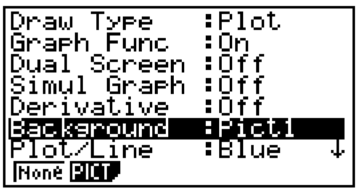
For example, if we select two points (1901, 7.61) and (1967, 8.35), the gradient of the line joining them can be calculated as $m = \frac{y_2 - y_1}{x_2 - x_1} = 0.0112$. Substituting this (rounded) value and the coordinates of one of the points into $y = mx + c$ gives an estimated equation of $y = 0.0112x - 13.68$. This function can then be plotted over the data points, and its appropriateness determined.

With the scatterplot displayed a picture is taken by pressing OPTN and then following the screen commands to store the picture

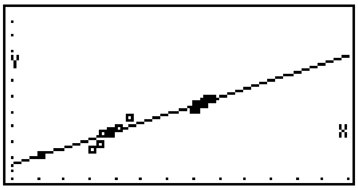
Go back to the MENU and select the GRAPH icon. Type in the equation of the estimated line of good fit, pressing EXE to store it.



The picture is placed in the background by entering the SET UP (SHIFT MENU) and changing the background to the stored picture (here Pict 1).

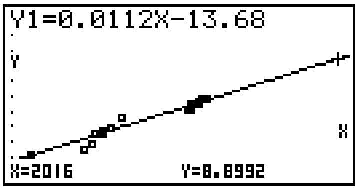


After returning to the GRAPH mode the resulting plot is produced by selecting DRAW (F6).

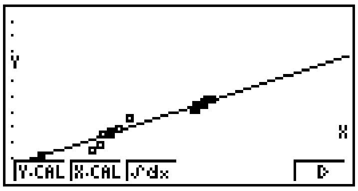


Students may wish to fine tune their equation until they are satisfied with the goodness of fit – this provides opportunities for them to explain how gradient and intercept alterations affect the graph.

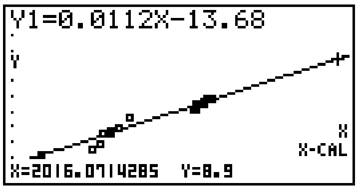
Tracing along the line (SHIFT-F1) allows us to find the year in which a jump of approximately 8.90 metres is predicted, based on the data before Beamon's incredible jump.



A more accurate answer can be obtained by using the G-Solve command (SHIFT-F5). Choose F6 to display the second screen of analysis options, and select X-CAL (F2) since we wish to determine the *x*-coordinate (year) corresponding to a known *y*-coordinate (distance).



Type in 8.90 and press EXE. The cursor moves along the graph until the desired point is reached, and the calculated coordinates are displayed at the bottom of the screen.



This analysis suggests that Beamon was 48 years ahead of his time – the time difference between 1968, when he broke the world record, and 2016, the year in which previous world record trends indicate such a jump would be expected.

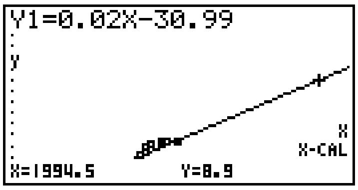
Another way of investigating this situation is by analysing the meaning of the gradient: our function suggests that, on average, the world record increased by 1.12 cm per year from 1901 until 1967. As Beamon increased the existing mark by 55 cm, we could perhaps say that he was around 54 cm ahead of his time!

Some students may argue that a single linear model is not adequate for describing the full set of data. For example, there seem to be two distinct time periods in which the record distance advanced at different rates: the first a time of rapid improvement from 1921 to 1935, and the second a much more gradual change from 1960 until 1967. It would be interesting to speculate on the reasons for this difference, and why Jesse Owens's record stood unchallenged for so long. (The Second World War obviously had an effect on international sporting competition; for example, the Olympic Games were not held between 1936 and 1948.)

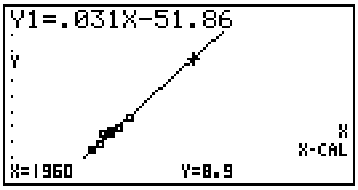
The calculator procedures outlined above can be repeated to separately analyse the data in these two time periods. For example, use Lists 3 and 4 for 1921-1935 records, and Lists 5 and 6 for 1960-1967 records. Before viewing scatter plots, change the GRAPH background back to to None. Store StatGraph2 (Lists 3 and 4) as Pic2 and StatGraph3

(Lists 5 and 6) as Pic3. Re-set the GRAPH background to Pic2 or Pic3 when plotting estimated lines of good fit over the scatter plots.

If we look first at the 1960-1967 data, a line of good fit can be calculated as $y = 0.02x - 30.99$. With the world record distance increasing as an average rate of 20 cm per year during this period, the equivalent of Bob Beamon's jump of 8.90 metres is predicted in the year 1994 – so was he only 26 years ahead of his time?



However, the data for 1921-1935 are even more interesting, as during this time frame the distance was advancing at 31 cm per year. Our line of good fit, $y = 0.031x - 51.86$, predicts a leap of 8.90 metres in 1960! What does this say about the danger of extrapolation far beyond the data provided?



Extensions

Sporting world records lend themselves well to this type of analysis, and other similar tasks could be easily devised – perhaps by the students themselves, using the Internet site noted above as a source of data. A new world record provides an ideal opportunity to assess the adequacy of a model developed from previous data – that is, how well did the model predict the new record?

Students could also consider whether a linear model is likely to continue to be the most appropriate one for describing human performance. Will a plateau be reached, or will improvements in training regimes, sports science, nutrition and so one lead to corresponding improvement in sporting achievement? The issue of drug use in sport arises naturally from such questions, demonstrating the potential for mathematics to be used in analysing social problems. However, Bob Beamon's feat should remind us that mathematical models are at best approximations requiring intelligent interpretation as much as mathematical knowledge and skill.

Explorations of these kinds have considerable potential to help students understand the nature of mathematical modelling. The graphics calculator is an invaluable tool to support such work, allowing students to take charge of the modelling process.

Reference

Spode Group (1982). *Solving real problems with mathematics. Vol. 2.* Cranfield, England: CIT Press.