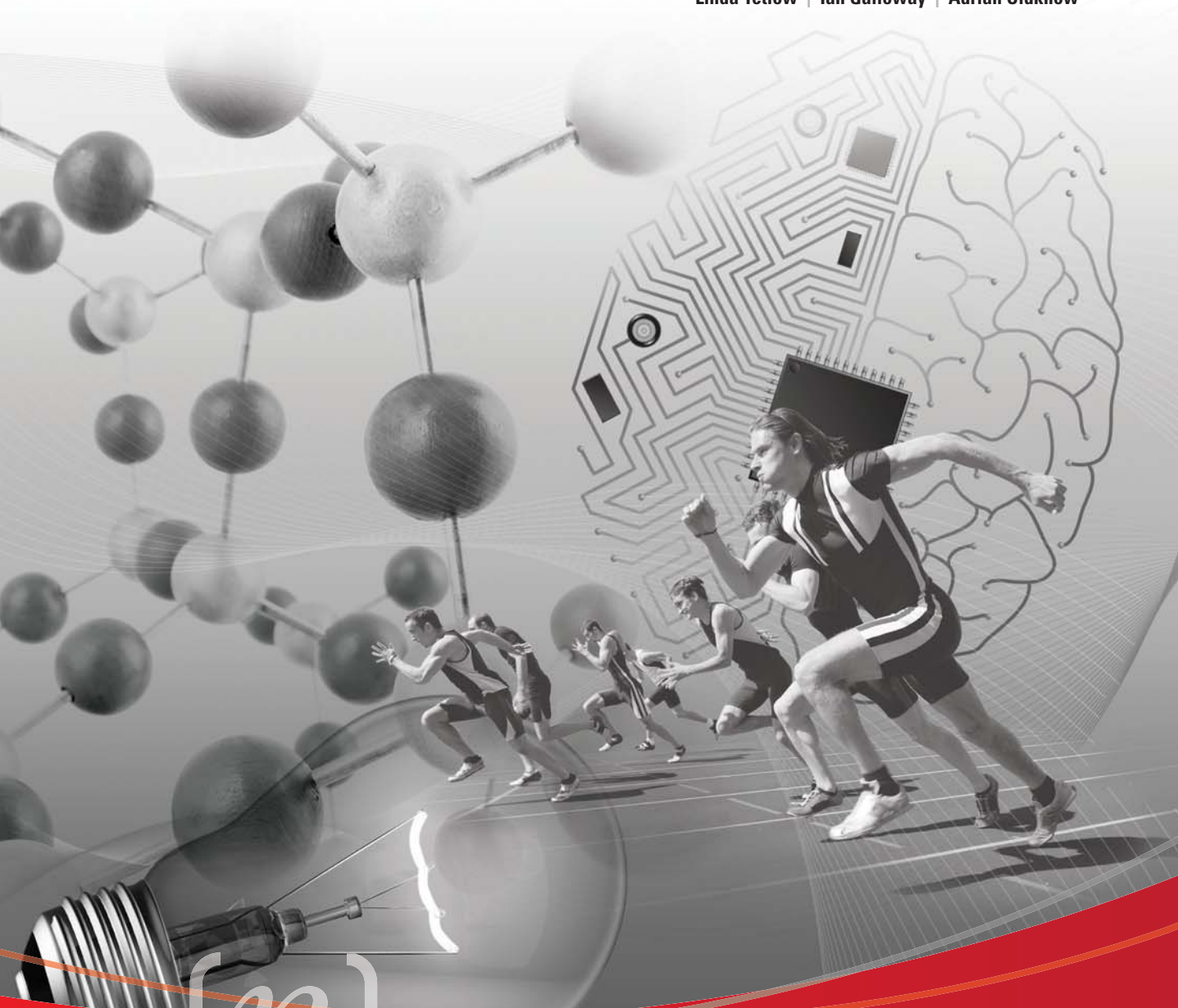


Introduction

STEM ACTIVITIES WITH TI-NSPIRE

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*(n)*spiringminds



Your Vision. Our Technology. Learner Success.

STEM ACTIVITIES WITH TI-Nspire

INTRODUCTION

Why use TI-Nspire?

The data handling features of TI-Nspire and the emphasis in the new secondary curriculum on real-life contexts, curriculum opportunities and cross-curricular dimensions all combine to give a strong rationale for introducing activities using TI-Nspire which use real data and link STEM subjects.

There is now a wealth of data available on the Internet in a variety of forms. TI-Nspire can make use of this data as it has the facility to copy and paste information from tables and spreadsheets into a 'Lists & Spreadsheet' page.

Data can also be captured using a variety of data logging probes linked to TI-Nspire, such as temperature probes or motion sensors. Motion data can also be collected manually or using video analysis. It is then possible to manipulate, display and analyse this data in a variety of ways using facilities from 'Data & Statistics'. It is also possible to further analyse or attempt to model the data by inserting movable lines, plotting functions or fitting a variety of functions using different forms of regression.

Curriculum opportunities

The new curriculum in England gives considerable importance to curriculum opportunities which include the following

Mathematics

- work on open and closed tasks in a range of real contexts
- work on problems that arise in other subjects and in contexts beyond the school
- work on tasks that bring together different aspects of concepts, processes and contexts
- work collaboratively as well as independently in a range of contexts
- become familiar with a range of resources including ICT so that they can select appropriately

Science

- research, experiment, discuss and develop arguments
- use real-life examples as a basis for finding out about science
- study science in local, national and global contexts
- recognise the importance of sustainability in scientific and technological developments

Cross-curricular dimensions

These are also emphasised and they include:

- healthy lifestyles
- global dimension and sustainable development
- technology and the media
- creativity and critical thinking

Mathematics and statistical education

In 2005 there was a review of the Mathematics curriculum and wide-ranging research was undertaken into the part that statistical education should play in this. The results of this were contained in a report from the Royal Statistical Society's Centre for Statistical Education in association with QCA (now QCDA). The key features of this report are that though it was felt that statistical education should be set in contexts from other curriculum areas especially Science, it should still be delivered by mathematics teachers. The mathematics teachers would however need to be supported by appropriate resources and background information.

<http://www.rsscse.org.uk/qca/recommendations.htm>.

Sets of materials for teachers for eight activities were produced jointly by the RSS and QCDA. One of these is 'What's in your bowl?' which looks at the nutritional content of breakfast cereals and is linked to one of the activities in the booklet '*STEM activities with TI-Nspire - Using Real World Data*'.

Real world data activities

The QCDA/RSS report conclusions combined with the availability of data over the Internet and the range of facilities of TI-Nspire provide a wealth of opportunities for STEM activities using real world data including:

Modelling

Some activities offer opportunities to try to find formulas or to fit functions to scientific data to model it mathematically.

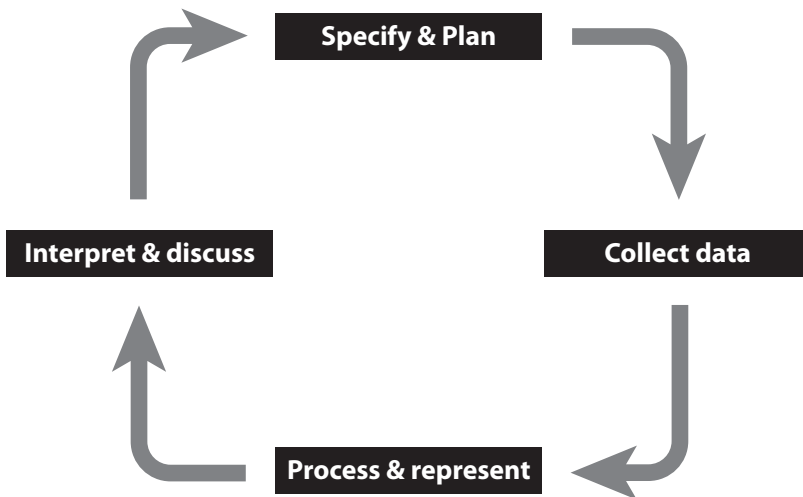
Handling data cycle

Other activities offer opportunities to examine real-world data to

- See what the data show and find representations to illustrate these findings more clearly.
- Make and test hypotheses using a student-centred problem solving approach.

This might include

- looking for trends in data and predicting future results
- comparing sets of data, presenting and analysing results and justifying conclusions



About the activity books

All the activities in the booklets contain some background scientific or other information together with links to appropriate websites for further information and other resources. Many of the activities are suitable for a range of ages and aptitudes with more challenging ideas being suggested as extension activities. The introduction to the activities gives some idea of the subject content and the TI-Nspire features that could be used. Some activities have additional information such as teachers' notes, further background information or additional advice for students including getting started with TI-Nspire. Further information and TI-Nspire files for the activities can be found at www.nspiringlearning.org.uk

Capturing Data: Modelling and Interpretation

contains activities which use a variety of data logging probes to collect real data and analyse it further.

Using Real World Data

contains activities which investigate and analyse data in a variety of ways from ready-made or easily generated data sets.

Mathematics in Motion

contains investigations into modelling motion based on different forms of data collection: manual, video and data logging.

Computer Graphics

brings together a number of different mathematical approaches which are used by computer programmers to create and manipulate images; techniques that have now found their way into "virtual reality". These activities make use of a variety of TI-Nspire features especially 'Graphs & Geometry'.

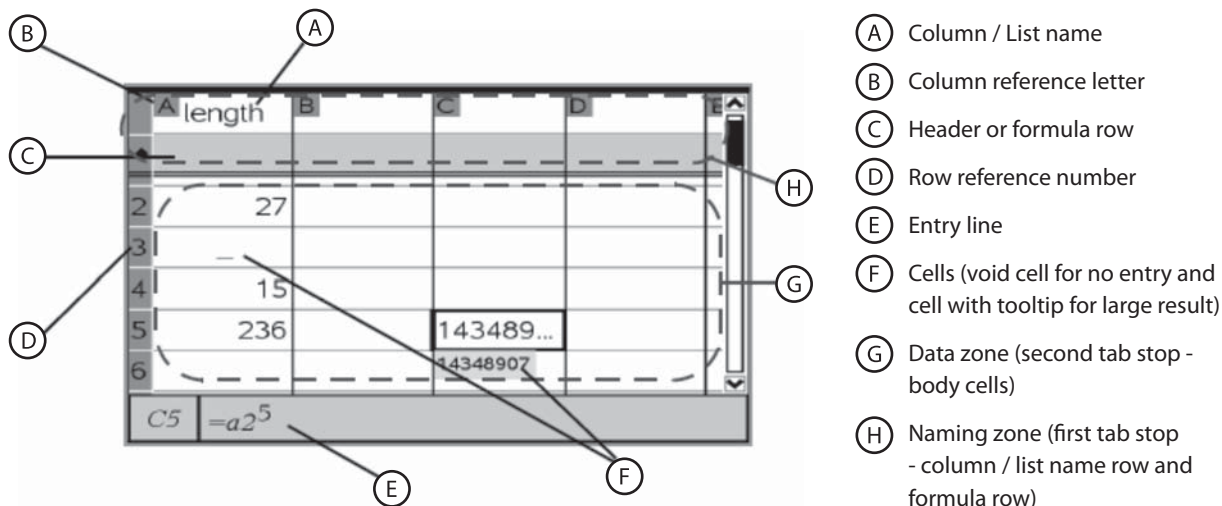
Introducing some features of TI-Nspire

TI-Nspire has the facility to insert different types of pages and to link the features of these. The activities in the STEM booklets use all of the applications: Calculator, Graphs, Geometry, Lists & Spreadsheet, Data & Statistics and Notes. Lists & Spreadsheet and Data & Statistics are particularly useful for STEM activities especially those which use real data.

Lists & Spreadsheet

A Lists & Spreadsheet page can be opened in a new document by selecting it as the application or in an existing document by going to the home page on the handheld and selecting the 3rd icon or using the 'Insert' menu on the software. A very useful feature is that data can be copied and pasted into a TI-Nspire spreadsheet page from other spreadsheets and from tables providing that the structure on TI-Nspire is the same as the original i.e. the same number of rows and the same number of columns. **Note** that the headings will need to be inserted manually and that speech marks may need to be used around categorical data if copying from some tables.

A column letter appears at the top of each column, and a row number appears in the left cell of each row. The top two rows and the left column of the spreadsheet remain in place as you scroll so you can more easily determine your location



fig_01

- (A) Name cells
- (B) Header or formula cells
- (C) For categorical data enclose it with speechmarks when typing it in

Two possible ways of entering formulae, Both start with =

- (D) Use a column reference in this case B the column which contains 'carbon'. Use square brackets [] to indicate column
- (E) Use the name of a column containing a list of data as the variable in this case 'carbon'

More about Spreadsheet Structure

The diagram below shows some of the features of a spreadsheet and two possible ways of generating data in a column. This example from the Hydrocarbons activity shows a possible attempt (which is incorrect) to find a formula to work out the number of hydrogen atoms in the chemical formula for alkanes (one particular type of hydrocarbon) if you know the number of carbon atoms in the chemical formula.

	(A) A	(B) B	(C) C	(D) D	(E) E	(F) F
		carbon	hydrogen	bonds	$=b[]*3+1$	$=3*carbon+1$
1	Methane	1	4	4	4	4
2	Ethane	2	6	7	7	7
3	Propane	3	8		10	10
4	Butane	4	--		13	13
5	Pentane	5			16	16
6	Hexane	6			19	19
A7	"Methane"					

fig_02

Lists & Spreadsheet menus

1: Actions	1: Move Column 2: Resize 3: Select 4: Go To 5: Recalculate 6: Sort	The 'Sort' feature is useful see below.
2: Insert	1: Insert cell 2: Insert row 3: Insert column	
3: Data	1: Generate sequence 2: Data Capture 3: Fill down 4: Clear data 5: Frequency plot 6: Quick graph	Examples of 'Frequency plot' and 'Quick graph' are given below.
4: Statistics	1: Stat calculations 2: Distributions 3: Confidence intervals 4: Stat tests	See below and in the Data & Statistics section for further information
5: Function table		
6: Hints		

Sort

allows data to be organised in ascending or descending order based on a particular column.

- From the Actions menu choose 'select' and then 'select range.'
- Use the cursor keys to highlight all the required cells in the table (this is likely to be the whole table). It is important to include all the cells so that when data are moved all the items in one row move together and the integrity of the table is preserved.
- Then from the Actions menu choose 'Sort'. Choose the column that you wish to sort in order and select ascending or descending.

Quick plot fig_03

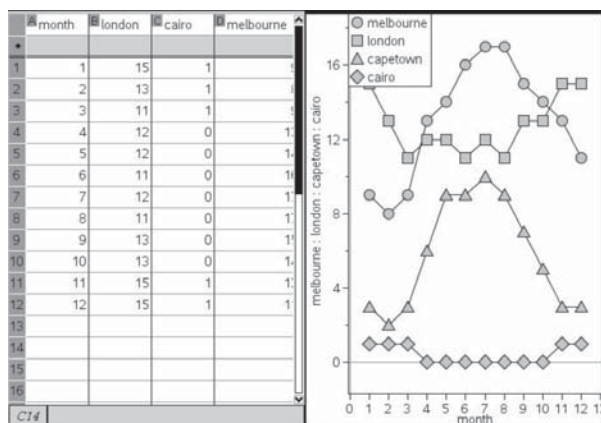
splits the page and shows a graph alongside the table. You might want to make a second copy of the table before doing 'quick plot'. The example shows the number of rainy days in different months of the year in four world cities. As the graph is very similar to the one that you get when you insert a 'Data & Statistics page' the details of how to do this are given in the next section.

Frequency plot fig_04

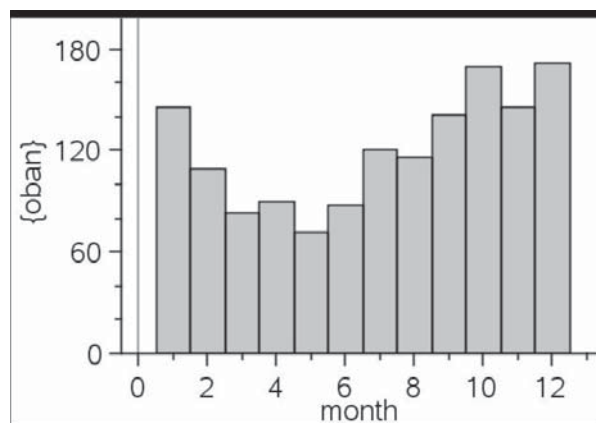
This graph was produced for one particular location (Oban in Scotland) from a table showing the number of mm of rain that fell in each month of the year in 20 world towns.

- A cell in the Oban column was selected followed by 'Frequency plot' and
- Data list was set to 'month'
- Frequency list was set to 'Oban' and
- 'Display on a new page' was selected.

If a new page is selected this is automatically a Data & Statistics page and other perhaps more suitable displays of the data could be used instead. More information in the next section.



fig_03



fig_04

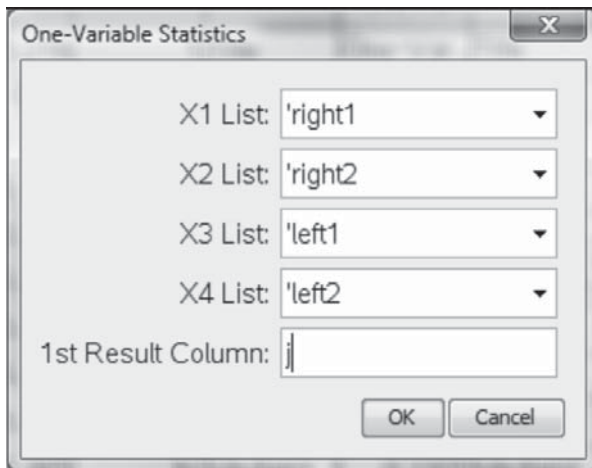
Data analysis fig_05 and fig_06

from the original spreadsheet other information can be found by

- Selecting menu 4 'Stat calculations' and 'one variable statistics'.
- Select the number of lists you want to do this for. Four lists were used in this example.
- Then select the titles for each list
- Finally select the first column to put the results in – in this case column I was used.

The example shown is for comparing reaction times. 20 trials for 2 people each with their left and right hand.

The table fig_06 shows a considerable amount of data but it is a useful functional skill for students to be able to select just the data they need such as the mean scores (\bar{x}) or the median scores as well as other figures such as the minimum and maximum values and the lower and upper quartiles (Q1 and Q2), and to ignore and not be put off by other items that look confusing.



fig_05

This gives

I	J	K	L
Right 1	Right 2	Left 1	Left 2

H	I	J	K	L
	=OneVar('	=OneVar('	=OneVar('	=OneVar('
Title	One-Var...	One-Var...	One-Var...	One-Var...
\bar{x}	0.33645	0.2897	0.3647	0.282
Σx	6.729	5.794	7.294	5.64
Σx^2	2.36172	1.74447	2.70514	1.6496
$s_x := s_{n-...}$	0.071726	0.058917	0.048675	0.055781
$\sigma_x := \sigma_{nX...}$	0.06991	0.057425	0.047443	0.054368
n	20.	20.	20.	20.
MinX	0.266	0.121	0.268	0.218
Q_1X	0.2805	0.2715	0.329	0.222
MedianX...	0.3305	0.279	0.3455	0.281
Q_3X	0.39	0.3285	0.39	0.3265
MaxX	0.547	0.39	0.457	0.39
$SSX := \Sigma...$	0.097747	0.065952	0.045016	0.059118

fig_06

Data & Statistics

It is possible to plot 'quick graphs' or 'frequency plots' and to perform statistical calculations directly from a Lists & Spreadsheet page, but inserting a Data & Statistics page enables a wider range of analysis and display of the data contained in the Spreadsheet page.

Opening a Data & Statistics page

Before opening a Data & Statistics page you will need to have set up a Lists & Spreadsheet page. You can insert a page by selecting option 5 on the home page of the handheld or by using 'Insert' on the software. Using 'Frequency plot' on a Lists & Spreadsheet page and selecting the 'new page' option will also do this.

Data & Statistics menus

1: Plot type	1: Dot plot 2: Box plot 3: Histogram 4: Normal probability plot 5: Scatterplot	6: XY line plot 7: Dot chart 8: Bar chart 9: Pie chart
2: Plot properties	1: Show/hide connecting lines 2: Histogram properties 3: Extend box plot whiskers 4: Add X variable 5: Add X variable with frequency 6: Remove X variable 7: Add Y variable	8: Add Y variable with frequency 9: Remove Y variable A: Force Categorical X B: Force Categorical Y C: Clear
3: Actions	1: Remove 2: Show/ hide text 3: Insert text 4: Insert slider 5: Select all points	
4: Analyse	1: Remove 2: Add movable line 3: Lock intercept 4: Plot function 5: Shade under function	6: Regression 7: Residuals 8: Plot value 9: Show normal PDF A: Graph trace
5: Window/ zoom	1: Window settings 2: Zoom-data 3: Zoom-In 4: Zoom-Out	
6: Hints		

Default page

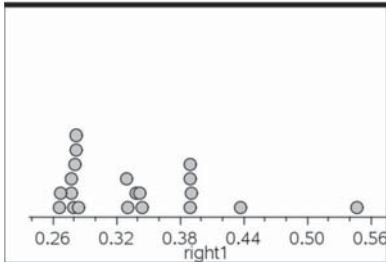
As long as a region of the spreadsheet is selected data in the form of dots will be seen on opening the Data & Statistics page. The variables can be changed in a variety of ways.

- Hovering near the centre of the lower edge or of the left-hand side edge will produce a message 'click to enter or change variable'. The variables for the x and y axes can be inserted from the menu which is displayed.
- This can also be done by going to menu 2 and selecting Add X variable or Add Y variable and then selecting from the list of variables displayed.

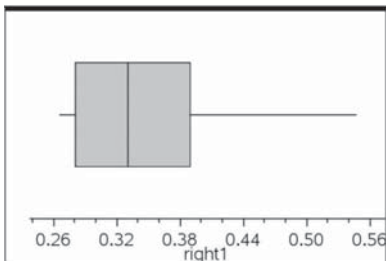
In the examples below two people numbered 1 and 2 have tried a 'Reaction time test (20 trials each) with both their left and their right hands.

	A right1	B right2	C left1	D left2	E trialnum
1	0.28	0.279	0.327	0.218	1
2	0.344	0.341	0.457	0.39	2
3	0.39	0.329	0.389	0.219	3
4	0.437	0.279	0.453	0.281	4
5	0.331	0.283	0.268	0.222	5
6	0.278	0.28	0.380	0.234	6
AI	0.28				

fig_07



fig_08



fig_09

- (A) Lowest value (bottom end of whisker)
- (B) Lower quartile (one quarter of the values are below this)
- (C) Median (half the values are below this)
- (D) Upper quartile (three quarters of the values are below this)
- (E) Highest value (top end of whisker)
- (F) Outlier (what happened here?)

One variable

Dot plot and box plot fig_08 and fig_09

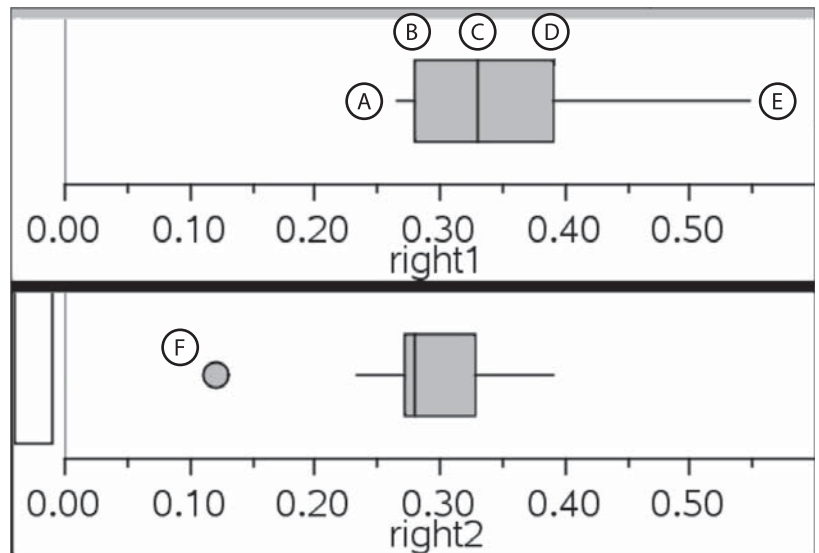
- Selecting a single variable (in this case the right hand for person 1) will produce a Dot plot. fig_08
- It is then possible to select **2: Box plot** from menu 1.
- Hovering the mouse over the **box plot** will reveal the **median, quartiles** and the **minimum and maximum values**. This is a quick way to obtain this data. There is further information on this later in this section.

Box plots for two or more sets of data can be compared side by side by using a split page and making sure that the window settings are the same for both plots.

Important Note: The ease with which TI-Nspire can produce a box plot and reveal the various statistical measures combined with the visual nature of the box plot can make using and interpreting these displays accessible to students who might struggle with more formal calculations. A diagram like the one in fig_10 might be useful.

To produce comparative box plots like the one in fig_10

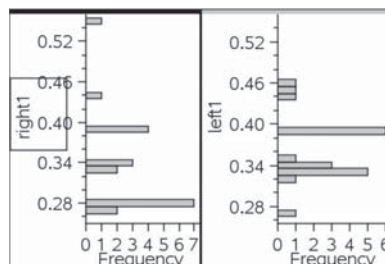
- Insert a Data & Statistics page and set the x - axis to one set of data (in this case right 1.) From menu 2 select **Box plot**.
- Change the page layout to show a split page (tools and 5 on the handheld). Insert a Data & Statistics page and repeat to show the Box plot for the other data (right2).
- Set the window (menu 5 'window settings') to the same scale for both diagrams so they can be compared. In this case x goes from 0 to 0.6.



fig_10

Histogram

This screen shot shows a split page with two ‘histograms’ which is produced in a similar way to the box plots described above. The appropriate use of histograms is quite a difficult concept but examples like this could be useful for discussion about interpreting the display, whether this is a good form of representation and whether there are better ways to display the data for comparison. **fig_11**



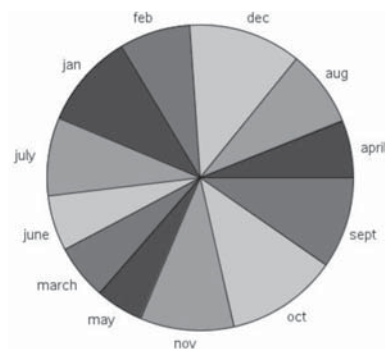
fig_11

Pie Chart and Frequency plot

In the example of a frequency plot of weather data in the previous section the months are numbered in order. If they were displayed as categorical data then the frequency plot would have separated bars. It would also be possible then to choose the pie chart option on the Data & Statistics page.

This pie chart would then show the proportions of the annual rainfall in Oban (Scotland) that fell in different months of the year.

Note that TI-Nspire has arranged the months in alphabetical order. **fig_12**



fig_12

Two variables

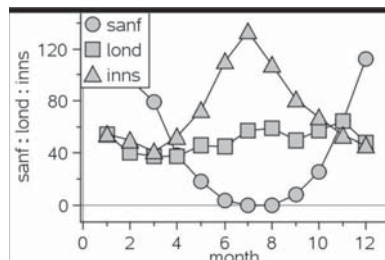
Scatter Plot and X-Y line plot

If variables are selected for both the x and the y axes in the default page for Data & Statistics, then a ‘Scatter Plot’ is produced.

- The data points can be connected by either selecting 5: ‘X-Y line plot’ from menu 1 or ‘1: Show/hide connecting lines’ from menu 2, if this is appropriate. Additional features that can then be added are:-

Adding additional Y variables (menu 2) **fig_13**

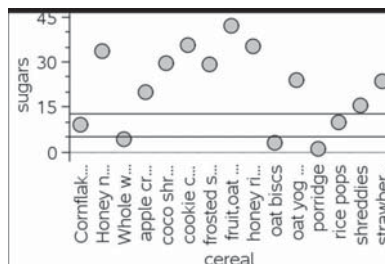
This can be used for comparison as in this example comparing the number of mm of rain which fell during different months of the year in London, San Francisco (USA) and Innsbruck (Austria)



fig_13

Adding a movable line **fig_14**

In this example movable horizontal lines were inserted in appropriate places to see whether the sugar content of certain breakfast cereals came into the low, medium or high categories for traffic light food labelling. This could provide an introduction to inequalities. If the breakfast cereals were numbered then this could also have been done using ‘Plot function’

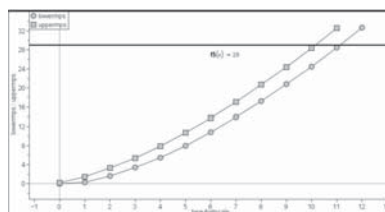


fig_14

In the second example **fig_15** from the extension activity in ‘Hurricane Force’ the graph lines show the minimum and maximum wind speeds for each point on the Beaufort scale for wind force. The movable line makes it possible to read off the Force number for any wind speed. Movable lines can also be used for regression and function fitting.

Plot function’ **fig_16 / 17**

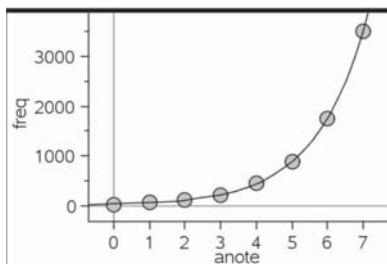
Students could experiment with plotting functions to fit the data in their Scatter plot. In this example from the ‘Perfect pitch’ activity they are looking for patterns and trying to fit a function to the relationship between the position (numbered from 0) of the A notes on a keyboard to the frequency of the note in Hertz. (Solution in the teachers notes for the activity)



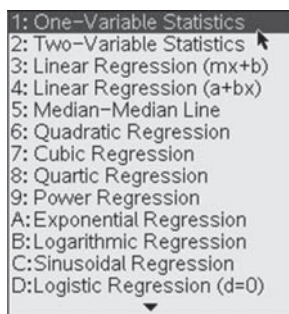
fig_15

	A:anote	B:afreq	C:awaveler
1	0	27.5	1
2	1	55	6
3	2	110	3
4	3	220	7
5	4	440	7
6	5	880	7

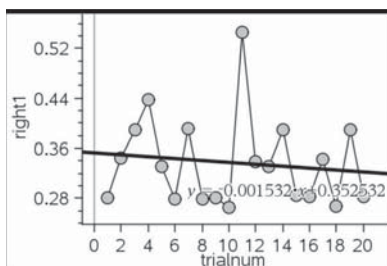
fig_16



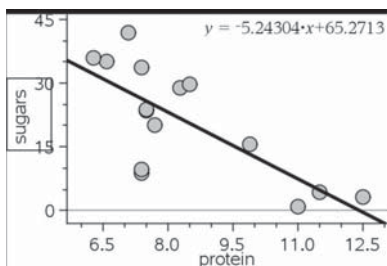
fig_17



fig_18



fig_19



fig_20

Regression fig_18

Regression curves can be fitted to a 'Quick graph' obtained from a Lists & Spreadsheet page as well as to Scatter plots on a Data & Statistics page.

The menu shown is from Lists & Spreadsheet fig_18

- go to menu 4 and select 'Stat Calculations'
- then select 'regression' and the type of regression that you want

For Data & Statistics

- go to menu 4 and select 'regression'

Linear regression and Exponential regression are particularly useful.

Exponential regression is much easier to interpret than might be expected and is frequently useful.

Linear regression

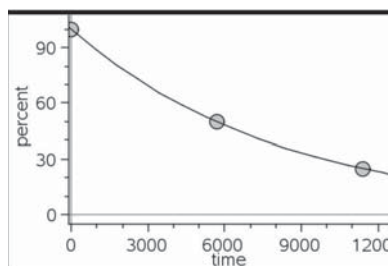
In the first example fig_19 which is from the Reaction times activity selecting 'linear regression' adds a straight line to best fit the points. This line could indicate a possible trend (that the person is improving with practice) but this needs careful interpretation.

In the second example fig_20 looking at the nutritional content of breakfast cereals a Scatter plot has been used to test out the question "Do cereals with more sugar contain less protein?" A linear regression line and further statistical analysis could be used.

Exponential regression and 'Graph trace'

This option can be very useful and **it is important to note** that exponential regression functions are given in the form $f(x) = k \cdot a^x$. This means that they do not contain e and so are easier for less advanced students to understand and can make quite complex ideas more accessible. In addition the ease of obtaining such functions to closely fit the data could encourage students to investigate them in further detail.

In this example fig_21 which uses simple data for carbon dating using the half life of C14 molecules (approx 5700 years), a very good fit can be obtained just by entering 100% for year 0, 50% for year 5700 and 25% for year 11400. Students could then use graph trace on menu 4 to find the ages of specimens from the percentage of C14 left.



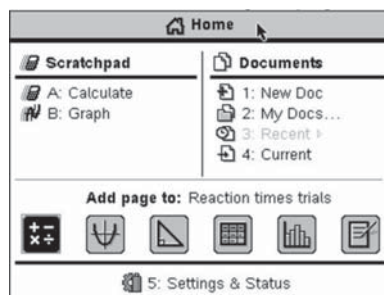
fig_21

Additional help getting started with data entry

Data can be entered manually into a Lists & Spreadsheet page of TI-Nspire as follows:-

- From the home screen select 1: 'New Document' then select the 4th icon: Add Lists & Spreadsheet' **fig_22**.
- Enter the data into columns, pressing 'enter' after each item to move down the columns. Use the arrow keys to move to the top of the next column. Use speech marks for categorical data. TI-Nspire will close speech marks for you but you need to insert them before the data.
- To label the columns scroll up to the box at the top of the column (white) and use the alphabet keys to type in the name, then press enter. (TI-Nspire will only accept a single word with no spaces)
- If you need to resize columns you can do this by choosing Menu then **1: Actions** then **2: Resize**

For some data displays with categorical data it may be useful to add an extra column which numbers the categorical data.



fig_22

Real Time Data Logging

TI-Nspire can be used to collect single data streams through the micro-USB port just above the screen. Some sensors produce an output in digital format and so can be connected directly to a TI-Nspire handheld (e.g. EasyTemp temperature probe and the CBR 2 motion sensor). Others need to be connected to the EasyLink adaptor which converts analogue to digital: over 40 sensors can be connected in this way.

If the TI-Nspire handheld is on and you have clicked on New Document, you will see a menu on asking which application to open. If you plug in a sensor, another menu will open and an auto-launch menu will appear providing four options. Generally the default first choice is a good one; Data & Statistics. Occasionally the sensor may need to be pulled out and re-inserted to trigger the launch menu. If the console has been switched off, pressing ctrl D will restore it.

Selecting Data & Statistics will open up two windows; a control console at the bottom for the sensor and a Data & Statistics page. Pressing ctrl and tab will toggle between the two windows. When in the control console, pressing tab will toggle across start, reading and stop. Pressing menu will open a window which allows the default parameters to be changed in experiment, set up experiment, time graph. Time between samples and experiment length can be changed but the maximum rate at which the EasyLink adaptor will convert analogue to digital is 200 samples per second, so it is not possible to collect data over very short time intervals. It is also not yet possible to trigger data logging which means that some experiments are not possible, or at best very difficult. However the opportunities for collecting real data are huge and the following set of examples will provide you with ideas for using these and other probes in different contexts.

With the start button highlighted, pressing enter will start logging data. Stop can be pressed any time and a warning menu will appear asking you to close data collection. Data are automatically named and prefixed with dc<number>.<name> (e.g. dc01.temp). To collect another set, simply press enter again and you will be asked if you want to store or discard. If you store you will be told how the data are being named. At this stage take care as selecting ok or discard automatically begins logging data.

The TI-Nspire Handheld Guide part 2 has a very good section on logging data at the end, pages 363-378. Refer to this if necessary but the essential operations are listed above. All the probes work in the same way and it is now just a question of knowing how to use the different representations within TI-Nspire to get the best out of data analysis.

http://education.ti.com/downloads/guidebooks/ti-nspire/TI-Nspire_Guide_Part2_EN_UK.pdf

Using the probes

Probably the easiest probe for beginners to use is the temperature probe. Use the Vernier EasyTemp probe or a standard probe connected to the Vernier EasyLink adaptor and have a go at the salt ice mixture or simply use hot or cold water. The examples use the commonly available voltage, temperature and light probes and the CBR 2 motion sensor.

Each example has an evaluated tns file for the teacher to see where the example is going and the likely results to be obtained. A word document containing notes to accompany the evaluated tns files is also included. These documents are available online at www.nspiringlearning.org.uk and can be used as the teacher wishes. However, trialling suggests that having the note pages to look at while using the handheld is helpful.

STEM activities with TI-Nspire

The coming decade will see an increasing need for a flexible work force possessing a wide range of skills in Science, Technology, Engineering and Mathematics (STEM) in order to meet the needs of the new high level industries and to be able to produce technologically complex products. The booklets in this series were developed with this need in mind. They aim to provide stimulating activities which link aspects of STEM and at the same time encourage the use of technology and an awareness of its potential.

Why use TI-Nspire for STEM subjects?

TI-Nspire provides a learning platform which dynamically links a variety of ICT applications including documents, graphs, geometry, statistics, spreadsheets, data logging and a calculator. This dynamic linking assists students in making connections not only between different areas of mathematics but also with other areas of the curriculum and STEM subjects in particular.

There is now a wealth of data available on the Internet in a variety of forms which can be copied directly into TI-Nspire. Data can also be captured by linking to a variety of data logging devices such as motion sensors or by recording manually or using video analysis. It is then possible to manipulate, display and analyse this data in a variety of ways or to try to model the data using a variety of data handling and function plotting tools.

About the booklets

All the activities contain some background scientific or other information together with links to appropriate websites. Many of the activities are suitable for a range of ages and aptitudes with more challenging ideas being suggested as extension activities. Further information and TI-Nspire files for the activities can be found at www.nspiringlearning.org.uk.

There are five booklets in the series:

Introduction - contains a brief introduction and instructions for getting started using some of the features of TI-Nspire that are used frequently in the other booklets.

Capturing data: Modelling and Interpretation - contains activities which use a variety of data logging probes to collect real data and analyse it further.

Using real world data - contains activities which investigate and analyse data in a variety of ways from ready-made or easily generated data sets in a variety of contexts.

Mathematics in motion - contains investigations into modelling motion based on different forms of data collection: manual, video and data logging.

Computer graphics - brings together a number of different mathematical approaches which are used by computer programmers to create and manipulate images; techniques that have now found their way into "virtual reality". These activities make use of TI-Nspire applications especially Graphs and Geometry.

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