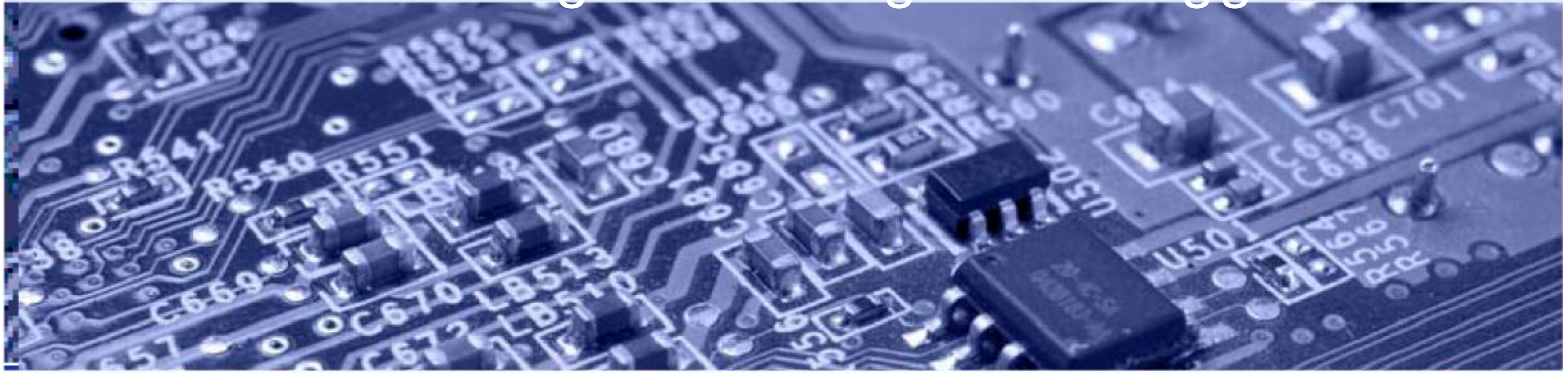
RRP
$15.95

The Teacher's SMART Guide
To Choosing and Using Data Loggers



Save time and money making your datalogging purchases

Make light work of covering the syllabus

Alleviate your anxiety about teaching practical lessons

Receive praise from parents, students and colleagues on your teaching ability

Transform your students from apathetic to enthusiastic

BY PHIL JONES
The Logical Interace

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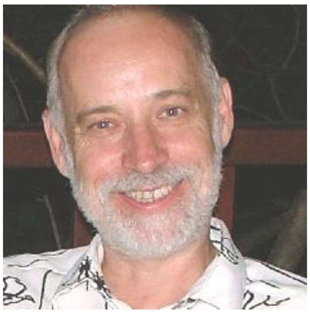
About the Author



Phil Jones is passionate about science and science teaching.

At the age of twelve, he cleaned out his school banking account to buy the parts to make a telescope. His parents were furious, not only about the money, but also because they preferred him to follow more “practical” pursuits.

This did not deter him. Phil went on to build his working telescope (which he later donated to one of the schools he taught in) and pursued his interest in science.

He achieved a Bachelor of Science with Honours from Sydney University, and a Master of Science with Honours from Macquarie University.

For four years, Phil was a researcher in bio-physics at Sydney University but kept being drawn back to his main interest, teaching others to share his love of science.

He took a Diploma of Education at the end of his first science degree and worked in schools in Australia, UK and Europe. Later, he moved on to teaching adults and to teaching teachers how to transfer their knowledge and interest in science to their students.

This led Phil to opening The Logical Interface (TLI) in 1986, a business dedicated to supporting maths and science teachers in making their classes more relevant and engaging. It sells interactive technology for use with science and maths classes, with much of the software and devices being designed by the TLI design team, specifically for the classroom.

Phil is a sought-after speaker at Science Teachers Association meetings around Australia. He also runs technology workshops for teachers at universities, TAFE colleges and schools.

What is a data logger and how does it work?

Data loggers collect scientific data. For example, data loggers can record temperature, pH, dissolved oxygen levels, position, force, heart rate, EKG, EEG, light intensity, sound etc. They record changes in these values with time. Some data loggers can measure only one quantity, others can be used to record many different types of data.

What are the different types of data loggers?

Data loggers can stand alone or work in conjunction with a computer.

Stand alone data loggers store data in their own internal memory and require batteries for power. There are two kinds of stand alone data loggers:

- Those that have their own LCD to display data in a table, or graphical form. Some have touch screens. Examples include Fourier Multilog Pro, Nova 5000, and Pasco Spark
- Those that store data and then have to be attached to a computer to analyse it.

Other data loggers only work when they are connected directly to a computer through the USB or serial port. These data loggers use the computer's memory and screen to collect and display data. e.g. TLI Ezilog USB. The introduction of mini notebooks and ultra mobile PCs has made the USB logger very attractive.

Each type of logger has advantages and disadvantages which you will discover as you read on.

Dedicated logger – does not require a computer.

USB logger – requires a computer.

Mini computers make USB logging portable.

What are sensors and what types of sensors are there?

Data loggers need sensors to collect data.

Sensors connect to data loggers through a cable. Some sensors, for example pH and DO2, use electrodes for measurement.

Each sensor measures a particular quantity. There are specific sensors for temperature, pH, heart rate, sound, etc. In more versatile data loggers you can use two or more sensors at a time. Most educational data loggers have this ability. This means you have flexibility in the experiments you can conduct with them. You will see some experiments at the end of this guide which ask you to use two or more sensors.

How do you record from a data logger?

In the laboratory the most effective way to use a data logger is to connect it directly to a computer and control it with software that comes with the logger.

In the field, it is more convenient to use a stand alone data logger to record data. The amount of data you can collect is only limited by the memory of the data logger. For more flexibility, you can take along a notebook computer, Ultra Mobile PC, or a PDA. When the data has been recorded, it can be uploaded to the computer for further analysis while you are still in the field.

This is fantastic for day-long field trips.

What are sample rates and sample numbers?

A data logger records its data against time. It must sample this data at regular intervals. It can, for example, record data once per second (s^{-1}), once per minute, once per hour, or even 50,000 times s^{-1}.

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On the specifications of the logger, the “maximum sample rate” quoted is always the number of samples recorded per second.

The number of samples recorded and the sample rate determine the duration of the experiment. You could, for example, conduct an experiment at 10 samples s^{-1} and record 1000 samples. Your experiment would then take 10,000 seconds.

How do I select the right data logger?

To select a suitable data logger, ask yourself the following questions:

1. What do I want to measure?
   The quantity you wish to measure will determine the sensor(s) you will need to use with your data logger.

2. How many sensors do I need for an experiment?
   Data loggers can have a number of inputs to allow more than one sensor to be used. You should have at least two inputs for your data logger so two sensors can be used together. See experiment examples at the end of the book.

3. What sample rate will I need?
   Many biology experiments only need to sample once every second, or even once every 10 minutes. Many physics experiments require sampling rates of 20,000 samples s^{-1}. If you require a data logger to work across all subject areas, you will need to buy a logger with a sampling rate of at least 20,000 samples s^{-1}.

4. How long does it take to collect data?
   The sample rate and sample number you select determine the duration of the experiment. The number of samples a data logger can collect depends on its memory. Data loggers that connect directly to a computer such as the Ezilog USB can collect large amounts of data at high sampling rates making them ideal for physics experiments.

5. Will I have access to a computer while I conduct an experiment?
   Direct connect data loggers that only work with a computer are generally cheaper and more robust. If you plan to use your data logger only with a computer then this type of data logger is most likely the best choice.

6. How sturdy do our data loggers need to be?
   Most educational data loggers are not waterproof and will break if mistreated. Stand alone data loggers are less sturdy than those that connect to a computer. The most likely points of failure are LCDs, battery packs and keypads.

   Industrial loggers like Australian-made TPS loggers are better for heavy duty field experiments. These are a good alternative to the educational loggers.

7. Which Data Logger is best for Field Work.
   The decision on which data logger to buy is often based upon their suitability for field work. Biology teachers look for portability and robustness so that they can take the logger into the field.

   Data loggers are designed to record data against time and are often used by researchers and industry for many applications including remote monitoring of environmental conditions, however electronic meters are ideal when you only wish to take individual readings and in most cases provide the perfect solution for field work. Electronic meters are accurate, very portable, easy to maintain and calibrate and consequently provide a more suitable alternative to data loggers for conducting measurements in the field.

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See the SMART buyer's guide at the end of this book to help you compare the data loggers you are looking at and make your decision.

Some purchasing traps

Trap 1: Sensors will be your biggest expense and some brands of data loggers will only allow you to use their own brand of sensors.

However, you will find other brands that allow you to use a number of brands of sensors. These brands provide greater flexibility in that you are not locked into one brand of sensor and can mix and match your data loggers and sensors if you want to.

For cost-effectiveness and long-term flexibility, avoid data loggers that will only receive data from their own brand of sensors.

Trap 2: Data loggers are often described as being 8 bit (binary digit), 10 bit, 12 bit and so on. This tells you the resolution of the data logger. For example, an 8 bit data logger can resolve the measured quantity to 2^8 = 256 parts, a 10 bit to 2^{10} = 1024 parts and so on. The greater the number of bits the greater the resolution of the data logger. Some sensors (for example the TLI Mass-Sensor balance) require at least a 12 bit resolution to satisfy their accuracy. That is the balance is 0-300 g with a 0.1 g resolution – it can resolve mass to 3000 parts.

For greater flexibility you need to look for data loggers with at least a 12 bit resolution.

The experiments at the end of this document refer to a number of suitable data loggers. This will be of assistance in selecting a data logger to suit your needs.

How much should I pay?

Price doesn’t always indicate a better solution. Frequently you will find that the most expensive data loggers are complicated and have features you may not use in a classroom. (This is much the same as the differences between an expensive professional digital camera and the simple point-and-shoot variety most people who are not professionals prefer.)

If you have not used data loggers before, you will find simple data loggers that do not have memory, or LCD, are less expensive, more robust, and provide an ideal solution if you have ready access to computers.

The biggest expense will be the sensors, so always check the sensor prices as well as the logger prices.

Using data loggers to improve class participation.

A generation ago, 70 per cent of students were what researchers Dunn and Price called “structured auditory learners”, meaning they learnt by listening to the teacher. Nowadays less than 30 per cent learn this way.

Students today have been shaped by technology almost from birth. They were playing computer games before they went to school. They carry mobile phones (with cameras) and MP3 players wherever they go. They spend hours chatting on the internet and playing virtual reality games.

They are multi-modal communicators, living in a highly visual hyperlinked world where they are 20 seconds away from any information they seek. They absorb information from multiple sources, and for them facts come and go. In their world, virtual reality has replaced scientific method, and text has replaced language as it used to be.

What this means - and you know better than most – is students today are cynical and easily bored.

So how do you ensure they don’t “dip out” before they even “dip in” to your class?

The good news about this generation is they are experiential and participative, and endlessly curious about “stuff”. They love doing things and working together, and have a sixth sense about using technology.

So you won’t need to worry about teaching them how to use data loggers or encouraging them to accept the technology. If you are comfortable about relinquishing some control, they’ll probably be able to teach you what to do with them! And if you set them a problem and give them the tools, they will find the answers in ways you might never have thought about.

“So tell me if the temperature around the room is constant and where’s the best place to sit?” will have them out of their seats and shaking their booties. They’ll be so involved they won’t even hear the end-of-class bell.

Don’t be surprised if you hear them tell their friends the class was “a bomb”.

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Unconvinced? Not comfortable with the technology?

Some TAFE Colleges run workshops for teachers or you can email Phil at philjones@logint.com.au to enquire about running a workshop at your school.

Data logging activities to get you started.

The following activities are designed to help you kick start your data logging. They are deliberately abbreviated with just the essential points to illustrate how a data logger can be used to acquire data for a range of activities. Detailed experiments for chemistry, biology and physics are available from The Logical Interface. See www.logint.com.au.

Exercise 1:

Using one or two sensors to examine DC and AC voltage from a school power pack (transformer), hand crank generator and two coil transformer.

Note: The data logger used for this exercise must have at least a sample rate of 20,000 s^{-1} It can be either stand alone, or a computer based logger, however the experiment is best done with the logger connected to a computer. It must have at least two in-puts:
e.g.TLI Ezilog USB, Nova or Fourier Multilog Pro

Part 1: Output from a power supply

1. Connect a suitable voltage sensor to the AC voltage of a school 0-12 V power supply.
2. Set your data logger to 25 samples s^{-1} and describe the appearance of the data on your graph.
3. Set the sampling rate to 20,000 samples s^{-1} and repeat the experiment. Using an appropriate method measure the period of the data obtained.
4. Repeat this experiment for the DC output.

Part 2: Output from a generator

1. Connect a suitable voltage sensor to a hand-crank generator.
2. Set the sampling rate to 20,000 samples s^{-1}.
3. Start sampling and crank your generator at varying speeds.
4. Examine the effect of speed on amplitude and frequency of the AC generated.

Part 3: Output from a transformer – two sensors are required for this activity

1. Connect a suitable voltage sensor (+/- 10 V) to the primary coil of a two coil transformer connected to a power supply.
2. Connect a second voltage sensor to the secondary coil of the transformer connected to a power pack.
3. Set the sampling rate to 20,000 samples s^{-1}.
4. Start sampling and note period, phase and amplitude of the primary and secondary voltage.

Exercise 2:

Using a single sensor to measure heart rate.

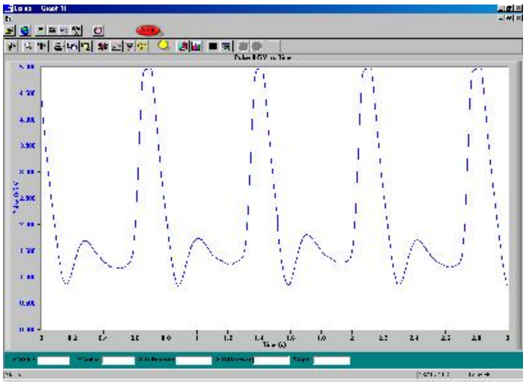
Note: The data logger used for this exercise must have at least a sample rate of 50 s^{-1} It can be either stand alone, or a computer based logger, however the experiment is best done with the logger connected to a computer.Suitable loggers include: Ezilog USB, Nova or Fourier Multilog Pro.

Connect a heart rate sensor to your data logger. If the sensor supplied uses a piezoelectric crystal to monitor your heart rate, place this tightly on your thumb as shown. If it is of the clip type, clip it to your ear lobe, or finger.

Set your data logger to 25, or 50 samples s^{-1} and observe the appearance of the data on your graph. Determine your heart rate by:

1. measuring the period between pulses and
2. counting the number of pulses within a given time.

If your data logger has a high sampling rate set the sampling rate to 20,000 samples s^{-1} and repeat the experiment. Observe and describe the features of the graph.



Output from a piezoelectric heart rate sensor at 20,000 samples s^{-1}

Exercise 3:

Using a single sensor to examine pH changes in Coca-Cola™ caused by an antacid.

Note: The data logger used for this exercise must have at least a sample rate of 50 s^{-1} It can be either stand alone, or a computer based logger. However, the experiment is best done with the logger connected to a computer. Suitable loggers include: Ezilog USB, Fourier Nova or Multilog Pro

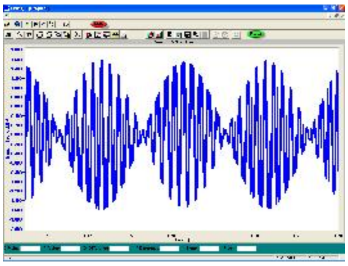
1. Place a small amount of Coca-Cola™ in a beaker (250 ml).
2. Connect a pH electrode to a data logger and connect the data logger to a computer.
3. Place the pH electrode into the Coca-Cola™.
4. Collect data at a sampling rate of around 10 samples s^{-1} for around 90 s.
5. Start your data logger collecting data.
6. Place an Alka-Seltzer™ tablet into the Coca-Cola™.
7. Observe the changes on the computer screen.
8. Estimate the change in pH and the time taken to reach the new pH level.
9. From the values obtained in 8 estimate the rate of change in pH.

Repeat this example with another brand of antacid. Experiment with crushed tablets and uncrushed to see if this makes a difference.

Exercise 4:

Using a single sensor to examine sound waves from a speaker.

Note: The data logger used for this exercise must have at least a sample rate of 20,000 s^{-1} It can be either stand alone, or a computer based logger. However, the experiment is best done with the logger connected to a computer.Suitable loggers include: Ezilog USB, Fourier Nova or Fourier Multilog Pro.



1. Use a dual channel signal generator to generate beats.
2. Set one channel to approximately 450 Hz and the second to 440 Hz.
3. Place a microphone near the speakers to record the sound.
4. Set your sampling rate and number of samples to appropriate settings (20,000 sample s^{-1} and 100,000 samples).
5. Record the data and determine the beat frequency from your graph.

Exercise 5:

Using two temperature sensors to record heat loss.

Note: The data logger used for this exercise must have at least a sample rate of 10 s^{-1} It can be either stand alone, or a computer based logger. However, the experiment is best done with the logger connected to a computer. Suitable loggers include: Ezilog USB, Fourier Nova or Fourier Multilog Pro.

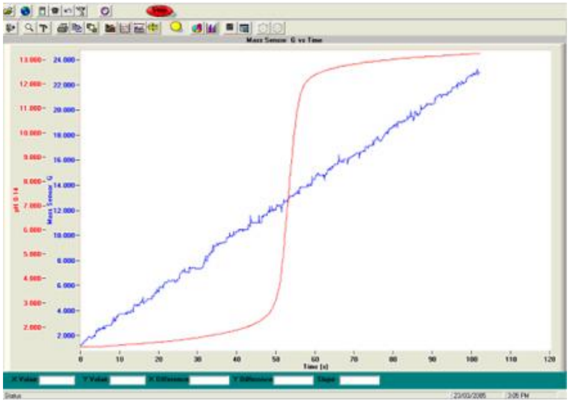
1. Place warmed water (150 ml) into a glass beaker and the same quantity into a polystyrene cup.
2. Place a temperature sensor into each container and connect the sensors to a data logger and connect the logger to a computer.
3. Start logging at around 1 to 10 samples s^{-1} for ten minutes.
4. Determine the rate of change of temperature for both the beaker and polystyrene cup.
5. Comment on the difference in rates. Was the difference as great as you thought? What is the main method of heat loss for the beaker and polystyrene cup?
6. Repeat steps 1 to 5 using a polystyrene cup with a lid in place of the beaker. The lid must be a typical coffee cup lid, with a hole through which we can place the temperature sensor.

Exercise 6: Titration.

Using two sensors to record volume (mass) and pH changes during a titration.

Note: The data logger used for this exercise must have at least a sample rate of 10 s^{-1} It can be either stand alone, or a computer based logger. However the experiment is best done with the logger connected to a computer. Suitable loggers include: Ezilog USB, Fourier Nova or Fourier Multilog Pro.

1. Connect a Mass Sensor Balance and a pH sensor to your data logger.
2. Set your data logger to an appropriate sampling rate (10 samples s^{-1}) and number of samples.
3. Using appropriate equipment, record both volume and pH changes during a titration (see below for comments on equipment setup).
4. Allow the solution to flow at a steady rate.
5. Start the logger.
6. Monitor the change in pH and volume.
7. Plot a graph of pH vs volume.



pH and mass for a titration using Ezilog USB

Note: This experiment should be performed with the beaker into which you are titrating placed on a magnetic stirrer, and the solution should be titrated from a container on the Mass-Sensor Balance. This allows the solution to mix and the pH to equilibrate more quickly. Failure to do this will mean that the true pH will fall behind the volume change.

Exercise 7: Ohm's Law.

Using two sensors to verify Ohm's Law.

In this activity a voltage and current sensor are used to collect single readings (snapshots). There are many experiments where you will want to plot one variable against another. This activity is an example. The ultimate aim is to verify Ohm's Law so we wish to plot current against voltage. Note that neither variable is to be plotted against time.

Note: The data logger used for this exercise must be capable of taking single readings, or snapshots. Suitable loggers include: Ezilog USB, Fourier Nova or Fourier Multilog Pro.

1. Connect a 5 Ohm resistor in a series circuit to a rheostat as a potential divider across a true DC source (for example, a battery).
2. Connect a voltage sensor in parallel with the resistor and a current sensor in series.
3. Connect the sensors to your data logger.
4. Adjust the rheostat to give 1 volt and take a single (snapshot) reading of the current and voltage.
5. Repeat for a number of voltage settings.
6. From the table of data collected create a plot of current vs voltage.

Exercise 8: Fermentation of sucrose.

Using one sensor to measure mass change during fermentation.

Note: The data logger used for this exercise must have at least a sample rate of 10 s^{-1} It can be either stand alone, or a computer based logger. Suitable loggers include: Ezilog USB, Fourier Nova or Fourier Multilog Pro.

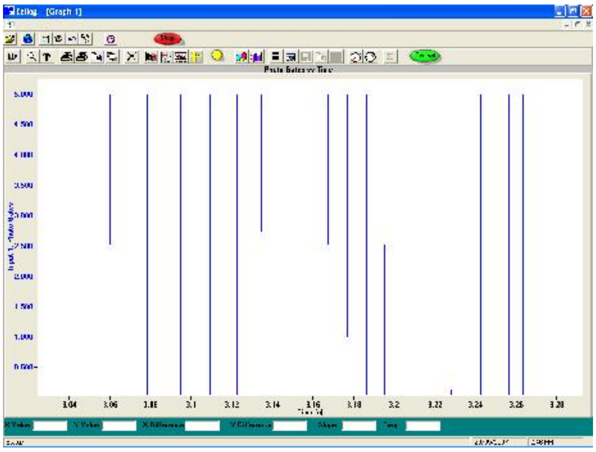
1. Set up a data logger, with a mass sensor attached, in a warm place such as a sunny window sill or near a heater (fermentation works best if the temperature is above 30°C).
2. Adjust the data logger so that it stores a mass reading every 10 minutes for at least 2 days.
3. Place 20.0 g of glucose powder into a clean, dry 500 mL flask.
4. Add 3.0 grams of dried yeast to the flask.
5. Add 150 mls of water to the flask and stir it to dissolve the glucose.
6. Place the flask on the mass sensor connected to the data logger.
7. Record the mass of the flask and its contents.
8. Start the logger.
9. Allow the flask to stand for the period over which the data collection is to occur.

Exercise 9: Position vs time graphs, and velocity vs time graphs. (A data logger based "ticker timer".)

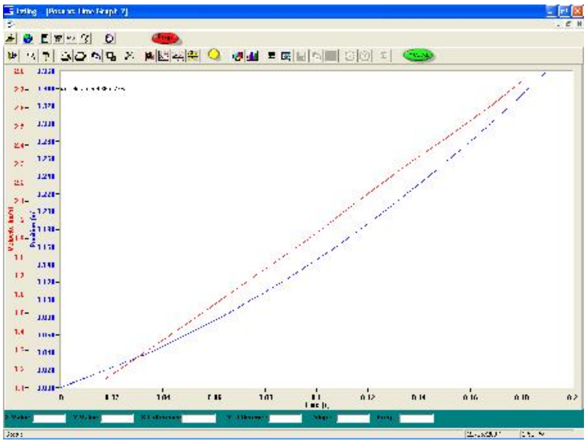
Using one sensor to produce position and velocity vs time graphs.

> Note: The data logger used for this exercise must have at least a sample rate of 20,000 s^{-1} It can be either stand alone, or a computer based logger. However, the experiment is best done with the logger connected to a computer. Suitable loggers include: Ezilog USB or Fourier Multilog Pro.

1. Connect a photo gate to your data logger.
2. Clip a calibration strip (picket fence) to an airtrack glider, or trolley.
3. Place the photo gate over the track so the picket fence will break the beam.
4. Start the logger – using a high sampling rate.
5. Place the glider/trolley onto the track and release.
6. Examine the pattern created by the picket fence on your graph. (You may have to zoom in.)
7. Measure and record the time interval from the first band to the next.
8. Repeat this process for successive bands.
9. Create a table of position vs time and graph this data.
10. Compare this with the graph created by your software.



a) Graph produced from dropping a picket fence through a photo gate using the Ezilog USB.



b) Position vs time and velocity vs time graphs generated from graph a using the Ezilog USB.

Exercise 10: Transpiration.

Using two sensors to measure transpiration rate during changes in light intensity.

Note: The data logger used for this exercise must have at least a sample rate of 10 s^{-1} It can be either stand alone, or a computer based logger. Suitable loggers include: Ezilog USB, Fourier Nova or Fourier Multilog Pro

1. Connect a mass sensor and a light sensor to your data logger to record both volume and light changes during a transpiration.
2. Place a suitable stem into a conical flask and place the conical flask on a Mass-Sensor balance. Support the stem with a retort stand.
3. Set your data logger to an appropriate sampling rate and number of samples (1 per sec).
4. Start the logger.
5. Allow the experiment to proceed over extended periods of dark and light.
6. Monitor your graph.
7. After a suitable time has elapsed stop recording.
8. Is there a relationship between light intensity and transpiration rate?

The SMART buyer's guide

Questions	Criteria	Data Loggers Matching Criteria
Can we connect to a computer when using the data logger?	e.g. Computer connected	
What do we want to measure? (What sensors do we need?)	e.g. pH	
What sample rate do we need?	e.g. 20,000 per second	
What resolution will we require to use our sensors?	e.g. 12 bit	
How many sensors will we use simultaneously? (How many inputs will the data logger need?)	e.g. two	
How sturdy does the data logger need to be?	e.g. Strongest educational quality	

Find out how to compare the data loggers that meet all your criteria on the next page.

The formula for a SMART decision

Check what brands meet all your criteria, list them, and answer the questions.

Brand and Model	Price	Is supply reliable? yes or no	Uses various brands of sensors? yes or no	Support service available from supplier? yes or no	Easy to use? yes or no

Just add up the number of “Yes” answers and compare the prices to decide.

The data logger best for us is ____________________________

Number of loggers required ________

(Note: One logger for every 2 students is recommended as a class set)

Sensors and quantity to be purchased ________________

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Budget Estimate

Data loggers $___________

Sensors $___________

Freight $___________

Total __ $___________