The role of Hand-held datalogging technology in Junior Certificate Science

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A thesis submitted for the degree of

Master of Science

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September 2003

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Master of Science is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work

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Abstract

This research investigated how the use of hand held datalogging in science affects the teaching and learning of Junior Certificate Science A total of 44 students took part in this research over a period of four years One third of these students used handheld datalogging technology to facilitate a constructivist teaching and learning approach to Science Education The remaining two thirds of students were taught in a traditional manner, without the use of this technology The students' performances in the Junior Certificate exam in June 2002 were examined and the results of each of the groups compared All three groups achieved comparable standards This showed that experience of datalogging in an investigative context, although not designed for the type of examination taken, does not harm students' ability to perform well on the Junior Certificate examination Six months later, in December 2002, the students were presented with the same June 2002 Junior Certificate exam to determine if there was a difference in their ability to retain the information learned during the three year Junior Certificate program On the same day the students were presented with a set of questions designed to test their ability to interpret graphs and apply scientific process skills Students who had used datalogging technology preformed significantly better in both tests This showed that students taught using an investigative approach with datalogging retained the science learned at Junior Certificate level better, were better at analysing and interpreting graphs and had increased scientific process skills Furthermore, a higher number of the students from the datalogging group went on to study science at senior cycle, showing that they remained highly motivated and interested in science To investigate teachers' attitudes to hand-held datalogging technology, a group of 26 teachers were trained on how to use datalogging equipment as part of an investigative approach to Science They were asked to use the equipment for a year and to then complete a questionnaire to reflect their experiences, good or bad, with this method of teaching Also, 5 different teachers, each with extensive experience of using handheld datalogging, were interviewed in detail All were positive in their attitudes to this method of teaching science It is clear from this research that the use of datalogging in conjunction with an investigative approach to teaching can do much to enhance students' experience of Science at Junior Certificate level

Chapter 1 Historical perspectives of the use of technology in the classroom.

1 1 Introduction

Powerful instructional technologies including datalogging have found their way into science and mathematics education Our challenge is to exploit these technologies to enhance students experience of science

Over the past 20 years, many people and companies have been involved in the development of probes, sensors, interfaces, supporting software, and related curricula for classroom science and mathematics activities There has been a particular surge of development recently mainly associated with the development of portable datalogging devices with easy to use software Eventually, these new developments will drive down the costs, increase the usability, and greatly improve the educational impact of datalogging

Although this type of technology has been around for a long time, and its educational value is well documented, it is not widely used by teachers The main barriers to its broad adoption have been identified as cost, accessibility and perceived difficulties of use

It is only in recent years in Ireland that schools have had widespread availability of computers in science laboratories Indeed, although capital grants were available to equip each chemistry and physics laboratory in the country with a computer, many schools waited before making the investment and, in some schools, the money for computers was redirected into other science equipment Also, it was felt that as far as datalogging was concerned, one computer was insufficient for a classroom full of students If practical science was left to the teacher, the added value of using datalogging would be diminished

In this chapter the research on portable datalogging technologies is outlined This history is included as it gives an interesting perspective of teaching culture The story of the development and dissemination of datalogging provides insights on educational change and the role of research and development

1.2 Development of hardware and software

Much of the research in electronic graphing technology has been on microcomputer based systems and is common in both mathematical and science education literature Early microcomputers, such as the BBC, started to be used in science classes as far back as the early nineteen-eighties Electronic probes or sensors began to appear soon after the arrival of the microcomputer Whereas the first probes were themselves easy to use, the software driving the user interface was not, and often required modifications or calibration This has often been cited as the reason why technology has not had the impact we might have expected in science education (Mokros,1985) However, as software systems in computers improved, so did the ease of using them There is now a new generation of datalogging software which will allow both the classroom teacher and students to undertake any given task without fear of the technology involved

Many physics teachers in the mid 1970s started to investigate how primitive computers could be useful to them in their teaching of physics Many of these teachers recognised several things that computers could do for physics teachers and students Timing events with a computer was an obvious use, as was monitoring events over a long period (cooling curves, weather studies, etc) or events that change quickly, like signals from microphones One problem, however, was that laboratory measurements provide analog signals and computers interpret digital signals During the mid 1970s the first analog-to-digital converters were produced, which made computers the perfect laboratory instrument

By the mid 1980s, inexpensive microcomputer chips were available that were used to give 'intelligence' to printers, hard drives and other peripherals So instead of designing hardware for each of the different types of computer available, an interface was designed that could be used with the serial port present in all computers Pricilla Laws, Professor of Physics & Astronomy, Dickinson College Carlisle, U S A in collaboration with David Vernier of Vernier software and technology, developed an interface known as the Universal Lab Interface, or ULI This was the first of many microprocessor based universal lab interfaces

This development came at a time when portable computing technology first appeared on the market The ability to move a computer to the student rather than move the student to the computer became an option The term "portable computers" gave way to the term "hand-held" as the technology advanced to make the size of the interface smaller The Apple™ Newton was the first hand-held computer to appear on the market With the advent of the Apple™ Newton, classroom trials of datalogging using portable computers began (Tinker, 2000) It was thought that the use of hand-held computers would enhance this innovative way of learning science, but moreover, it would allow students to have individual access to the technology, thus making the experience inclusive and meaningful

The Newton turned out to be too far ahead of its time Early models were bulky, expensive and bug-ridden Apple™ marketed the Newton poorly Computers and interfaces used in the field need to be particularly reliable, robust, and require a minimum of connections, the Newton didn't meet these requirements, and was soon taken out of production Later models were vastly improved, but the Newton never became popular Palm™ stepped in and quickly dominated the handheld market with the wildly popular Palm™ Pilots, which were smaller, cheaper and easier to use

Improved software for the data capture systems incorporated 'self-identification' schemes for probes This made data capture much easier, as it reduced the options available to the user This was the first in a concerted move towards the idea of one piece of generic software capable of conducting any experiment devised by the user with any connected probe

The next generation of portable computers was the Apple™ e-Mate These had a simplified word processor, spreadsheet, and other utilities built-in that were more than adequate for educational uses It supported infrared "beaming" that allowed students to share data or other files by simply aiming two computers at each other and pressing a button

Apple™ stopped making the e-Mate However, the feasibility of using hand-helds in education, especially for datalogging applications was proved (Tinker & Papert, 1989)

It was also felt that hand-helds could well be the "equity computer" that could bridge the digital divide The e-Mate demonstrated that powerful education could be done with pared down computers

Datalogging should have established a place in the curriculum in the U K in the mid 1980s with the appearance at a low price of a VELA (Versatile Electronic Laboratory Aid) Clarke & Jones (VELA users group, University of Leeds) claim that although VELA had some impressive specifications, it was, like the Apple™ Newton, ahead of its time, and many teachers had problems with it As a result, it had a negative impact on technology in science education, gaining the reputation of being troublesome and unreliable (Scaife & Wellington, 1993)

Graphing calculators first appeared in the early 1990s These were revolutionary, because they allowed you to not only compute numbers but also display graphs of functions This new functionality allowed mathematics and science teachers to teach mathematical behaviour without getting bogged down in the rudiments of graphing

In 1994 Texas Instruments™ produced the first "Calculator Based Laboratory" (CBL) data collection system Using the CBL, students can gather a variety of real-world data and transfer it directly to a graphing calculator to generate graphs and analyze the results of their experiments virtually anytime and anywhere This data can be viewed on the calculator, or transferred to a P C

Graphing calculators are a flexible, low-cost resource for whole-class teaching Their low cost and portability means that each student, or each pair of students, in a classroom can have hands-on access to the technology A teacher's model connected to an overhead projector can give teachers instant access to a wide range of facilities for whole-class work and, since graphics calculators do not require connection to a computer, ICT can be available on demand in ordinary classrooms They can be moved around easily as they are battery operated

Graphing technology has changed dramatically since those first calculators in the 1990s Products now have operating systems that can be electronically upgraded via the Internet, calculator software applications (Apps) for adding specific functionality, and peripherals for data collection and real-world experimentation

1.3 Impact on education

Research on the use of datalogging and graphing technology mainly deals with pedagogy and methodology What has emerged is that technology helps to keep students from getting frustrated with handling data and graphs In a relatively short period of time students are able to gather data, produce graphs and use them in meaningful classroom discussion (Mokros, 1985)

The early application of electronically tracking temperature change during a change of phase became a powerful example of the educational potential of computers as lab instruments The first classroom studies on the use of datalogging using microcomputer based laboratories (MBL) were conducted in the early 1980s (Lam, 1984) These studies gave the first indication of the power of real-time interactions which lead to understandings of abstract representations Real-time data displays, made possible by MBL, established an active learning environment where Individual or small groups of students were able to take part in experiments This involvement in the experiment stimulated ownership of the data (Sokoloff and Thornton, 1997)

One of the initiatives, started in the latter part of the 1980s, was from the Educational Technology Centre (ETC) at Harvard directed by Judah Schwartz and David Perkins (Perkins et al 1995) This was by far the largest research effort at that time designed to look at how technology could improve mathematics and science learning ETC decided to concentrate on math and science concepts that were considered difficult to teach and to explore ways technology could improve student understanding of these concepts A project using datalogging was launched to address persistent student difficulties with understanding heat and temperature

A study group consisting of teachers, researchers, and scientists was formed to design and conduct a study

This early datalogging group was a failure The design of the educational experiment and materials was left entirely to the teachers in the study group A strictly controlled experimental design was selected in which the same teacher taught the same cooling curve experiments with and without computers Since the computer class could have an "unfair" advantage because it is easier and quicker, it was fixed so that exactly the same experiments were done in both classes The extra time gained by using datalogging was spent giving students detailed step-by-step instructions on how to use the equipment, which they had never seen before The natural advantage of speed and flexibility using datalogging was eliminated by design The added value of the graph being generated in real-time was not exploited

Not surprisingly, no significant difference in student understanding of heat and temperature was found between the two groups Many researchers interpreted these results as proving the failure of MBL, but it simply demonstrated that technology *per se* offers no inherent advantage, it must be exploited through appropriate instructional strategies This research fell down on the fact that it did not adapt the instructional methodologies to fully exploit the technology

In 1987 Jan Mokros and Bob Tinker conducted an important research project on the impact of microcomputer based laboratories on children's ability to interpret graphs (Mokros & Tinker, 1987) This research was undertaken by them at the Technical Education and Research centre (TERC), Cambridge, Massachusetts, U S A as part of a five year effort to improve science education by developing curriculum materials that use the computer in the laboratory for real-time data gathering and analysis

Before undertaking an experimental study on the effects of MBL on children's graphing skills, information was obtained on how these children think about graphing The initial phase of the study looked at children's graphing skills in order to identify common graphing misconceptions

The most frequent problems encountered by students were found to be confusion between the slope and height of lines on the graph, and the tendency to see the graph as a picture rather than as a symbolic representation of information

The initial phase of this research was followed up by an examination of how students learn graphing skills through datalogging technology The study consisted of five days of activities that challenged students to construct different types of graphs using their own movements as well as those of a toy car, using an ultrasonic motion detector attached to a computer interface

The students were able to see the emergence of the graphs in real-time as they completed the activities

Results of this preliminary study showed that following the five days using the MBL to construct graphs, students had a solid understanding of distance and velocity

Given these promising results, a follow-up study was carried out to determine how graphing skills would develop over a three month period of use with MBL in science classes Pre-and post-testing was done on 125 students who received a minimum of 20 class sessions that emphasised hands on MBL activities A carefully constructed set of graphing problems, some involving graph interpretation, and others graph production was administered

The results indicated an improvement in students' ability to interpret and use graphs between pre-and post-tests Mokros and Tinker suggested that the reasons that this technology appeared to be such a powerful vehicle for teaching graphing is that it allows the student to connect graphical representations with real events It eliminates the drudgery of graph production as it can transform collected data into a graph instantaneously Traditional laboratory methods of collecting data by hand and then plotting points on paper create gaps between the event happening and the student seeing the graph depicting the event Datalogging technology can decrease or eliminate these gaps This brings the student closer to the actual event which can lead to deeper understanding

This study concluded that the main features that are responsible for the success of using datalogging technology in science teaching and learning are that it

- Uses multiple modalities
- Pairs events with their symbolic graphical representations
- Provides genuine scientific experiences
- Eliminates the drudgery of graph production

Unfortunately, all of the graphs used to test the "graph-as-picture" misconceptions in this study, involved distance and velocity Further testing would be required to see whether the same results held for other contexts

Thornton (1985) showed that the linking in time of a physical event with simultaneous graphic representation may facilitate an equivalent linking in memory Mockros (1986) further suggested that the real-time graphing may operate as a bridge to formal reasoning and development Because movement in a display dominates vision, real-time graphing may encourage students to selectively attend to important points on the graph, for example where there are changes in the physical event, e g speed or direction Or it may motivate them to find out how to create changes in the graph Real-time graphing also provides opportunity for students to modify the initial or experimental conditions and immediately see the effect of their modification on the resulting graph

These conclusions were corroborated in further studies by Linn et al (1987) who concluded that the major advantage of computer generated graphs is that they are formed as the experiment is carried out and are immediately related to an experience the student is having The graph is likely to be seen as a dynamic picture, rather than a static one

Heather Brasell (1987) hypothesized that the real-time nature of the graphs produced by datalogging technology was critical to its success She used pre- and post-tests to study the effects of one hour of instruction on four groups of high school students The group was divided in four, the first group received no instruction, the second received paper and pencil instruction, the third used a motion sensor as it is normally used, in real-time, and the fourth used the motion detector with modified software, in which the graph was not produced until after the motion was complete The delay was typically 20 to 30 seconds

Brasell found that the group using the motion detector in real-time with no delay significantly outperformed all other groups, including the delay group Most of the difference was found in the items related to distance She estimated that the real-time feature accounted for about 90% of the improvement that Microcomputer Based Laboratories offered over pencil-and-paper instruction

Brasell's work is widely quoted in the literature as evidence of the benefit to learning of real-time graphing as opposed to delayed graphing of data However, the treatment period was confined to a single class period A longer treatment period would be required to provide further insights into the benefits of real-time graphing on learning graphic representations

Following on from Brasell's research, Beichner (1990) argued that it was not necessary for the student to actually produce the graph by using a motion sensor to measure his or her own motion Since Brasell had shown that the key point was the real-time nature of the graphing, Beichner hypothesized that the students could learn just as well from pre-recorded videotapes of motion not produced by the students, so long as the graphs were displayed in real-time along with the display of the motion on the videotape Beichner developed a test very like that of Helen Brasell in which a total of 165 high school and 72 college students participated in the study

Contrary to his expectations, Beichner found no significant differences among the groups in his study He suggested that the difference between the two groups lay in the fact that the students in the Brasell study had the ability to control the motion He concurred that this ability to make changes and then instantly see the effect is vital to the success of datalogging technology in the study of kinematics The feedback appeals to the visual and kinaesthetic senses

Brungardt and Zollman (1995) felt that the delay effects might not be as noticeable if the studies were conducted over a longer period of time They conducted a similar study, but over four class periods The students in Brungardt and Zollman's study generated graphs from videotapes of sports events Students used acetate sheets placed on the video screen to record the position of the object or person at various times during the motion They then measured the position of the object at each time, and entered the information into a spreadsheet, which was used to produce the graphs Half of the students then saw the graph displayed as the videotape of the motion was replayed The other half watched the motion replayed, and then saw the graph displayed several minutes later

Unlike Brasell, Brungardt and Zollman found no significant effects of real-time versus delayed display of the graphs The main difference appears to lie in Brasell's use of motion detectors, so that the students were studying their own motion, as opposed to Brungardt and Zollman's use of videotaped motion, which the students did not produce From these studies it would seem that the real-time effect is critical when the students actively produce the motion being studied, but not as important when the work involves pre-recorded motion Further studies need to be carried out to see if the effect that Brasell noticed is still apparent if the studies are conducted over a longer period of time

These findings agree with those of Barclay (1985) who suggested that both the student-controlled kinaesthetic experience and the real-time graph production are important aspects of computer generated graphs in science education

1 4 Impact on classroom management

One of the issues surrounding the use of computer technology in the classroom is how to ensure that each child has access to the technology, and that each child actively participates in the investigation Many of the benefits associated with datalogging may be lost if the student is merely an observer A possible answer to this problem is to use hand-held datalogging devices

In terms of classroom management, graphing calculators or personal digital assistants (PDAs) offer a portable, economic alternative to classroom computers and facilitate many learning experiences not otherwise possible A graphing calculator can be connected to an interfacing device with an accompanying electronic probe (such as temperature, pressure, and pH level) The calculator can display the information in table or graph form The use of a view panel connected to a calculator makes it possible to project the screen of a calculator The technology's relatively small size, ease of portability and low cost make the systems more accessible to students and teachers, while providing the convenience of remaining in the regular classroom

Friedler and McFarlane's (1997) study on the use of portable datalogging equipment showed that students found the hardware easy to master They also found that the portable nature of the equipment allowed them to be deployed quickly and effectively, and argued that this would have been impossible with desktop machines due to their bulk The small size of the machines meant that they became part of the apparatus for an investigation and did not dominate the workspace Furthermore, they did not obstruct the view the group of pupils had of the apparatus as a whole Rogers (1997) also cites the flexibility of portable dataloggers as an important consideration

A study carried out by Saurino et al (1999) looked at how middle school classroom management is affected by the use of graphing calculator technology They found that students were able to complete higher level work with understanding and without frustration Students enjoyed the use of technology in the science classroom which made classroom management easier

Cooperative group size is another important consideration For most activities, a group of four seems to be the optimum number Even with the optimum number of students, while technology gathers data, students are free to do other things

In the USA, Kelly and Crawford (1996) analysed the contribution the computer made during group work The computer was seen to contribute information for discussion This work was done on post-16 physics classes Pupils drew on the computer representations for support in their developing, thinking and experimental work

1 5 Impact on teachers

Regardless of what technology is used, the teacher is a critical factor in determining its success The overall success of technology in the science classroom depends upon the teacher's confidence and understanding of it

A study conducted by Krajcik et al (1991) emphasises that the overall effectiveness of computer technology hinges upon the teachers' confidence and understanding of the technology, their knowledge of the science concepts involved and their ability to help students connect experiences with the concepts

Wetzel and Varella (1999) explored how student teacher's concerns over the use of graphing calculator technology changed if the instruction they received during the course of their teacher training was meaningful They found that as the student teacher's technical ability and procedural knowledge grew their confidence level increased This increase in confidence helped them integrate datalogging technology into their science classrooms once they become teachers

A teacher must feel a certain level of confidence in order to be able to use technology in the classroom Students expect teachers to be able to use the technology competently and that puts added pressure on the teacher It is important that the teacher believes that the technology is the best instructional tool, but she or he must also be confident to risk the attempt As with any instructional tool, if the teacher becomes proficient and competent, the tool can then become a medium for many learning possibilities

Pedretti et al (1999) in their Technology Enhanced Secondary Science Instruction project (TESSI), integrated the use of multiple technologies into science teaching Teachers designed instructional devices that put the technologies into the hands of students The instruction played a supportive rather than didactic role

As a result of access to these technologies and revised curricula that took advantage of these technologies, interviews and surveys carried out suggested that students gained a stronger sense of purpose and self-direction in their classroom work than when taught traditionally

What gradually emerged from the teachers' critical rethinking of their use of technology was a redesigned classroom where students worked in collaborative groups Classroom-based student work stations developed where individuals or groups of students explored scientific concepts largely through computer based resources, such as datalogging In this classroom arrangement, the students assumed new roles and responsibilities for their own learning Students became involved in active learning, interactive problem solving, self-monitoring, and peer-coaching

1.6 Impact on students

Linn and Songer (1988), Thornton and Sokoloff (1990), Linn et al (1991) showed that the use of computer based technology during science practical classes led to students making predictions before the investigation had been completed This they argued enhanced perceptual understanding When a student is encouraged to make predictions, there is more likelihood of him or her asking questions about the results they obtain rather than regurgitating the accepted explanation or methodology dictated to them by the teacher However, Rogers and Wild (1994, 1996) indicated the importance of the context of use and teaching approach adopted for the achievement of these benefits

Leonard Newton (1999) surveyed some of the benefits claimed for data logging methods that have been identified through research He discusses the range of influences on science teachers adopting and developing data logging methods He claims that there are two main benefits to computer based approaches to science Firstly, they are labour-saving and secondly, there are also advantages which can be considered higher order Pupils have greater opportunities to exert control over the management of their activity The rapidity of the data collection process means that pupils can collect multiple sets of data and therefore control the exploratory style of work Demand can be higher in data logging activities because they lend themselves to more open-ended approaches to practical work Whether pupils experience the higher order demand is dependant on how the teacher wishes the class to work

The U K Schools Examination and Assessment Council Report (Taylor & Swatton, 1990) showed that by the age of eleven most children did not understand the concepts behind graphs and so were not able to interpret graphs drawn by others or make predictions based on the graphs McFarlane (1997) questions the traditional way in which graphing skills are taught She suggests that it would be a better idea to teach students why they are graphing and what the graph represents, before teaching them how to manually plot the graph Subsequent work by Taylor and Swatton (1994) with children 11 and 13 years of age shows that even when children have the ability to read coordinates with some degree of competence, they are unable for the most part to describe patterns or relationships between variables which are illustrated through bar charts or line graphs Without these skills it is difficult to see how pupils can engage in the interpretation of the underlying phenomena represented in the graphs, and so develop an understanding of related content matter Rogers (1994) and Barton (1997a) both felt that the use of Information Technology could help to shift the emphasis from data collection to data interpretation

Barton (1997b), in a comparative study of the computer approach to graphing by pupils of secondary school age, provided evidence of the contribution that computer generated graphs of data can make to pupils' appreciation of the meaning of the data and of the advantages of computer-drawn graphs over the manual paper and pencil methods Weller (1996) showed that the opportunity to collect and work on first-hand experimental data offers genuinely scientific experiences to pupils Also, data-logging can contribute to pupils' skills in scientific enquiry and add to their understanding and interpretation of graphically presented information

Barton also found the group using manual methods spent most of their allocated time processing the data, whereas the group using computer-based methods spent the largest proportion of time in question and answer sessions with the teacher

Barton cites a study by Jackson et al (1993) where the focus was on the use of the equipment with students of low ability There were marked improvements in the students' ability to interpret and modify graphs Barton found that in the group only using manual methods, the average and above average students were able to complete the tasks they were given without help Those using the computer-based methods were all able to complete the task

Graphical representations of data, according to Roth (1992), have added power for cognitive development They can be used for many things in science learning including use as a tool for teachers to evaluate student conceptual understanding and as a mediating tool to assist students and teachers to make sense of each others' understanding They allow teachers, to satisfy themselves that the learning outcomes have been properly understood

1.7 Conclusions

Research as far back as the early 1980s has shown that integrating datalogging into science teaching is a valuable way of increasing the student's enjoyment and understanding of science It has also been shown that the majority of students are comfortable using this type of technology, in fact they are enthusiastic about learning science this way

Student difficulties with the construction of appropriate graphs are shown to restrict both understanding of the teaching point and the motivational enjoyment needed to support quality learning in science

The strength of support offered by real-time graphing of events is clearly demonstrated in kinematics Quality of learning is strengthened by the ability to adapt and change the parameters of the investigation and observe the effects in real-time This becomes more important when research suggests that the ability to interpret graphs enhances the cognitive development and the enquiry learning skills of students Predicting outcomes and then testing the result is also shown to enhance the learning process and deepen the students' understanding of the principles being taught

The coupling of the kinaesthetic experience of, for example, the motion of an inanimate object and the related graph seems to be very powerful Researchers suspect that the speed of the feedback obtained by students allows them to clarify any misconceptions or errors thereby aiding understanding

Ability to interact with the equipment is fundamental in the delivery of this learning style Student access is crucial and historical attempts using a few P C s with problematic software/hardware have been shown to lessen the impact of the teaching and learning approach Handheld technology and improved software interfaces have served to improve the classroom environment to allow teachers and students to engage more fully in the learning process as well as confirm the teaching aims for the lesson have been met

No long term studies have been conducted on comparable groups of students taught using datalogging technologies in conjunction with appropriate investigative teaching methodology, and ones using a more text book based, didactic approach Whilst many studies have shown that using an investigative approach to teaching and learning enhances students' understanding of scientific concepts, little has been done on evaluating the long term effect of this method of teaching, either in retention of science facts or in influencing their choice with regard to further studies in science

This research will add to the current research by addressing both of these questions

References

Barclay, W H (1985) Graphing misconceptions and possible remedies using Microcomputer Based Labs *Technical report 85-5 Cambridge, MA Technical Education Research Centre*

Barton, R (1997a) "Does datalogging change the nature of children's thinking in experimental work in science?" In Using Information Technology Effectively in Teaching and Learning Studies in pre-service and in-service teacher education, ed *Bridget Somekh and Niki Davis,* 63-72 London and New York Routledge,

Barton, R (1997b) "Computer-Aided Graphing a comparative study " *Journal of Information Technology for Teacher Education 6,* no 1 59-72

Beichner, R J (1990) The Effect of Simultaneous Motion Presentation and Graph Generation in a Kinematics Lab *Journal of Research in Science teaching*, 27 (8), 803-815

Brasell, H (1987) The effect of real-time laboratory graphing on learning representations of distance and velocity *Journal of Research in Science Teaching*, 24, 4, 385-395

Brungardt, J B and Zollman, D (1995) Influence of interactive videodisc using simultaneous-time analysis on kinematics graphing skills of high school students *Journal of Research in Science Teaching 32* (8), 855-869

Friedler, Y and McFarlane, A E (1997) "Data Logging with Portable Computers A Study of the Impact on Graphing Skills in Secondary Pupils " *Journal of Computers in Mathematics and Science Teaching* 16, no 4 527-550

Jackson, D F , Edwards, B J and Berger, C F (1993) Teaching the design and interpretation of graphs through computer-aided graphical data analysis, *Journal of Research in Science Teaching*, 30, pp 483-501

Kelly, G J and Crawford, T (1996) Students' Interactions with Computer Representations Analysis of Discourse in Laboratory Groups *Journal of Research in Science Teaching* 33 693-707

Krajcik, J S , Layman, J W , Starr, M.L and Magnusson, S (1991) The development middle school teachers' content knowledge and pedagogical content knowledge of heat energy and temperature *Paper presented at the AERA annual meetings*

Lam, T (1984) Probing microcomputer based laboratories *Hands on!*, *TERC 1*, Winter 1984

Linn, M C, Layman, J and Nachmias, R (1987) Cognitive consequences of microcomputer-based laboratories Graphing skills development *Contemporary Educational Psychology*, 12 (3), 244 - 253

Linn, M, N B, Lewis, E L and Stern, J (1991) Using technology to teach thermodynamics Achieving integrated understanding *In D L Ferguson (Ed), Advanced technologies in the teaching of mathematics and science*, Berlin Springer-Verlag

Linn, M C and Songer, N B. (1988, April) Cognitive research and instruction Incorporating technology into science curriculum *Paper presented at the American Educational Research Association Meeting, New Orleans, LA*

McFarlane, A (1997) Datalogging with portable computers a study of the impact on graphing skills in secondary pupils, *Journal of Computers in Mathematics and Science Teaching v 16, no 4*

Mokros, J R (1985) The impact of microcomputer-based labs *TERC, Technical report 85-2 Cambridge MA*

Mokros, J R (1986) "The Impact of Microcomputer- Based Science Labs on Children's Graphing Skills" *Paper presented at the 1986 annual meeting of the National Association for Research in Science Teaching* San Francisco, March 1986

Mokros, J R and Tinker, R F (1987) The Impact of microcomputer-based labs on children's ability to interpret graphs *Journal of Research in Science Teaching*, 24 (4), 369-383

Newton, L (1999) Data-logging in the science classroom approaches to innovation
(Available on line) http //www ipn uni-kiel de/projekte/esera/book/020-new pdf

Pedretti, E, Mayer-Smith, J and Woodrow, J (1999) Teaming Technology Enhanced Instruction in the Science Classroom and Teacher Professional Development *Journal of Technology and Teacher Education* 7(2)

Perkins, D N, Schwartz, J L, West, M M, and Wiske, M S (Eds) (1995) *Software goes to school, teaching for understanding with new technologies* NY Oxford University Press

Roth, W M (1992) Bridging the gap between school and real life Toward an integration of science, mathematics, and technology in the context of authentic practice *School Science and Mathematics*, 92, 307-317

Rogers, L (1994) *"Data-logging " In Computer Based Learning Potential into Practice*, ed Jean Underwood, 116-136 London David Fulton Publishers Limited

Rogers, L (1997) New datalogging tools- new investigations, *School science review, 79(287)*

Rogers, L T and Wild, P (1994) the use of IT in practical science - a practical study in three schools *School Science Review 75, 273, 21-28*

Rogers, L T and Wild, P (1996) Data-logging effects on practical science *Journal of Computer Assisted Learning* 12, 130-145

Saurino, D , Bouma, A and Gunnoe, B (1999, March) Science classroom management techniques using graphing calculator technology A collaborative team action research approach *Paper presented at the annual meeting of the National Association for Research in Science Teaching, Boston, MA*

Scaife, J and Wellington, J J (1993) *Information Technology in Science and Technology Education,* Open University Press 1993

Swatton, P and Taylor, R M (1994) Pupil performance in graphical tasks and its relationship to the ability to handle variables *British Educational Research Journal*, 20(2), 227-245

Sokoloff, D R and Thornton, R K (1977) Using interactive lecture demonstrations to create an active learning environment *The Physics teacher Volume 35 Sept 1997*

Taylor, R M and Swatton, P (1990) *Assessment matters No 1, Graph work in school science* London Her Majesty's Stationery Office

Thornton, R K (1985) Tools for scientific thinking Microcomputer based Laboratories for the naive science learner *Technical report 85-6 Cambridge, MA Technical Education Research Centre*

Thornton, R K and Sokoloff, D R (1990) Learnıng motıon concepts usıng real- tıme mıcrocomputer-based laboratory tools *Amerıcan Journal of Physıcs*, 58, (9), 858- 867

Tınker, R F and Papert, S (1989) *Tools for Scıence Educatıon*, ın Ellıs, J (edıtor) *Informatıon Technology & Scıence Educatıon* Columbus, OH, AETS

Tınker, R F (2000) A comprehensıve hıstory of probeware
Avaılable onlıne http //www concord org/research/probeware_hıstory pdf

Weller, H G (1996) Assessıng the Impact of Computer-based Learnıng ın Scıence, *Journal of Research on Computıng ın Educatıon, 28, 4, pp 461-485*

Wetzel, D and Varella, G (1999, September) Pre-servıce teachers' concerns regardıng calculator-based laboratory probeware *Paper presented at the annual conference of the Mıd-Atlantıc Assocıatıon of the Educators of Teachers of Scıence,* Kıngsport, TN

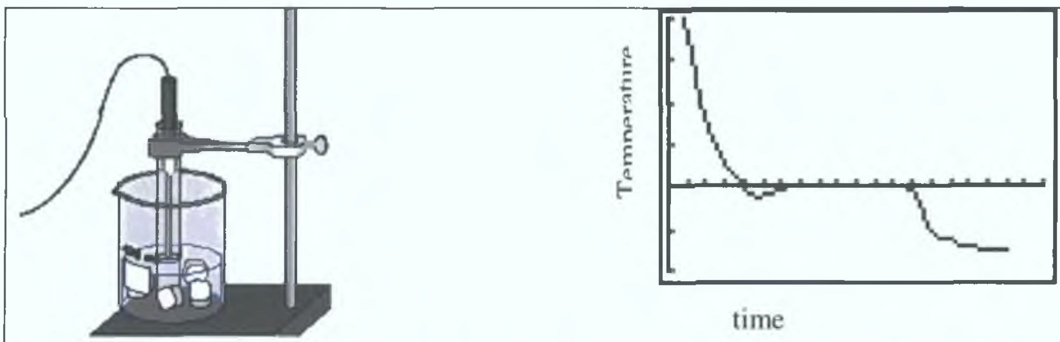
Chapter 2 Context of use of handheld datalogging in Science

Can the use of datalogging help to encourage students to focus on higher order analytical reasoning and critical thinking to develop high level conceptual understanding of science? In an attempt to answer this question, the added value that datalogging can offer will be considered under various headings.

2.1 Automation of the measurement process:

Automation of the measurement process takes away the drudgery of recording multiple measurements and allows students time to observe the reactions or events that are taking place during the investigation.

An example that illustrates this point is plotting a cooling curve. Without datalogging apparatus, students will take a long time to gather the data for one cooling curve and then plot the data later. They have difficulties taking multiple readings from the thermometer. Reports written later on in the day or for homework often contain more information about temperatures and the thermometer than energy changes taking place during a change of phase. Students often fail to understand the connection between features on the graph and the properties of the substance that is cooling. Having never seen a normal cooling curve, they often fail to understand the significance of the plateau observed during a liquid-solid transition [Fig. 2.1].



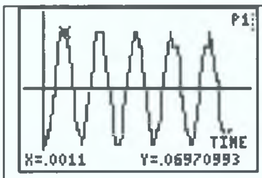
Temperature probe inserted in 10 cm^3 water in an ice bath	*Cooling curve for water taken over 10 minutes. (From a graphing calculator)*

Figure 2.1

Because the probe responds quickly to the change in temperature, the sample can be small. This means that one cooling experiment can be completed in a few minutes. The advantage here is that the process can be repeated several times. Students can see the graph evolving as the experiment is underway. They can speculate and think about the reasons for the temperature being constant while the phase is changing. As the set up is very straightforward, they can then reverse the procedure, this time heating the water bath up to investigate energy changes as the substance goes from the solid phase to the liquid phase.

2.2 *Wide range of inter-sample times available (microseconds to hours)*

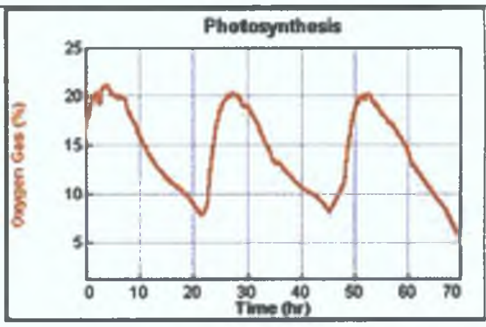
This creates new opportunities for collecting data that have previously not been available to second level students. For example, very fast data collection rates allow for capture of vibrations produced by sound waves. This allows students to investigate the wave nature of sound [Fig. 2.2].



Typical display produced when a tuning fork is struck and held up to a microphone.

Figure 2.2

The ability to log data over very long periods is also beneficial. Very slow sample rates allow measurements over long periods of time. An example of this is to monitor the relative concentrations of CO_2 and O_2 over a plant under normal conditions [Fig. 2.3].

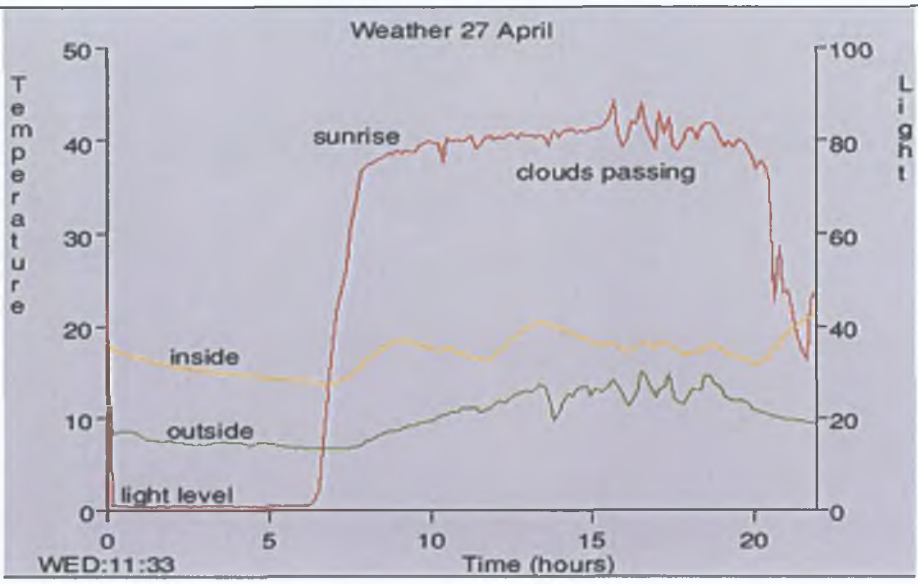


Monitoring the oxygen uptake for a photosynthesizing plant over 70 hours.

Figure 2.3

2.3 Expanded range of opportunities for students to obtain data that relates to everyday life.

Datalogging makes it possible to measure changes in weather conditions over a period of hours and days. An example of this is shown in [Fig. 2.4] (Rogers, 2001).



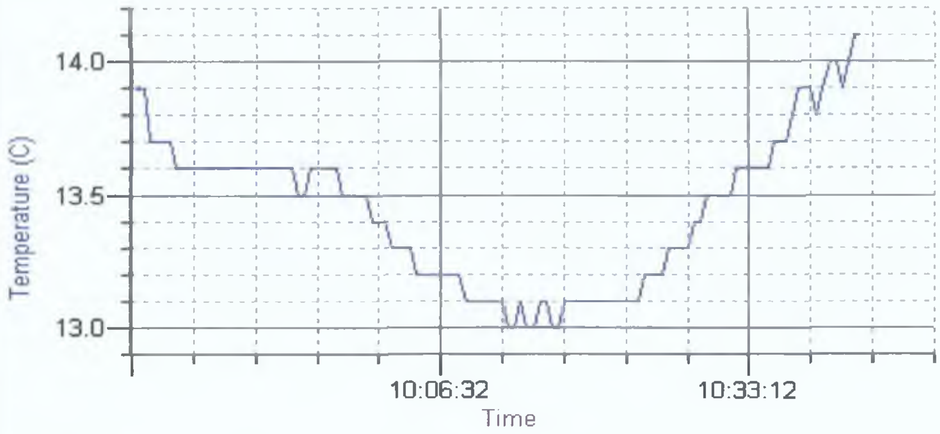
Changes in weather conditions over a 24 hour period.

Figure 2.4

(This graph was taken from Laurence Rogers http://www.le.ac.uk/se/lto/logging/test3.html).

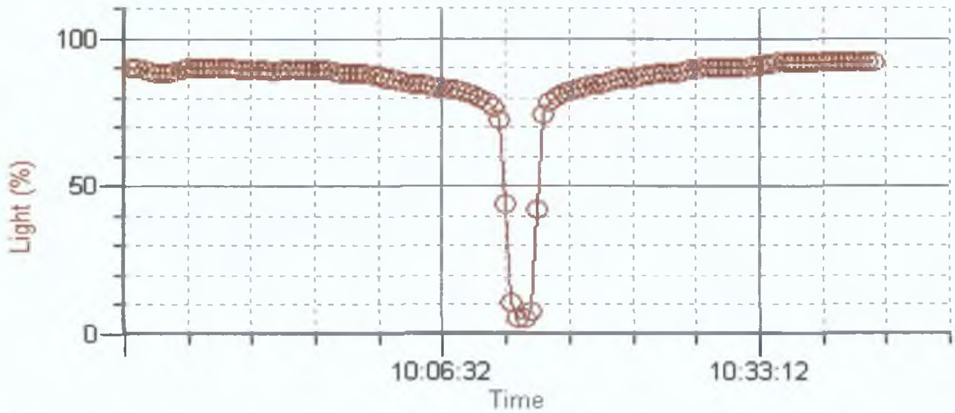
A pressure probe could also be attached to a datalogger for a period of days to record pressure changes which could then be related to the weather.

In the summer of 1999 there was a total solar eclipse. The following graphs were obtained by attaching a light probe and a temperature probe to a datalogger and recording temperature and light intensity over the period of the eclipse [Fig. 2.5]. The graphs are taken from work completed by John Hennessy. (Hennessy, 1999)



(33.1, 13.15)

graph of temperature over time during an eclipse



(39.1, 42.91)

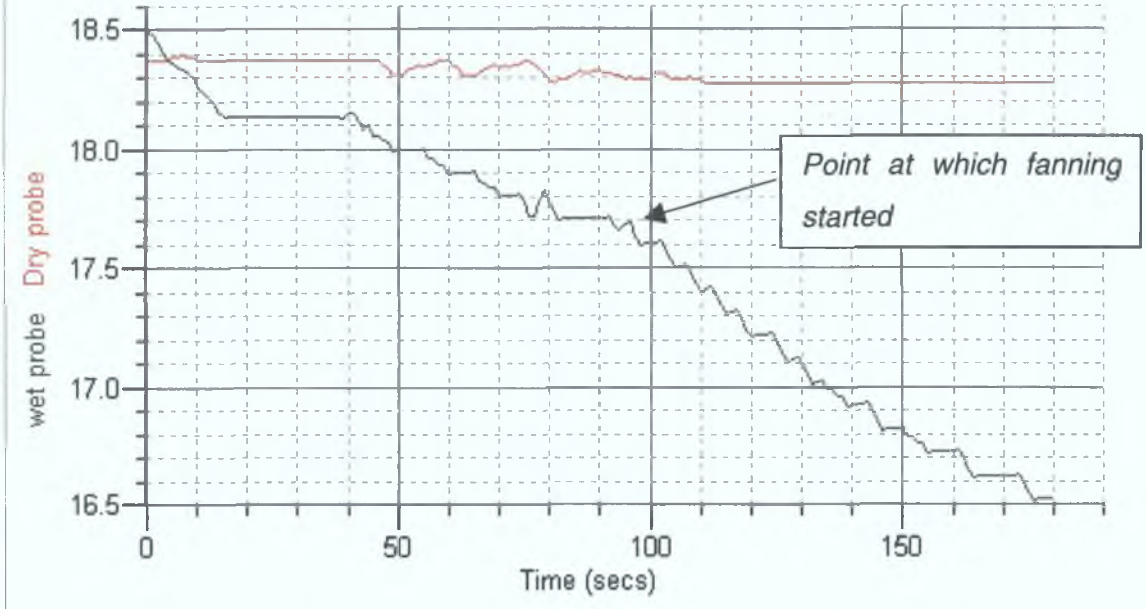
graph of light intensity over time during an eclipse

Figure 2.5

2.4 Real-time graphing

As the graph appears in real-time students are presented with the whole picture. They have the advantage of seeing the graph appear on the screen before they try to interpret the shape. With real-time datalogging the emerging graph simultaneously reflects physical events in the investigation. Changing one of the variables in an investigation will result in an immediate change of shape of the graph.

This can be illustrated [Fig. 2.6] by recording temperature changes during evaporation of water from a wet tissue wrapped around a temperature sensor. The student can deliberately change one of the variables, and observe the effect immediately. If the wet tissue is fanned, the rate of evaporation increases, and the graph of temperature against time will drop at a faster rate. This provides an instant reaction to an intervention by the student.



Temperature changes during evaporation of water

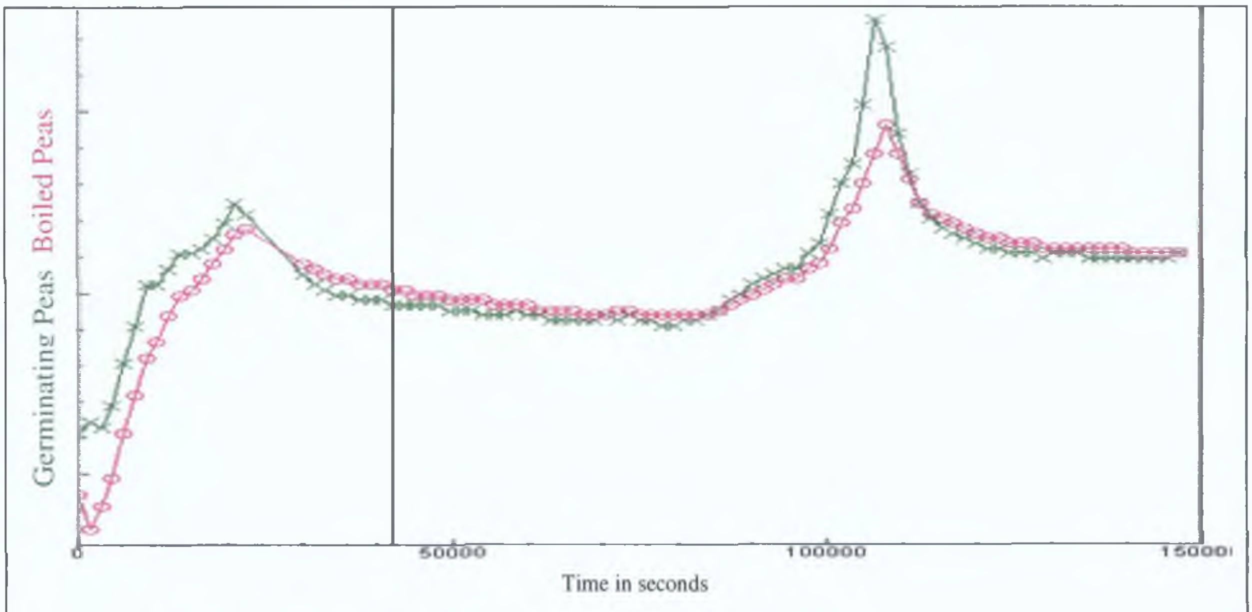
Figure 2.6

The measurements are displayed on the screen as the experiment is in progress. The immediate effect on the graph of changing a variable offers a student an opportunity to engage with the investigation and move away from the recipe type approach to science. It can completely change the dynamics of the learning process accompanying the experiment. Investigations of this type which feature intervention and which promote a "what would happen if....?" approach provides useful ways of promoting higher order skills.

2.5 Added opportunities for learning.

Very often students do not get the graphs they expect from an investigation. If the data do not agree with predictions, students look for reasons why. An illustration of this came from an investigation to show that germinating peas release heat energy during respiration. Two sets of peas, one live one dead, were placed in two thermos flasks and the change in temperature over a period of time was recorded.

The following graph [Fig. 2.7] was obtained from a group of second year Junior Certificate students (6 dataloggers all produced similar graphs).



Change in temperature over time of germinating peas

Figure 2.7

As the thermos flasks were not very efficient, the students correctly interpreted that the two peaks corresponded to the warmest part of the day (this experiment was conducted in a laboratory with central heating. The heating was turned off at night.). Students observed that there was no difference in the temperature of the two sets of peas when they were in the range 0 - 10^0C, however, as soon as the temperature went above 10^0C the temperature of the live peas extended beyond that of the boiled peas.

They concluded that not only do germinating peas release energy, but that they do not germinate at temperatures below 10^0C. This set of data provided students with an opportunity to discuss a set of results, and come up with a hypothesis based on experimental evidence. It is important to point out that datalogging of itself is unlikely to make the students more reflective but the teacher's role in stimulating the discussion is crucial. Datalogging facilitates the open-ended nature of the investigation.

2.6 Added opportunities for investigation and analysis.

When investigating Ohm's Law students traditionally set up a simple circuit containing a number of batteries an ammeter and a voltmeter. They change the number of batteries and record the voltage and the current. A graph of current against voltage shows that V/I is a constant.

With a datalogger attached to such a set up, and using a variable power supply instead of batteries the current and voltage can be monitored continuously as the power supply is gradually increased to a maximum and then decreased back down to zero [Fig. 2.8].

If the data for both current and voltage are presented against time on the same graph both current and voltage can be seen to increase or decrease in unison, the shape of the two graphs is very similar.

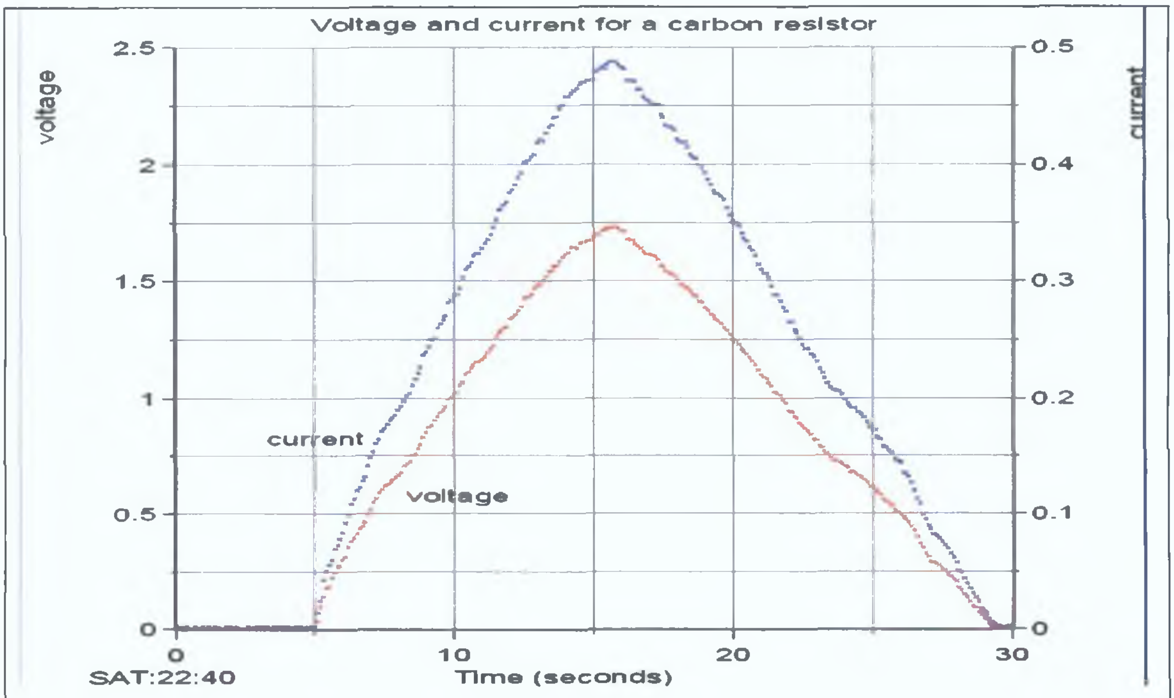


Figure 2.8

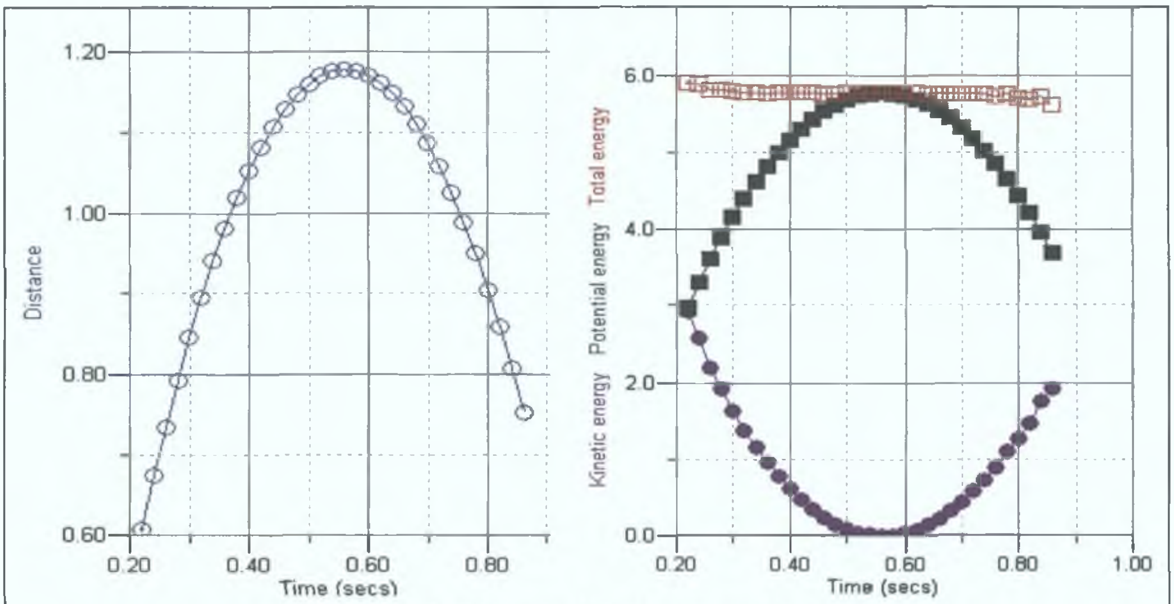
The advantage of presenting the data in this way is that the student can adjust the variable as much as they like, they will see that the current and voltage change in unison. This reinforces the idea that current and voltage are proportional to each other.

Further data can easily be calculated from the raw data. For example, it is easy to add another column of data such as current × Voltage, or Voltage / current. From these graphs they can move on to investigate power and resistance. Instead of being told that resistance does not vary with voltage, they can discover it for themselves. They may also go on to investigate the relationship between power and voltage and discover the quadratic relationship. The use of datalogging has the potential to turn this experiment into a true investigation.

2.7 New experiment opportunities

The use of datalogging offers many new opportunities for investigation that were not previously possible. These investigations can be very useful in aiding understanding of difficult concepts. Students are expected to understand the principle of conservation of energy. This has previously not been easy to demonstrate in a quantitative way. Using datalogging, it is possible to use a motion detector to graph the motion of a ball as it is thrown in the air [Fig. 2.9].

Students input the mass of the ball, and the calculator calculates the kinetic energy and the potential energy. The student can then add these two values on the calculator to obtain a value for the total energy. Not only can the student see the results on the calculator, but they also have the added advantage of relating the movement of the ball to kinetic and potential energy. This involves active learning on behalf of the pupil; they have control over the ball and are actively involved in converting the movement of the ball into graphs of different forms of energy.



Energy of a ball thrown into the air under gravity.

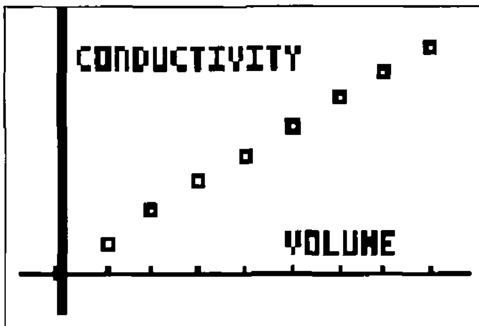
Figure 2.9

The graph on the left represents the displacement of the ball as it is thrown. The graph on the right shows the kinetic energy, potential energy and potential + kinetic energy. The fact that the student has to actively add the kinetic and the potential energy together on the calculator to get a total approximating a constant value that represents the total energy reinforces the idea that energy is not lost during the movement of the ball, it is simply converted from one form to another. They can see from their graph that the total energy remains the same. Close inspection shows that there are small variations in the value of the total energy, and that the total energy tends to decrease over time. If perceptive students note these points discussion of errors and energy dissipation can follow.

2.9 An aid to clearer understanding

When investigating the ability of ionic and covalent substances to conduct electricity students would set up a simple circuit to show that ionic substances conduct electricity and covalent substances do not. By using a conductivity probe attached to a datalogger, this qualitative experiment can become quantitative.

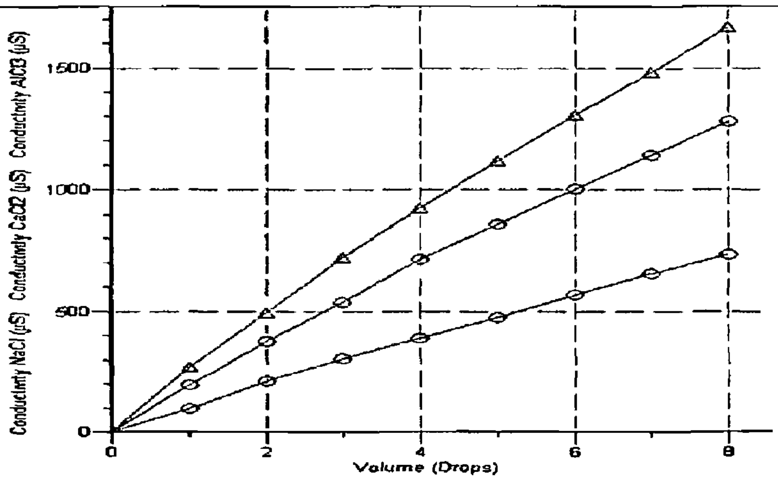
The student can enhance this investigation by adding different amounts of salt solution to water and logging the conductivity, a graph of concentration against conductivity can be drawn [Fig 2 10]



This shows that as the student increases the number of ions by adding increased volumes of salt, the conductivity increases

Figure 2 10

If they repeat the investigation using the three different salts [Fig 2 11], for example NaCl, $CaCl_2$ and $AlCl_3$ the student will see that the rate at which the conductivity increases is greatest in the salt that dissociates to give the greatest number of ions This may also help the student understand about valancy and how atoms of elements combine to form compounds



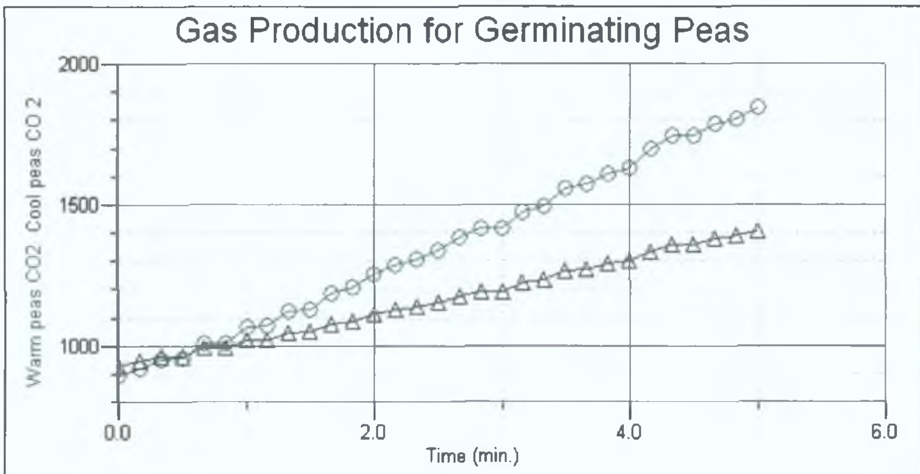
Conductivity of different salts over volume

Figure 2 11

2 10 Increased accuracy and error analysis

Computer generated graphs are generally more reliable than those produced by students The precision of sensors is far greater than traditional instruments For example, a temperature probe can usually offer measurement of 1/10 degree Celsius Also, there is a guarantee that the recording of results will be accurate Generally, the quality of data offered to students is much better using a good quality sensor and a computer This has clear benefits for subsequent analysis and interpretation

Apart from generating reliable data, accurate measurement is crucially important when the data recorded represent very small changes. In an investigation to show that respiring organisms produce CO_2, changing the temperature will quickly show a change in rate of CO_2 production, which although very small, will give a significant change on the graph [Fig 2.12].



CO_2 production at 24^0 C and at 14^0C

Apparatus for measuring CO_2 production

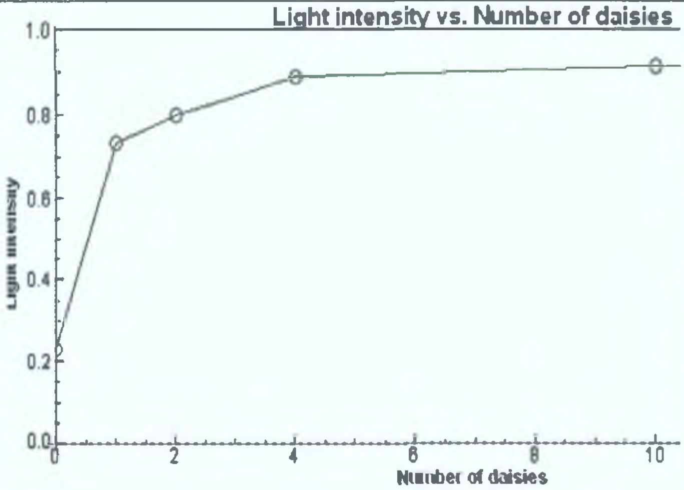
Figure 2.12

This accuracy encourages students to have confidence in the recorded data. If the results are not as they predicted, they do not assume that the equipment hasn't worked, they look for reasons why the results were at variance with their predictions.

2.11 Ability to collect and analyse data in the field.

With the use of portable technology in the field, students can gather analyse and store their data and use it to understand their environment in context. They can link their observations directly with their environment. As the data is graphed as they see it in the field, they have an immediate graphical representation of environmental phenomena.

The following data was collected in the school garden by second year students observing the distribution of daisies [Fig 2.13].



Graph of light intensity vs. numbers of daisies

Boys counting daisies

Figure 2.13

2.12 Conclusion

The process of measurement is an integral feature of science investigation. Measurement combines procedural skills, such as controlling variables, evaluating reliability, precision and accuracy; and operational skills, such as manipulation of apparatus, use of measuring instruments and reading scales. Technology has now progressed to the point that data collection and graphical representations have become automated. This allows for a stronger focus on the procedural effects of the investigation.

Dataloggers can record and graph data instantaneously, in "real-time", or they can store the data in memory to be connected at a later time to the computer or hand-held device for viewing and analysis. They can take a series of discrete measurements with irregular intervals whereby data collection is prompted by a button press, so is completely under the control of the student. Dataloggers can also be programmed to delay the data collection process for a specified time or until a particular event such as a threshold of sound, temperature or light, triggers the initiation of the data collection.

Unless otherwise stated all graphs and tables cited in this chapter were produced by the Sutton Park students who took part in this research study.

References

Hennessy, J (1999) graph on page 28 [Fig 2 4] taken from material produced for Teachers Teaching with Technology, Ireland

Rogers, L graph on page 27 [Fig 2 5] taken from http //www le ac uk/se/lto/logging/test3 html

Chapter 3 Sutton Park Study

3.1 Introduction

The purpose of this research was to examine the results of teaching a group of mixed ability students for three years of the Junior Certificate Science syllabus using an investigative teaching and learning approach which included the use of electronic sensors for collecting data These results were to be compared to those of two comparable groups in the same school who were taught in a traditional manner with no great emphasis placed on investigative learning, and without the use of electronic sensors for collecting data

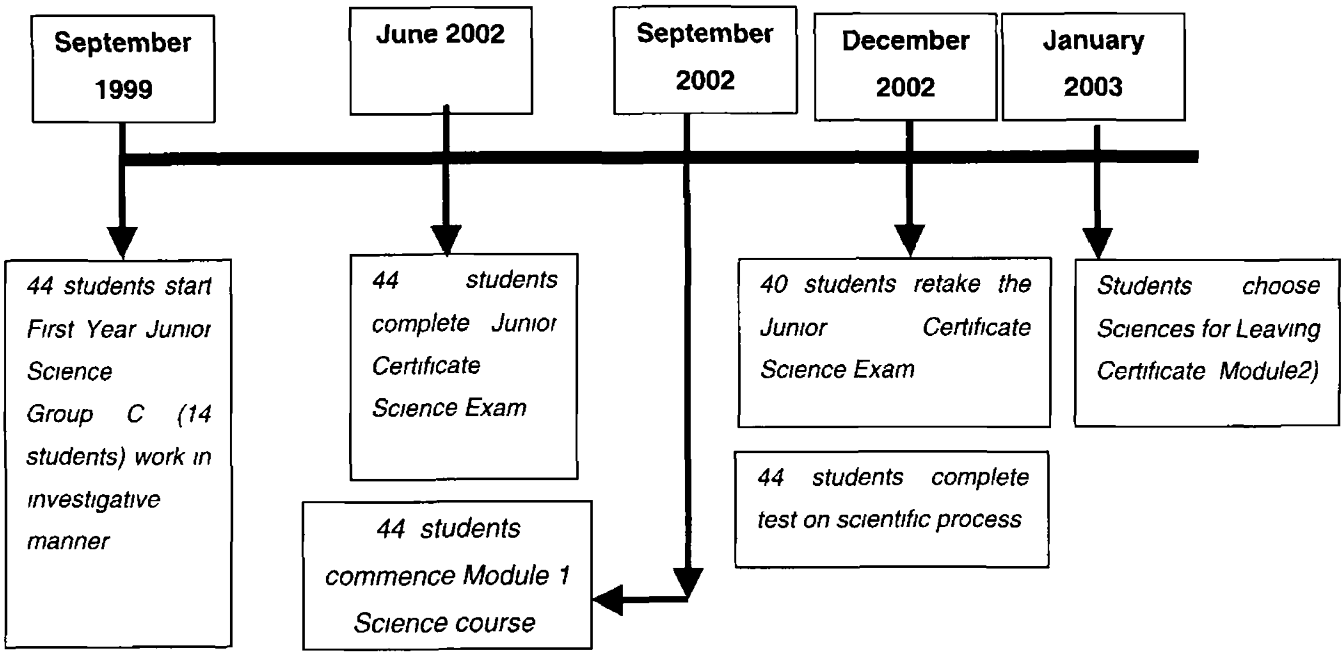
The study was conducted between September 1999 and June 2002 on a group of 44 first year students The groups were divided into three and named group A, B and C Group C consisted of 14 students, taught using investigation as a basis for learning These students collected data electronically using sensors, and analysed it using graphics calculators and/or computers Groups A and B each consisted of 15 students respectively, taught in a traditional manner with the text book and instruction forming the basis for their learning These groups carried out all the recommended experiments in the syllabus, but did not use datalogging at any time during their practical classes

3.2 Data gathered

The groups were compared under the following headings

- Performance in the State Junior Certificate Science Examination 2002
- performance in the same State Junior Certificate Examination repeated in December 2003
- Understanding of scientific concepts
- Ability to interpret graphs relating to (a) general science topics and (b) kinematics
- Subject choices for leaving certificate
- The relationship between student ability in science and mathematics
- Gender comparison within each of the groups

3.3 Timeline.



3.4 Background of research group.

The students in this study all came from Sutton Park School Sutton Park is a mixed gender private school with a typical cohort of 250 – 270 students in total It has established a strong reputation in the community for enabling students with mixed academic abilities to reach their full potential both socially and academically

The school is situated in Sutton, an area of North East Dublin The school has good and improving facilities with long established dedicated laboratories for each of the sciences Each laboratory has full facilities although little of the equipment is new All aspects of the curriculum can be met in-house As is typical in other schools, there are no technicians for science and preparation work is undertaken by the five science teaching staff

Some Science classes take place in classrooms due to pressure on laboratory space The students in this study typically spent at least one of their four Science periods each week in a classroom

Students and parents are active in the life of the school and science is seen as an integral part of the school day All students must take science at Junior Certificate level, and most admit to liking it Parents are generally supportive of science as a subject at Junior Certificate level

The teaching cohort is mixed ability with a wide range of abilities in a typical teaching group Students are randomly split into two or three groups depending upon the size of the intake This study ınvolved a year group of some 44 students grouped ınto three mıxed abılıty classes As detaıled earlıer, for the purposes of thıs research, these groups have been classıfied as A, B and C

3.4 Materıal and Equıpment

Investıgatıve learnıng ınvolves the regular use of equıpment to facılıtate the exploratıon of ıdeas The equıpment used for thıs purpose by Group C generally ınvolved dataloggıng wıth the Texas Instruments TI 83+ graphıng calculator and the assocıated Calculator Based Laboratory (CBL) wıth selected software for storıng and analysıng software both on the hand-held calculator and P C as requıred

3 4 1 TI 83+ graphıcs calculator

These calculators have all the functıons and features of tradıtıonal scıentıfıc calculators [Fıg 3 1] They contaın programmıng language and suffıcıent RAM to store large amounts of data and programs They have I/O ports, whıch allow for data ınterchange between calculators, and also to data-loggers and computers

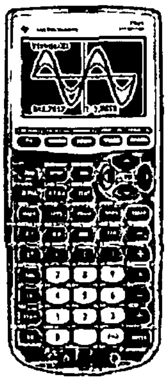


Fıgure 3 1

Graphıng calculators are powerful hand-held computers wıth much of the functıonalıty of desktop PCs They are a flexıble, low-cost resource for scıence teachıng as they ınterface wıth a small data collectıon devıce (see fıg 3 2) whıch enables data to be collected and analysed Data tables or graphıcs can be dısplayed on the screen

- More than1000 data points can be stored on a TI83+ graphing calculator - enough for any experiment at second level

- Sampling at > 10000 s^{-1} allows sound wave capture and analysis – fast enough for most school use

- Accuracy is confirmed by the measurement of standard values - often within 1% error

- An auto trigger feature allows the capture of very fast events

- A manual trigger feature allows the datalogger to be disconnected from the calculator Measurements can then be made over weeks or in hostile environments and can later be retrieved for analysis on the calculator

- A trigger/prompt feature allows the measurement of one parameter while another is entered manually

3 4 2 Calculator Based Laboratory (CBL)

Figure 3 2

The CBL 2 is a powerful, portable data-collecting device that allows students and teachers to collect data and store/graph it directly to the graphing calculator [Fig 3 2] More than 40 sensors can be connected to the CBL 2 including Light, temperature, pressure, colorimeter, microphone, heart rate and pH

Since the CBL 2 is portable and battery powered, it can be taken out of the classroom for experiments such as monitoring the temperature, dissolved oxygen, and pH of a lake or stream Within the classroom, the CBL 2 and a graphing calculator can be used as a low-cost alternative to computers for collecting and analysing real-world data

The selected software for the hand-held device, 'DataMate', is custom software for the TI 83+ system designed to accept a range of probes for gathering data with the minimum of student involvement for setup and calibration of the probe

3.4.3 Calculator Based Ranger (CBR)

The CBR is a Sonic motion detector [Fig 3.3]. It collects distance, velocity, and acceleration data while connected directly to a TI Graphing Calculator. This allows students and teachers to explore the relationship between time, distance, velocity and acceleration.

Figure 3.3

3.4.4 TI view screen

When interfaced to a teacher's calculator, the TI Viewscreen allows for projection of data and graphs to an audience via a traditional overhead projector [Fig 3.4].

Figure 3.4

3.4.5 Vernier graphical analysis software

'Graphical Analysis', the P.C. software used, was written by the probe manufactures, Vernier Ltd, and was selected for ease of use and compatibility with the selected materials. This software provides a way of moving data from the calculator to the computer for further analysis and printing. 'Graphical Analysis' creates a graph as students enter their data either manually or directly from the calculator. Data may also be imported to the clipboard or a text file.

All aspects of the equipment worked as expected and no issues were recorded hindering student use or understanding because of limitations of the equipment. I.T. skill levels of students were not recorded before the research as this was not felt to be an issue. Although there was some variation, student acceptance and skilled use of the technology generally was rapid.

Sample worksheets were prepared and modified throughout the research period. The modification was done in response to students' and teachers' feed back. Much of the detailed instruction was removed as it was found to be superfluous to student needs. A sample of both the initial worksheets and the modified worksheets are included in Appendix A (pg 3-10) and II (pg 11-65)

3.5 Research methods

3 5 1 Junior Certificate scoring in June 2002

The Junior Certificate (June 2002) Science results of each of the groups A, B and C were compared to establish any significant difference in performance in the state exam

It was not possible to get detailed scores from the Department of Education an Science for the students involved in the study The official school data provided by the department was made available to the researcher and student grades were recorded by banding It was decided to use the equivalent point-scoring matrix used by third level institutions to compare results from different certificate levels This is summarised in Appendix E (pg 95) The same system was used for student performance in both science and mathematics This would be used for the comparison between subjects

3 5 2 Junior Certificate in December 2002

The groups were again given the June 2002 exam paper in December 2002 The results of this test would establish the extent to which the students had retained the knowledge gained in the three years of Junior Certificate Science It was completed under exam conditions Students were given no warning of the December testing, so they were unable to prepare

3 5 3 Test booklet

A series of questions were designed to test the students understanding of scientific concepts and ability to read and interpret graphs These questions were set out in three sections Section1 Interpreting data, section 2 Kinematics, and section 3 the scientific process

The questions were presented in a booklet (Appendix C, pg 66-90) The students were asked to complete the booklet under exam conditions, they were not pre-warned that this was to happen, so could not prepare for it This test was conducted on the same day as the other testing

Each part of each question was given equal scoring and the questions were constructed to ensure that all parts were accessible to students without regard to previous parts or sections This was to avoid bias to any subject content

The test booklet was given to all students on the same day and students were allowed 1 5 hours to complete it

This was considered to be a suitable timescale and would not place students under any time pressure thereby ensuring that ability and understanding of the concept being examined would not be hindered by time constraints or time pressure

The three teaching groups were mixed into two larger groups and the testing conducted under examination conditions

The students' results were recorded by Research Number and classified into teaching groups The three groups were the same as the teaching groups during the three years of the Junior Certificate Course A total score was given and percentages established

3 5 4 Bias controls

- The Junior Certificate exam paper given in December was marked by an independent science teacher
- The test booklet was marked by a separate, independent science teacher
- Each student was given a research number and asked to identify themselves only by that number
- The teachers conducting the marking were only given the research number ensuring impartiality in the marking process
- Two non-science teachers were hired to invigilate the testing
- Marks for the Junior Certificate tests were awarded in accordance with the standard marking instructions to teachers
- A suitable marking scheme was established for the test booklets allowing for the range and experience of the students (Appendix D, pg 91-94)
- The teachers of each of the groups A, B, and C have at least ten years' experience of presenting students at this level In previous years no distinction has been made by students, parents or the school with regard to student performance when in any particular teacher's classes
- Influence of current subject choice on test results was considered (see section 3 7 4) and considered negligible

3 6 Type of analysis conducted

As the data gathered for the various aspects of the research were test scores and were for comparison, some assumptions were made as to the type and distribution of the scores It was assumed that the distributions of ability in each of the groups were similar and that the scores on the test were normally distributed

The size of each group was Group A – 15, Group B – 15, Group C – 14

Data are analysed by **t**-score All tests were considered to be two tailed as no prescriptive hypotheses were used This would allow for any one group to be shown to have performed better than the other without prejudice Fully detailed analysis is shown in Appendix G, pg 106-113

The **t**-score test was used to indicate statistical significance The **t**-score compares the mean of each sample along with the sample variance In identical samples the difference in the mean would be zero and $\mathbf{t} = 0$ Values of **t** are considered significant when, along with the degrees of freedom, the value indicates a variation from zero in accordance with the standard deviation In each figure following, the values of **t** are indicated along with the probability

The value of **p** indicates the probability of the test result happening randomly Small values of **p** indicate the unexpected quality of the result i e that the result is unlikely to be random, high values of **p** indicate that the result could be expected normally Throughout the research an α value of 5% is taken as significant Values of **p** will be compared to this α value

3.7 Comparison Tests

3 7 1 Comparison of Results in Junior Certificate Science in June 2002

All three teaching group Junior Certificate Science examination results were obtained from school records and analysed by performance in science

The results from groups A and B were compared as both of these groups were taught in a traditional manner with no great emphasis on experimental or enquiry based learning approaches There was no significant difference in the test scores achieved by the two groups, as expected for mixed ability classes (Details are available in Appendix G, pg 113)

Comparison was then made between Group C and the combined groups A and B (Details are available in Appendix G, pg 111) It was felt to be reasonable to combine groups A & B for comparison as they were clearly of similar ability and scored equally well as shown previously The results shown in figure 3 5 suggest no significant difference in the attainment between the groups

With a **p** value of 0 981 with α= 0 05 there is no significant difference between the attainment of group C and the combined groups A & B This comparison shows that, in terms of current examination requirements, there is no disadvantage to students in using an investigative approach to learning science

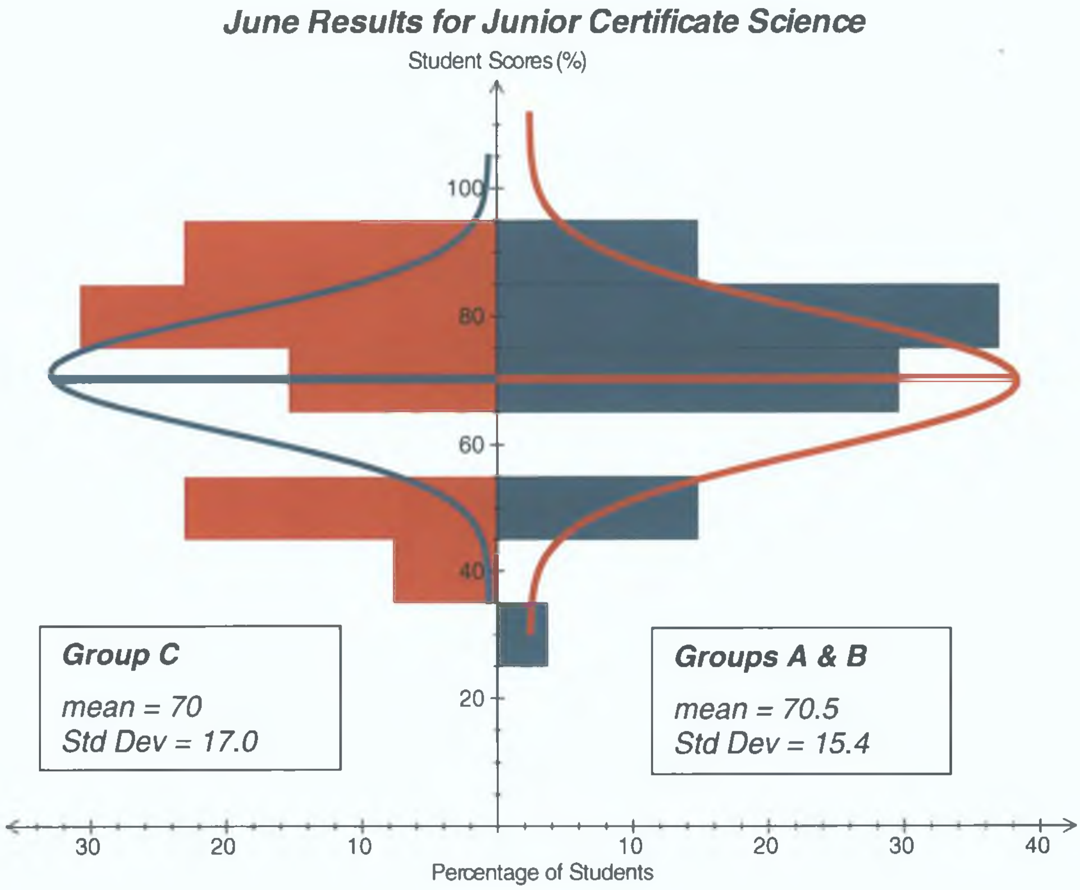


Figure 3.5

t = 0.024, **p** = 0.981

This comparison also serves as a benchmark for the relative abilities of each group showing that groups are equally able and spread in ability in science. It also confirms that students gain no significant advantage when taught by any of the three teachers. According to these results student performance in the Junior Certificate examination is not a suitable measure of the efficacy of an investigative science course.

3.7.2 Comparison of results for Retention Testing in December 2002

To compare the retention and understanding of students in each group, the June 2002 Junior Certificate Science exam was re-taken by all students again in December 2002. A number of students in each group had continued science courses after third year, but this did not influence the results. (See Section 3.7.5, pg 68).

Once more the groups are compared by teaching style, group membership being exactly as before. There was no significant difference in the test scores achieved by groups A and B, both of which were taught in a traditional manner with no great emphasis on experimental or enquiry based learning approaches either group. (Details are available in Appendix G, pg 114)

Group C and the combined groups A and B were compared. (Details are available in Appendix G, pg 112). The results shown in figure 3.6 show a significant difference in the attainment between the groups. The students taught in the investigative manner have retained/understood significantly more of the science concepts than the other groups. The mean score of group C is 17% higher than the mean score of the combined groups A & B. The group C marks are again strongly skewed towards high scores.

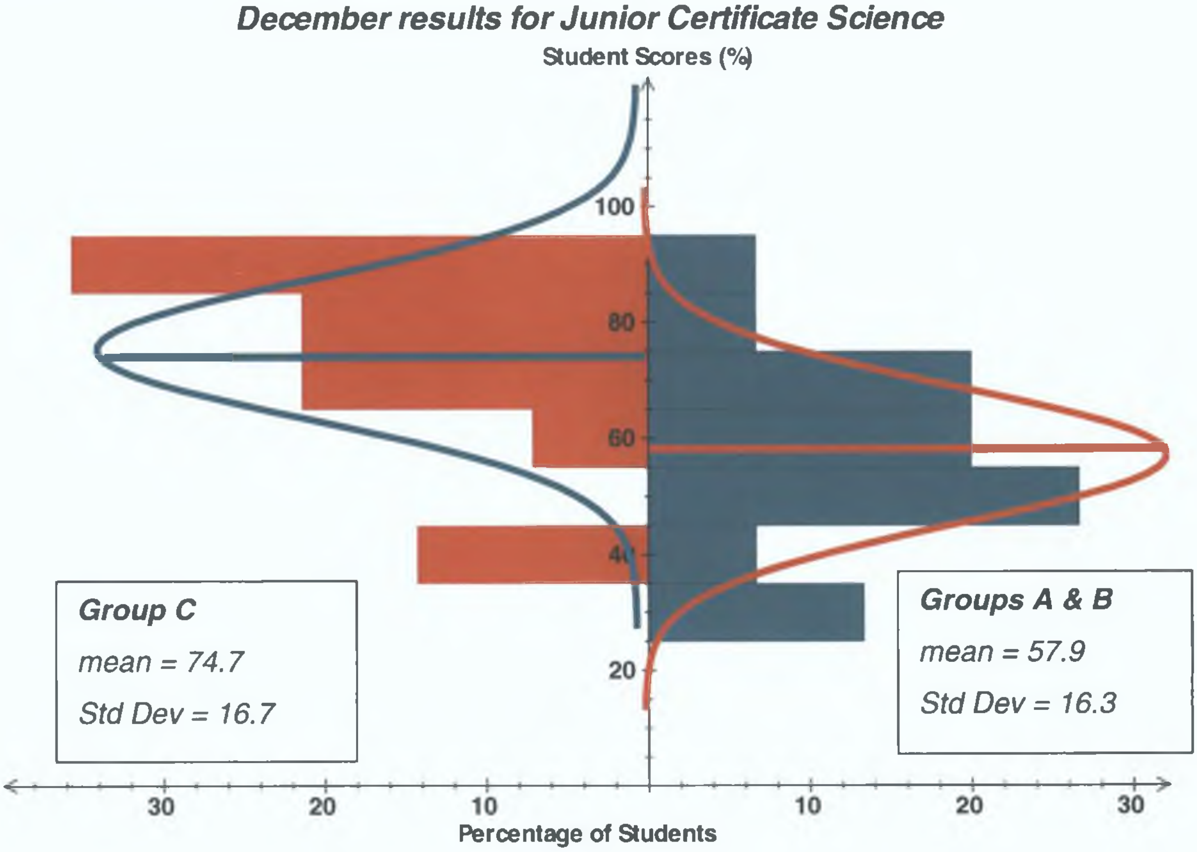


Figure 3.6

t = 3.074, **p** = 0.004

With α= 0.05, and even at α=0.01, the **p** value of 0.004 shows that there is a difference in the results for group C compared to groups A & B.

Summary of Junior Certificate exam results, June and December 2002.

We now consider the individual scores achieved by the students in June and December.

The student band (median score) in June 2002 was compared to the same band analysis when December 2002 scores were restructured in the same manner. After June 2002, 4 students left

Sutton Park School to continue their studies elsewhere. Only the results from students who sat both exams (June and December) were compared.*

The change in percentage score was recorded for each student and graphed. It can be clearly seen that Groups A and B both show a similar reduction in scores but that Group C shows an improvement in score. (Details are available in Appendix F, pg 102-103) .

	Size	Difference in performance	Average Gain/Drop
Group A	14	-190%	-13.61%
Group B	12	-140%	-11.66%
Group C	14	55%	3.92%
Total	*40		

Table 3.1

*Only the results from students who sat both exams (June and December) were compared.

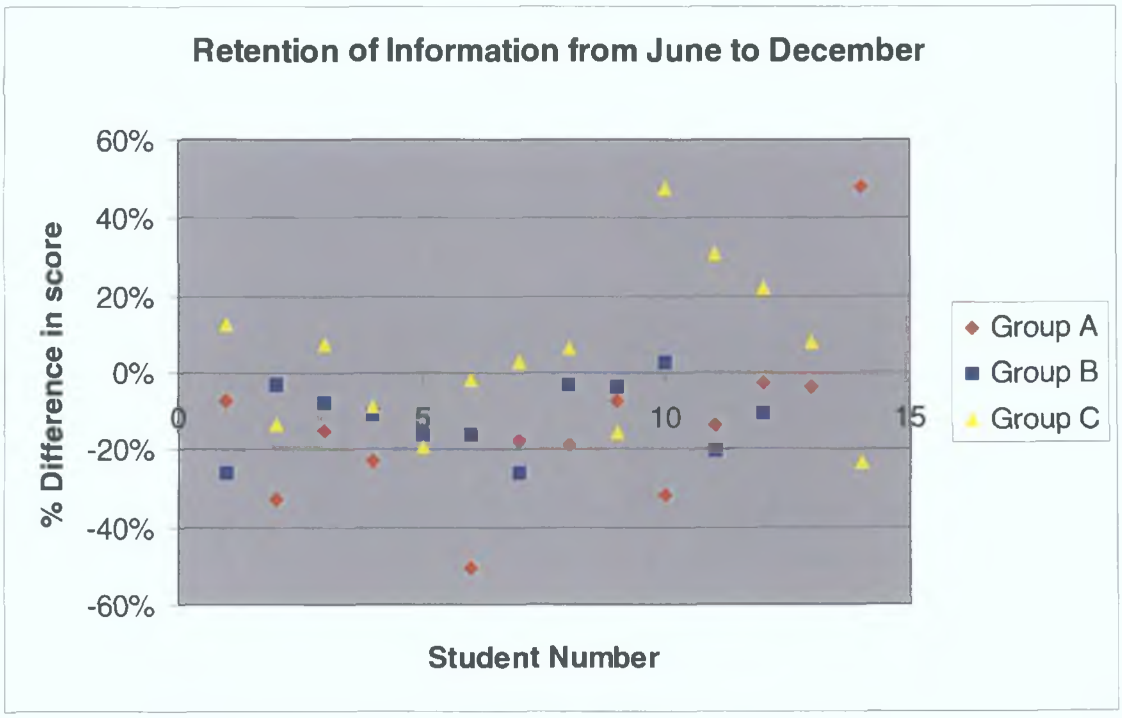


Figure 3.7

The difference in achieved grades in December 2002 for Groups A and B follow what would have been expected to be a natural reduction through lack of retention of information memorised prior to the State Examination in June 2002 Group C students have not shown the same reduction Rather, their roughly similar performance confirms that an understanding of the concepts being tested as facts were not forgotten in the period between the examination and the retest six months later Whether students studied Physics, Chemistry or Biology from September 2002 to the time of testing in December 2002 was considered (see section 3 7 4, page 55) and was thought not have influenced the findings

The findings clearly show that students, who could not be separated in ability by the State Examination in June, have markedly different abilities in Science after a further six month period The effects shown are most likely the result of the investigative process over the three year period contributing to a clear understanding of many of the scientific concepts of the syllabus

3 7 3 Comparison of results for Science Test Booklet

The science test booklet (Appendix C, pg 66-91) was designed to test student ability in three areas,

- Section 1 interpreting data
- Section 2 motion-time graphs
- Section 3 the scientific process

As before, performance of groups A and B were compared As before, there was no significant difference in the performance of students in group A & B and so they could be combined for research purposes (Details are available in Appendix H, pg 116)

A comparison was made for the overall score on the test booklet between the combined groups A & B and Group C Results are shown in Figure 3 8 (Details are available in Appendix H, pg 117)

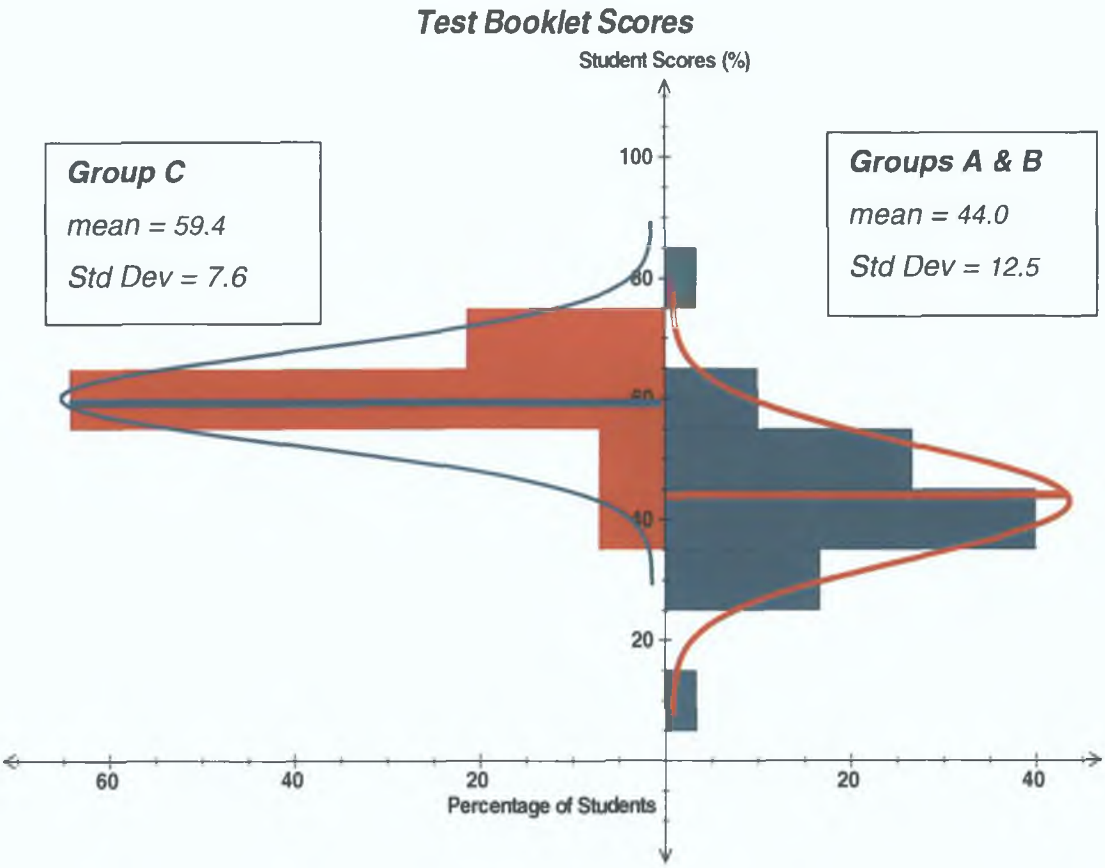


Figure 3.8

t = 4.161, **p** = 0.0002

As in the Junior Certificate December results, the students from group C have performed significantly better than students from the more traditional teaching approach. Their average score was 15.4% higher than the average score from the combined groups A & B. It is interesting to note that groups A & B contribute the highest (80%) and lowest (33%) recorded scores. These outliers have no marked influence on the statistics.

The information acquired from the test booklet was analysed in detail to determine which areas were significantly different between the groups.

3.7.3.1 Section 1: Interpreting data

Questions in section one of the test booklet, *Interpreting Data*, were designed to test students on their ability to read and interpret data from graphs. (Details are available in Appendix H, page 118).

Research (Mee, 2002) and informed opinion through observation (Tinker, 1999) have suggested that students using datalogging are not able to read specific information from graphs as well as students used to manual methods. This is a common belief held by teachers who do not use datalogging technology, and is often cited as the reason why they do not use it.

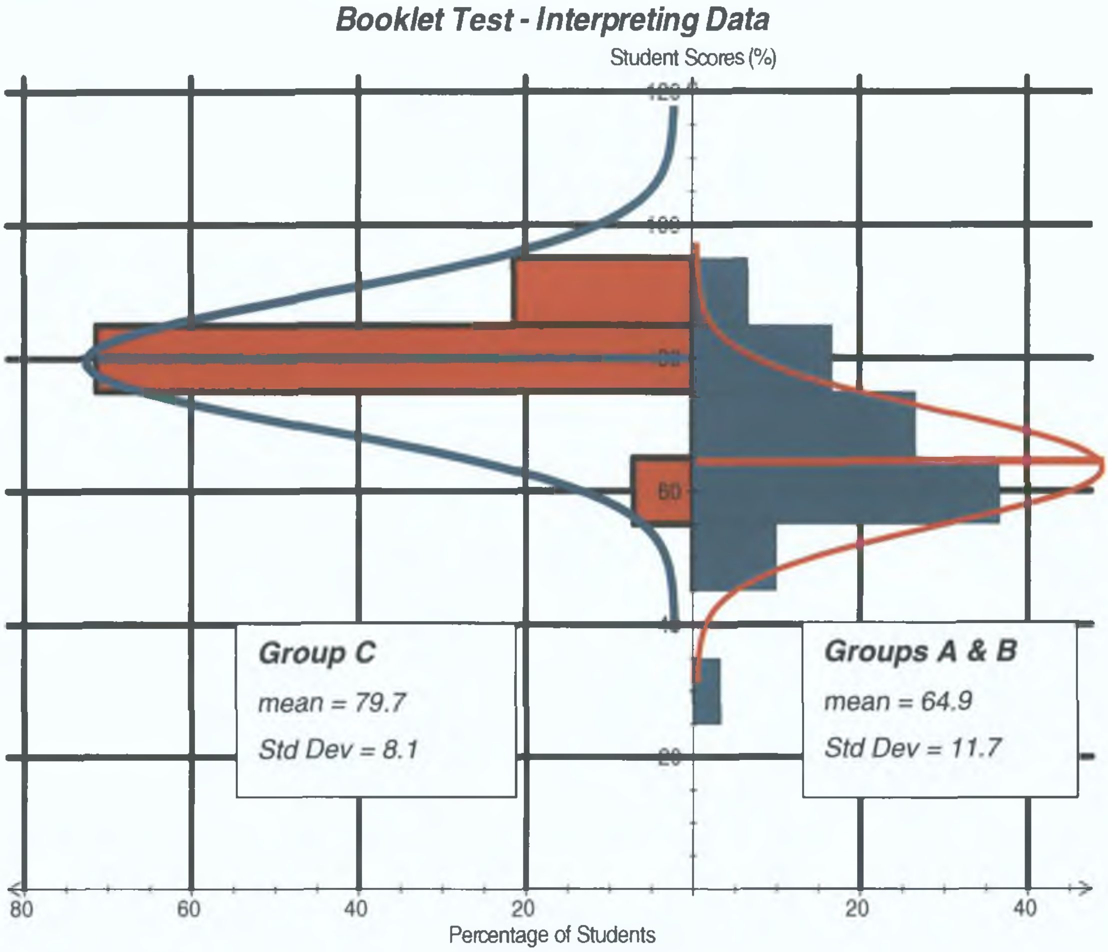


Figure 3.9

t = 4.154, **p** = 0.0002

Results Section 1:

The results in Figure 3.9 show that students from group C have performed better than those from groups A & B- the mean score of group C was 15% higher than that of groups A & B. The students using datalogging as part of their investigation clearly show a better ability to read specific data as well as data trends from graphs. Those students who have been more used to drawing graphs manually have found greater challenges in interpreting the data. Indeed this result is not surprising as drawing graphs and interpretation of data is not a skill required for Junior Certificate science.

Statistical analysis was carried out on each question in section 1 to determine if there was any difference between the scores obtained on individual questions. The **t**-score for each question was calculated and recorded. The questions showing **t**-score values greater than the critical value of α at both 1% and 5% significance was noted Particular data can be found in Appendix H, pg 123

Seven questions were found to show statistically significant differences (at the 1% level) in response between the combined groups A & B and group C In no cases were the results of group C students poorer than that of the combined groups This would appear to completely disagree with the findings of Mee (2002) and of the observations of Tinker (1999)

Of the questions highlighted, four involved interpreting the shape of a graph and the other three required students to read data directly from a graph and interpret the information The strongest disparity in response was for reading data from a pie chart

If significance is lowered to the 5% level, a further 11 questions show differences in the quality of response All of those questions involve the ability to read and interpret data from graphs or tables Again, Group C students fared better in all cases than students from the other groups

It could be argued that prolonged use of datalogging hardware and graphing software when used and questioned properly can offset any tendency to casualness from students Conceptualisation of ideas along with the ability to recognise hard data would appear to be equally possible with prolonged use of this investigative technique

3 7 3 2 Section 2 Kinematics

This section tested the students' ability to interpret motion time graphs The questions were restricted to distance / time graphs and velocity / time graphs (Details are available in Appendix H, page 119)

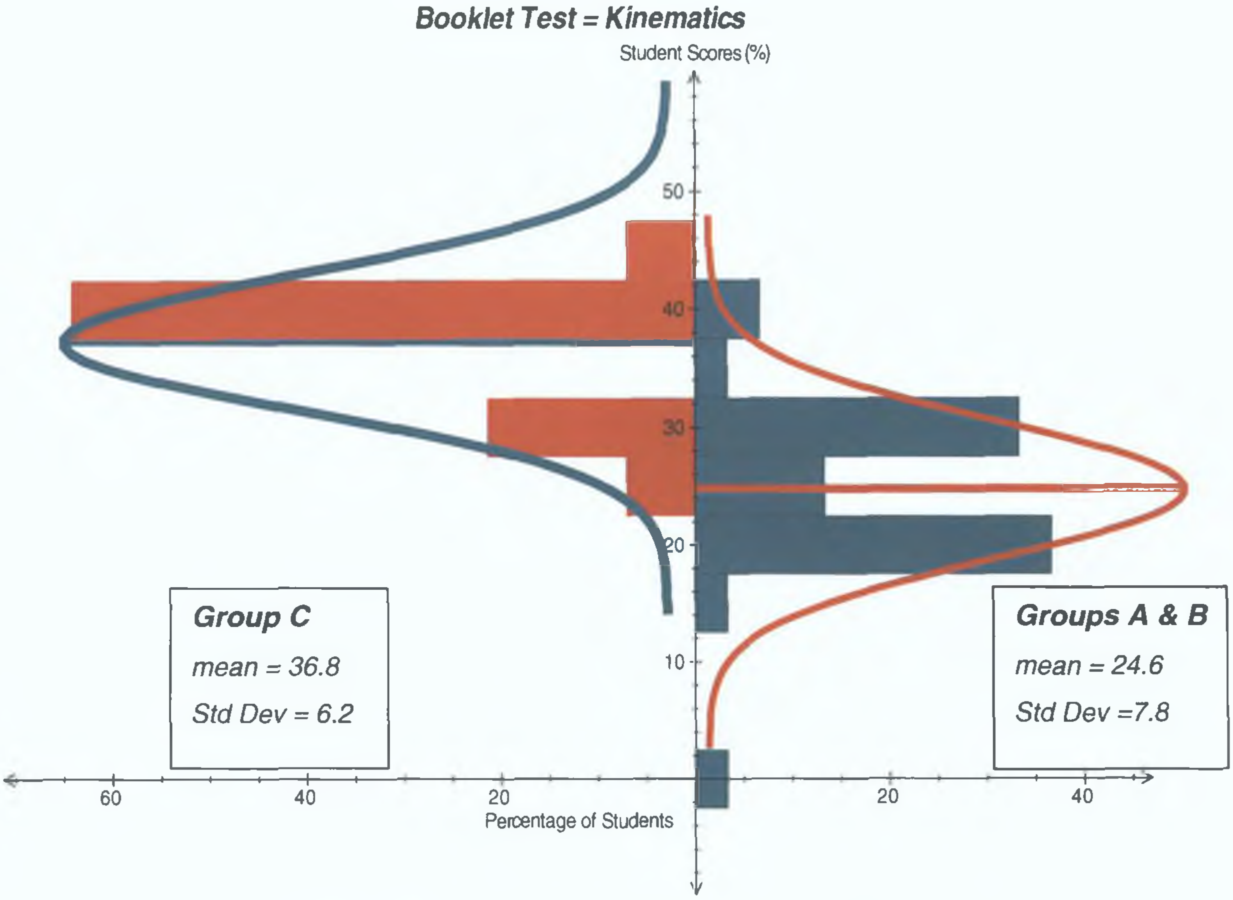


Figure 3.10

t = 5.023, **p** = <0.0001,

Figure 3.10 shows the comparisons between groups when tested on kinematics. Students from group C show a 12% increase in score over students from groups A & B.

The main difference was in the students' ability to interpret distance time graphs. Both groups of students performed poorly on velocity time graphs. The poor scores on the velocity /time graphs contributed to the poor overall results for this section. Velocity /time graphs are not examined at junior certificate level.

These findings agree with research (McKenzie & Padilla, 1986) that has found that students who study kinematics using real-time graphing have a better understanding of motion time graphs than those who use traditional methods. Analysis of questions relating to concepts outside the curriculum, *viz.* velocity-time graphs, shows no significant difference between the teaching groups. The difference lies in the understanding of topics that they have been taught.

3.7.3.3 Section 3: Scientific process

In this section students were asked to consider possible outcomes of investigations, construct their own experiments, make predictions based on experimental data and describe relationships between variables. (Details are available in Appendix H, page 120).

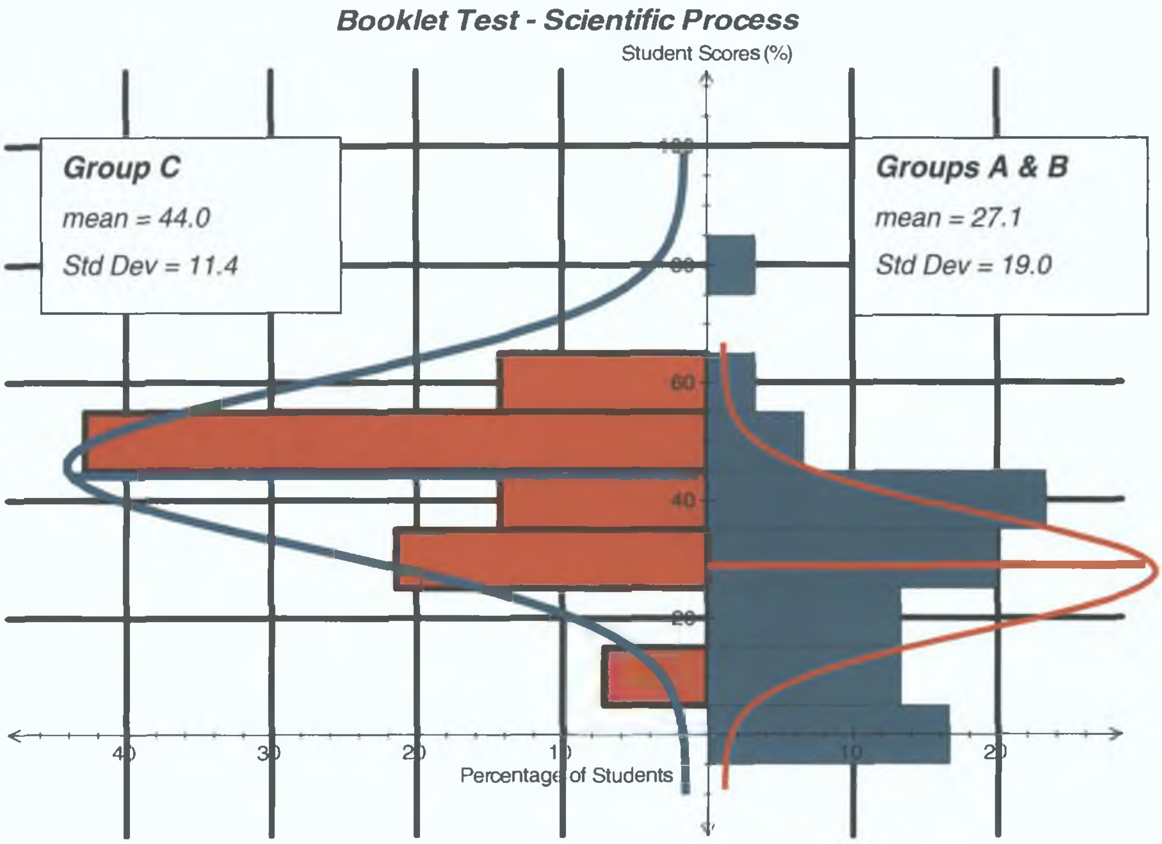


Figure 3.11

t = 2.999, **p** = 0.005

Figure 3.11 shows the comparison between students' abilities to use the scientific process to consider problems and situations and design experiments to suit. As with the other sections, students from group C show a significant (17 %) increase in score over students from groups A & B.

3.7.3.4 Conclusion

The results for all sections of the booklet are consistent, and show that those students who were taught in an investigative way using datalogging performed better in graph analysis and interpretation and the scientific process than those who have been taught in a more didactic way. The lack of manual graph drawing during the three years of this study did not affect the ability of those students to use graphs; in fact the use of electronically derived graphs during investigations has improved their understanding.

3.7.4 Influence of current subject choice on test results

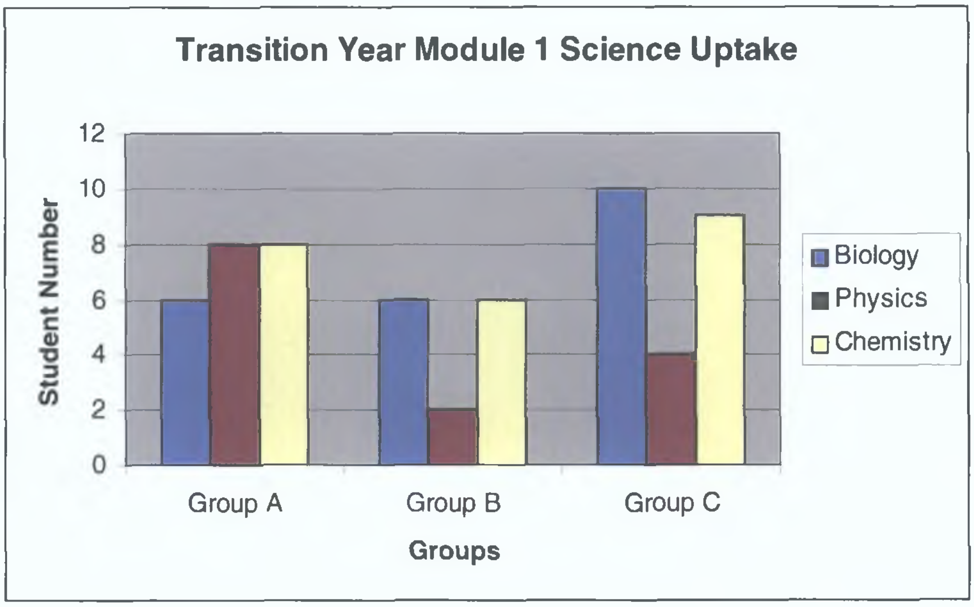


Figure 3.12

As this testing was done in December of fourth year, a survey was carried out of students to determine which science subjects they were currently studying to compare possible influences in discrete subject scores. (Details are available in Appendix F, pgs 99 and 106). It was thought that an unequal distribution of subjects between the class groups could have an effect on the test results. Figure 3.12 shows the distribution of students at the date of testing. All subjects are well represented; therefore there is no significant effect on results achieved by current subject study for students in any of the three groups. (See section 3.7.6, page 57).

3 7 5 Comparison between Mathematics and Science scores

The comparison of student performance in science and mathematics was considered to be potentially significant as it may serve to influence the ability of students to read and interpret information obtained graphically The results of the students in their Junior Certificate mathematics examination were compared in the same way as the science results (Details are available in Appendix F, page 104 - 105) This should allow a direct comparison between performances of the whole group in each subject discipline

The Pearson Product Moment correlation coefficient was calculated for the data to establish if there was a significant correlation in ability between subject pairs Results obtained suggests

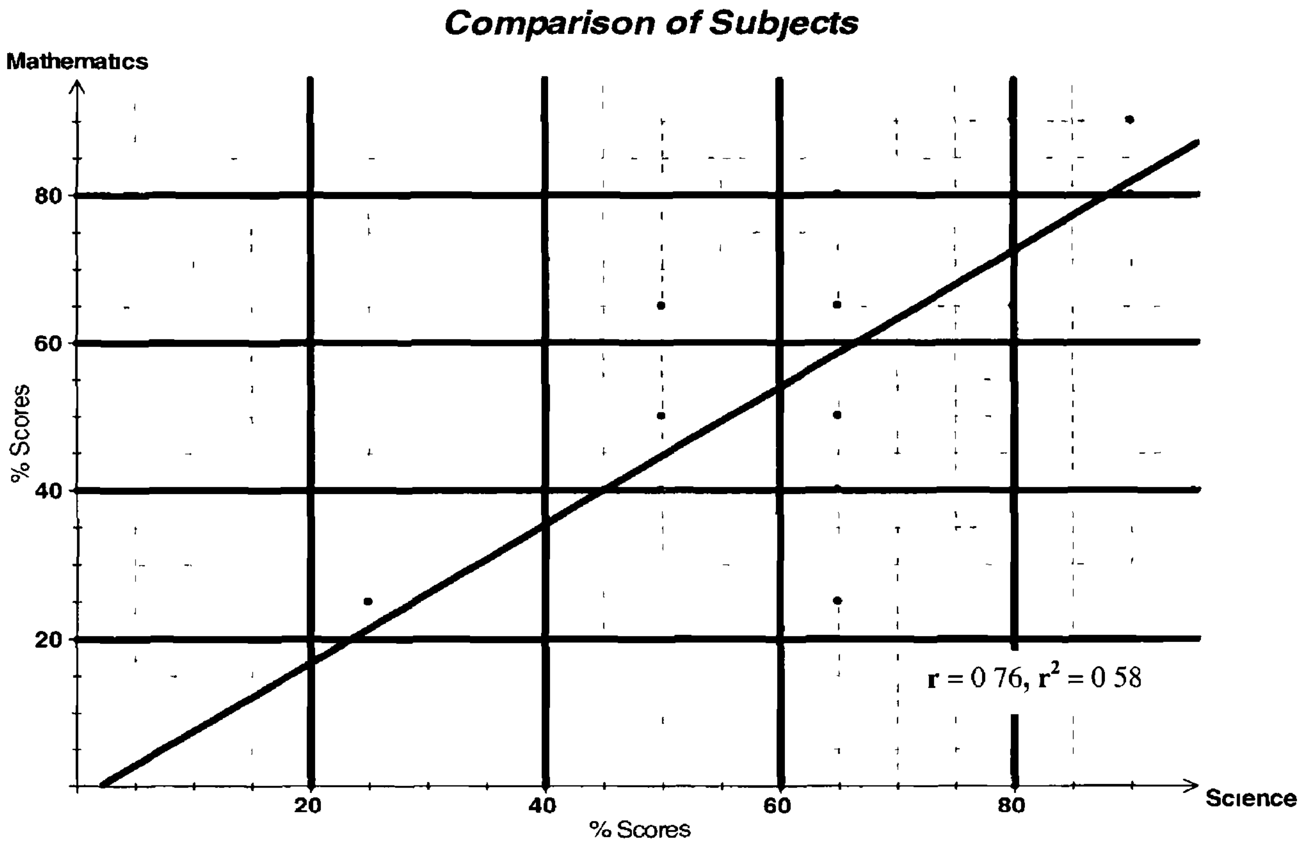


Figure 3 13

that there is a highly positive correlation ($p<0\ 001$) between ability in each subject but values of r^2 (58%) suggests that, in line with widely held beliefs, abilities in maths are generally found to coincide with abilities in science (Details are available in Appendix F, page 104)

3 7 6 Transition Year Subject Choices

In Sutton Park School, transition year is divided into two modules, the curriculum subject choices are the same as those for Leaving Certificate shown in Table 3 2

Physics	Chemistry	Biology
History	Geography	Economics
Music	Art	

Table 3 2

In Module One, which runs from September until December, students are encouraged to choose the option within each of the subject choices that they are least likely to continue through to Leaving Certificate level This is to ensure that each student gets the broadest possible experience of all subjects on offer All students must study at least one science subject in Module One

In Module Two, students choose the option they intend to take at Leaving Certificate level
The science subjects studied by transition year students during Module One were not thought to affect the results of the December 2002 testing for the following reasons

- Each of the subjects was well represented by each of the groups A, B and C ensuring an even spread of physics, chemistry and biology students throughout the three groups [Fig 3 12]

- The science content in Module One of transition year consists mainly of Science and Technology in society The aim is to give the 'non-scientist' a sense of the place of science in our lives, as well as to consider the importance of Science in a historical context

- Junior Certificate curriculum material is not covered in any way during Module One, nor is kinematics or graphical interpretation

Student choices for Chemistry Physics and Biology for the past five years are outlined below in Table 3 3 Biology has been consistently more popular than either Chemistry or Physics

		1998	1999	2000	2001	2002	Mean
Science	chemistry	7 (15%)	8 (18%)	6(12.5%)	9(24%)	9(18%)	17.5%
	biology	20(43%)	19(43%)	18(37.5%)	20(39%)	22(40%)	40.5%
	physics	10 (21%)	10(22%)	8(22%)	8 (16%)	9 (16%)	19.4%
	Total	37	37	32	37	40	
	Year Group Total	46	44	48	51	55	

Table 3.3

The data are summarised in figure 3.14.

Figure 3.14

The uptake of Sciences for Leaving Certificate by the research group is summarised below in figure 3.15. (Details are available in Appendix F, page 99).

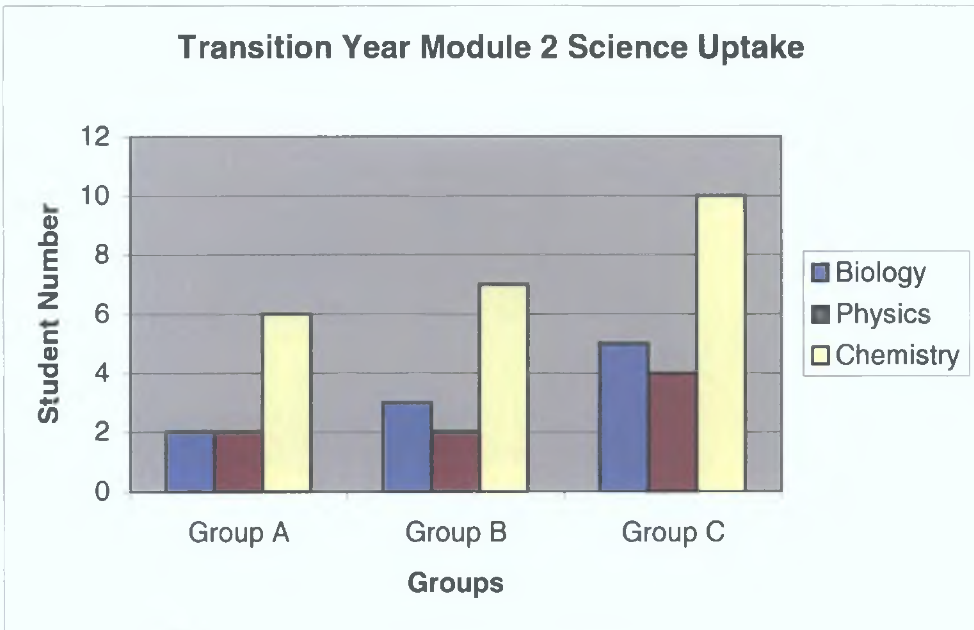


Figure 3.15

Generally, the uptake of Science for Leaving Certificate in Sutton Park School is slightly above the national average. The average uptake of Science subjects in the 5 years up to 2002 was: Physics 19.4%, compared to the national average of 16%, and Chemistry 17.5%, compared to a national average of 12%. (Physical Sciences Task Force Report details are available in Appendix F, page 100).

This trend is continued with students from groups A & B, Physics (16.6%), Chemistry (30 %) and Biology (13.3%). An interesting trend in this group is the increase in uptake of Chemistry and the decrease in the uptake of Biology, against the national trend. This may be explained by the fact that In Sutton Park School, of all the sciences, datalogging is used most in leaving certificate chemistry as the researcher is the chemistry teacher.

In group C the uptake of science subjects for leaving certificate was: Chemistry 71%, Physics 50% and Biology 48%, showing a marked increase in numbers electing to continue studying science into Leaving Certificate. The actual numbers of students electing to take science within each group are as follows:

Group A: 6 from 15, Group B: 5 from 15, Group C: 12 from 14.

It is often argued that student experiences at Junior Certificate greatly influence their subject choices for Leaving Certificate. The Physical Sciences Task Force (2001) commented on the lack of practical work undertaken by many students and sees this as one of the contributing factors influencing student uptake of Chemistry and Physics.

As has been highlighted earlier, performance in State Examinations was similar for all students in the three groups, and with the other factors equal, the only substantial difference in influencing students would appear to be the practical nature of their experiences at Junior Certificate On this basis, this research supports the comments of the task force on the physical sciences Although the research did not set out to examine the influence of datalogging on the uptake of science subjects for leaving certificate, this result is seen as a key outcome of the research project, and should not be overlooked, and is worthy of further research

3 8 Comparison of Performance by Gender

One of the recurring points made by commentators of Irish and international science courses is that of the poorer performance of girls in science and the numbers of girls continuing science into Transition year and beyond The performance of students by gender in both sets of December tests and in the June test was examined

The analysis was conducted for the combined groups A and B who had followed the traditional teaching style and then for the students of Group C who had followed the investigative teaching style There is no difference in ability of female students to male students in all cases The results by gender for all tests may be found in Appendix J, pg 133-140

3.9 Conclusions

Students who have participated in this study have shown a marked difference to their school counterparts in the variety of tests given It is clear that teaching and learning in an investigative manner using datalogging systems influences students' abilities to understand the fundamental concepts of Junior Certificate Science

Theories of multiple intelligences (Gardner, 1993) affirm the student need for a variety of teaching and learning approaches to broaden their ability to fully understand the concepts being taught It is evident from the testing that an extended period of time using an investigative approach to teaching and learning has a beneficial long term effect on students

It is also clear that students are not disadvantaged within the current examination system with its clear emphasis on memory However, as the six month retest clearly demonstrates the current state curriculum and assessment practices do not foster student understanding of fundamental concepts and longer term recall This is an issue which is being addressed within the revised

Junior Certificate Science Syllabus Hopefully, the evidence portrayed here will generate the discussion required to move towards a more thoughtful examination at this level

Retention and understanding are clearly improved and student numbers participating in further scientific study are improved, but further research is required to quantify these gains beyond the observations described here

This research shows that students engaged in the scientific process from an early stage of second level education show improvements beyond that expected from traditional approaches in science There is no evidence to support the view that students become 'lazy' when software produces graphs or tables There is strong evidence to support the well established view that students who engage in discussion before, during and after experiments gain more fundamental knowledge of the scientific concept being taught than would be the case otherwise

The numbers of students continuing to study science at Leaving Certificate clearly demonstrates that using an investigative approach coupled with datalogging technology motivates students towards continued studies in science

It is important for science teachers to become more aware of the issues surrounding the learning and teaching strategies available to them and consider influential approaches in the use of investigative learning and graphicacy approaches to develop fuller, deeper understanding of this engaging subject

References

Report of the Task Force on the physıcal Scıences,(2000) avaılable at

http //www scıencetaskforce ıe/report/report pdf

Gardner, H (1993, 2nd Edıtıon) Frames of mınd the theory of multıple ıntellıgences *London Fontana*

McKenzıe, D and Padılla, M The constructıon and valıdatıon of the Test of Graphıng ın Scıence (TOGS) *Journal of Research ın Scıence Teachıng 23,* 571-579

Mee, A (2002) Are Students Who Use Data Loggıng ın Leavıng Certıfıcate Practıcal Work at any Dısadvantage ın Drawıng Graphs Manually?, *WORKING PAPER, School of Computer Applıcatıons, Dublın Cıty Unıversıty,* June 2002

Tınker, R A Hıstory of Probeware, *The Concord Consortıum,* avaılable at

http //www concord org/research/probeware_hıstory pd

Chapter 4 Datalogging and teachers

4.1 Introduction

Research suggests that context of use is a significant determinant in realising the potential of data logging Therefore, it is important to consider the practicalities of using data logging methods at classroom level Five science teachers who use datalogging on a daily basis were interviewed to record their experience in using data logging in their science teaching The teachers volunteered to be involved in this research study and were invited to do so because of their interest in using data logging methods in the laboratory The teachers were enthusiastic about the use of ICTs in general, and between them have many years' experience in science teaching

A further 26 teachers from different schools all around the country were asked to introduce datalogging to their teaching of Junior Certificate Science, and then answer a detailed questionnaire reflecting their experiences These teachers were given a full day's training on datalogging for Junior Science, and a detailed book of instructions written by the researcher (Appendix B, pg 11-65)

4 2 Interviews with 5 teachers:

The teachers were asked to discuss the following topics

- Teachers' rationales for using data-logging methods in their science teaching
- Factors which facilitated the use of data logging in teaching
- Potential problems
- The influence of curriculum and assessment on practices of data-logging

4 2 1 Teachers' rationale for data logging

The main reasons given by the five teachers for datalogging were as follows

- In an information age, technology is a vital part of the everyday life of students The ability to use technology is a life skill Hand-held data logging is a way of placing useful technology into the hands of the students

- Hand-held data logging equipment allows students to perform the experiments themselves and collect their own data thus encouraging student participation in investigations

- Investigations that were previously impossible are facilitated by the range of sensors and the range of sampling times.

- Using this equipment facilitated mixed ability teaching; Students are able go at their own pace. Those with the cognitive ability to go beyond the scope of the investigation can explore further. Those with less ability still have the satisfaction of obtaining a graph that is clear and easy to read. Each of the teachers surveyed found this technology particularly suitable for use with students with learning difficulties. By following simple instructions, students can produce an accurate graph and "get it right". This can be used as a confidence builder. The student's progress in an investigation is not hindered by his or her inability to draw a graph.

- There is demand for a higher order type of investigation when data logging is used because the equipment lends itself to a much more open-ended approach to practical work. Students often use the fact that they have multiple probes and multiple capabilities of data-collection to invent new activities.

- Because of the sensitivity of the equipment it is possible to use smaller volumes of solutions at lower concentrations. This has implications both for running costs and environmental costs.

- Students enjoyed using the technology.

4.2.2 Factors which facilitated the use of data logging

Money (IR £ 6,000) was made available for the purchase of datalogging equipment by the Department of Education and Science. A list of equipment needed for chemistry and physics was furnished to each school in Ireland that offered Chemistry or Physics at Leaving Certificate.

In service training in Physics and Chemistry datalogging was provided by the Physical Sciences support services. All the data logging experiments were set out and each teacher was encouraged to complete each one of them.

The teachers involved in these interviews also attended a day-long training session conducted by the researcher in Dublin City University in January 2002. They also received a manual written by the researcher which contained very clear written instructions for 26 Junior Certificate experiments (see Appendix B, pg 11-65)

The data loggers work with a simple menu driven program Students are very familiar with this type of interface, as it is not unlike a mobile phone menu Several options appear on the screen one is chosen and this takes you to the next screen as in the example shown in Figure 4 1

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen from DataMate on a Calculator

Figure 4 1

Two of the teachers mentioned the advantage of having at least one or more enthusiastic and experienced colleagues Enthusiastic colleagues help and support each other, and brainstorm problems

4 2 3 Potential problems

With any use of new technology there is a steep learning curve to be overcome There are many teachers who still have a fear of technology and are wary of anything that may challenge their methodology in teaching This is a very natural and common response to the introduction of something which has the potential to change the method by which they teach their subject

Time in implementing new technology was seen as a potential obstacle, however, once the equipment was in regular use, this problem was overcome Some teachers do not like using equipment with students unless they are expert in its use themselves

All the teachers alluded to the fact that the use of this type of equipment actually enabled students to become more empowered which, although liberating for some teachers, is terrifying for others

As with any technology, dataloggers malfunction occasionally The teacher has to know how to fix these problems fairly quickly or else the whole class may lose its focus To get a misleading result from an electronic piece of equipment can be damaging as children tend to believe what they see on the screen It is important that the teacher has enough confidence to sort out any problems on the ground Class time can be wasted setting up or fixing faulty equipment

4 2 4 Curriculum and assessment issues

If datalogging activities were specifically written into the curriculum, more teachers would use it Planning at Department level was seen to be important as it can be matched with a whole planning of ICT skills development for pupils Implementation of ICT must be done in a very structured way so that it is built into the teaching and learning and enables both teachers and pupils to develop skills with time

The choice of context in which data logging was used was seen to be important Teachers should make judgements about the purpose of an activity and whether there is added value by including data logging If data logging is used just for the sake of using it, some investigations may become over complicated One other teacher said that he does not use data logging unless it makes the practical easier for the students, easier for him, and, more importantly, clearer and easier to understand All teachers agreed, the simpler the data logging approach, the more likely it was to win the teachers' support

With regard to assessment, the teachers all agreed that any change in teaching methodology and approach should be linked to a change in assessment It was thought that datalogging may not have much of an effect on assessment as it is now Students are generally asked to regurgitate learned-off facts, so their text book is more useful to them for the exam than carrying out experiments

Teachers felt that if the assessment did reflect the investigative nature of a syllabus, the use of datalogging would benefit students, also, any assessment of course work will advantage those students who use datalogging compared to those who don't, both in accuracy of results and presentation of reports

One of the teachers surveyed said that he did not include much evaluation of data, because the emphasis is still on the acquiring of the data Students know the shape of the line that they are supposed to get before they get it, and they are not asked to evaluate it The same teacher said that he would like to include more evaluation, but that given the constraints of the assessment he felt that there was not time, or need to do this The evaluation of data requires a higher order level of thinking and a whole other set of skills which, though desirable, were not really necessary at this point for assessment

4. 3 Proposals / suggestions for future development:

The 5 teachers were then asked to discuss the following issues in relation to future development

- The ways in which data logging activities might be integrated into a lesson sequence
- The skills needed to be developed by pupils and teachers using data logging
- Identification and aspects of data logging that teachers would like to develop next

4 3 1 Ways in which data logging activities might be integrated into a class

This group of five teachers said that the best examples of using datalogging in the classroom occur when the logger and the software work as tools for the teacher and for the students, not as content, but as teaching and learning aids This allows for scientific enquiry to take place, the students use the technology to answer questions that they ask themselves, not questions that the teacher asks

When very detailed instructions are given there is a danger of the procedure taking on more importance than the science All the teachers used in this survey were provided with a very detailed set of pupil worksheets (see Appendix B, pg 11-65) Initially, all teachers thought that these would be an invaluable resource to them, however as students became more familiar with the apparatus they found that they did not need such detail This led to teachers producing different types of worksheet which, instead of giving instructions on which buttons to press to record the data, asked them questions about the events occurring during the investigation Observation plays an important role during most datalogging activities Questions asked of pupils as the investigation is ongoing have much more relevance when answered at the time of the investigation Often events happen during an investigation which the student will forget about later that evening when writing a report for homework

4 3 2 The skills needed to be developed by pupils and teachers using data logging

Proficiency in ICT is becoming increasingly important as a life skill for all students Schools that take their role as educators for life seriously are aware of this need and try to broaden the exposure of students to the regular use of ICT Science is a vehicle which is well suited to such developments

All the teachers interviewed agreed that the students benefit in many ways from the regular use of the data logging systems They suggested that a number of skills require to be developed to make best use of the learning potential of the system and that this is best built up over a period of time

All were agreed that the students need time to become familiar with the calculator interface and the use of probes in the datalogger itself The hardware was not seen as difficult to master or difficult to use and the students quickly grasped the functionality available The concept of connecting a number of probes was easily accepted

This was reflected in the time taken to master the software interface Again, time spent initially was well rewarded in later use as students quickly grasped the use of the technology to carry out tasks Students quickly moved from following a 'recipe' of instruction, as shown previously, to accepting general instruction as to the setup of the interface to collect specific types of data over a given time interval and to display the results accordingly

When students undertake the type of open-ended investigations that datalogging facilitates, they require understanding of the variables involved and the range of values being collected as well as an understanding of the nature of the relationship between sets of data Two of the teachers interviewed felt this was beyond the necessary skill level required of students, being content merely to discuss the general shapes and features of graphs The other three felt that this level of enquiry supported the full understanding of the experiment, the concepts being investigated and the skills required of further study in all aspects of scientific examination

Storage and retrieval of data was not found to be difficult when student access to a stand-alone P C system was available in the laboratory Students were able to demonstrate advanced skills when reporting, as graphs and data were 'dropped' into word processing packages to enhance the delivery and presentation of information

Most importantly, all teachers noted the willingness of students to engage in extended use of the systems This generally involved dealing with the curious questioning of students and the posed 'what if ' scenarios This was seen as important enough in itself to justify the time and effort spent in encouraging students to use and experiment with the data logging systems This observation and reaction by the teachers supports much of the constructivist theory of learning and learning styles

Teachers' formation of skills was by their very nature similar to that of the students They also had to familiarise themselves with the operation of the systems and software They felt that they had to have a greater understanding of the system to allow them to pre-empt problems which their students would meet

Teachers commented on the need to develop new teaching skills When students become more involved with the planning of an investigation, they tend to ask more open-ended questions The ability to pose a question and allow students to examine, by themselves, a solution or suggestion was seen as rewarding to teachers

Finally, teachers found themselves consulting others to discuss different approaches to experiments, as well as considering the syllabus more thoughtfully to find more engaging practical approaches to effective learning using the data logging system Again, the ability to discuss with others is known to be fundamental in the reasoning and learning process, and it may be this which has had the greatest influence on the interviewed teachers' positive response to the teaching and learning capabilities of this system

4 3 3 Identification and aspects of datalogging that teachers would like to develop next

Teachers were agreed of the need to extend their knowledge of new developments, new probes and improved interfaces Most teachers had already extended the data logging system beyond use only in Junior Certificate The remainder were agreed that the capabilities and flexibility of the systems allowed for use throughout the school

Colleagues of the 5 experienced teachers have started to ask for more support materials to extend the use of the data logging systems All teachers were agreed, as previously, that material should be of the form of suggestions of approach rather than a detailed pupil sheet More discussion of the actual concepts and extensions would be more helpful for the staff This was thought to be essential in the longer term

Three of the interviewees were concerned that the effective learning approach employed here may well create problems for the more traditional experiment where data logging was not possible or useful They were concerned with the continuity of teaching approach, especially when it had proved to be effective, in these other cases The syllabus and particularly the assessment were thought to require revision to account for this approach

Teachers were strong in their assertion that assessment should reflect the greater emphasis on analysis and understanding of the scientific concept rather than the mere collection and recording of data. Without this development, it was thought that science education in Ireland would fail to grasp the opportunity to advance beyond the rote learning style of old towards the

Qu. 9	I demonstrated most experiments pre datalogging?
Qu. 8	My students seldom did experiments pre-datalogging.
Qu. 1	I regularly used technology in my classroom before using datalogging.

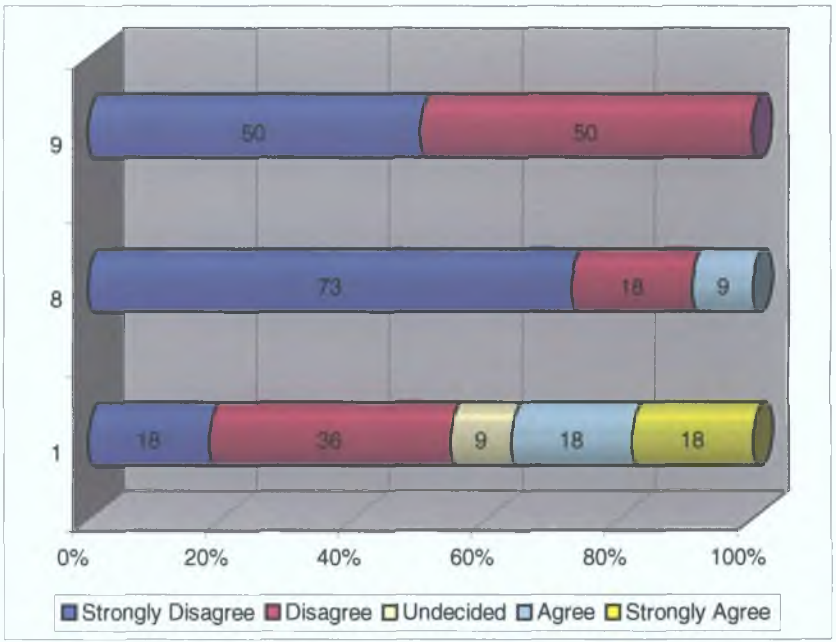


Figure 4.2

more systematic investigative approach available to students using this learning system.

4.4 A questionnaire involving 26 teachers

A questionnaire was constructed to survey the experiences of 26 teachers after using datalogging for a year with Junior Certificate students. The number of responses from the teachers was good with 22 responses from 26 requests. The teachers' responses are grouped into question categories as appropriate. The questionnaire and graphics of results are shown in Appendix I, pg 124-132. The main outcomes are reported here.

4.4.1 Questions on Previous Practice

The teachers were asked about their approach to practical work and their expertise or otherwise in technology before using datalogging [Fig 4.2].

Over 50% of teachers had engaged in practical work with students before the acquisition of datalogging technology. More than half of teachers admitted to not using some form of technology, which suggests a traditional learning environment for students.

4.4.2 ICT skills

Although some found the datalogging system difficult to use (<20%) there was a strong feeling amongst the teachers that the process had improved their overall IT skills [Fig 4.3].

Qu. 10 I found the datalogging systems difficult to use.

Qu. 3 I have improved my I T skills as a result of using this technology.

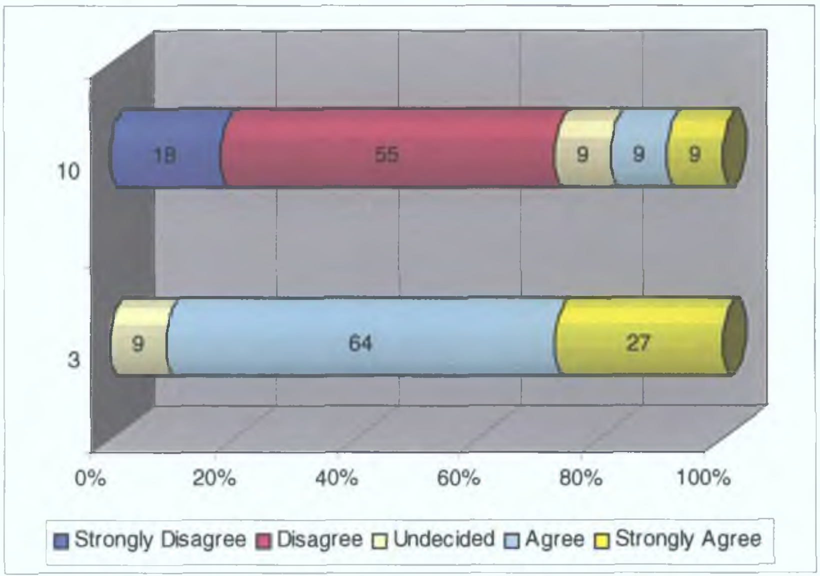


Figure 4.3

4.4.3 Teacher attitudes to the Professional Development Training

Qu. 14 I need more training.

Qu. 13 My training was adequate.

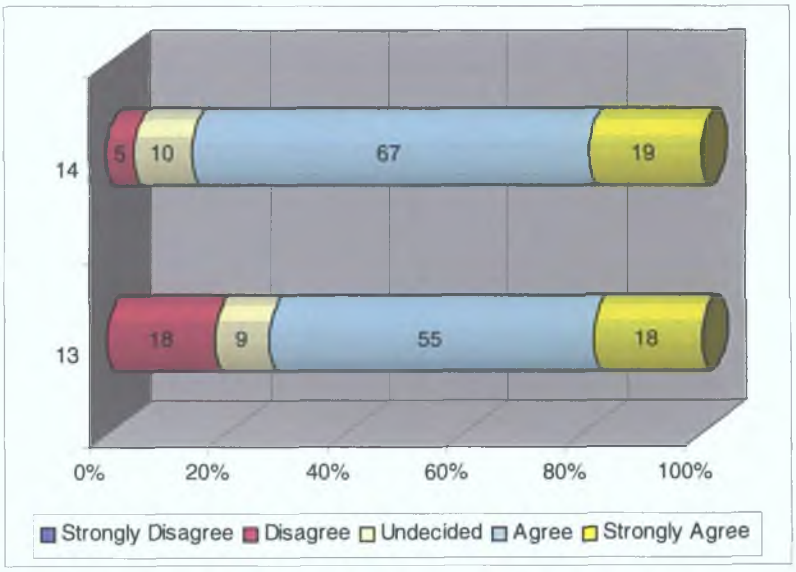


Figure 4.4

73% of teachers said that they felt their training was adequate, yet 65% said that they needed more training [Fig 4.4]. When this is coupled with the previous question that 86% of teachers did not find datalogging systems difficult to use, it can be assumed that the training teachers now want is in the form of professional development on how to exploit this technology to further enhance their teaching of science and scientific concepts, rather than simply how to use the equipment, or perhaps on other aspects of technology

The positive response to the need for further training would also indicate that those teachers will continue to use datalogging system in their classrooms

4 4 4 Teacher attitudes to Student Science Practices

A common concern expressed by teachers in the course of this study is that datalogging systems are too difficult to use They worry that time spent by students trying to grapple with technology will detract from the science lesson, and as a result, they will gain little from the class

According to this questionnaire, teachers stated that students did not find the datalogging system difficult to use (Qus 11, 23) and were comfortable using the equipment This is in contrast to some 20% of teachers who experienced some difficulty (Qu 10)

Qu. 27 Students' awareness of experimental error has increased.

Qu. 26 Students have increased expectations of accuracy.

Qu. 25 Students' observation skills have improved since using datalogging.

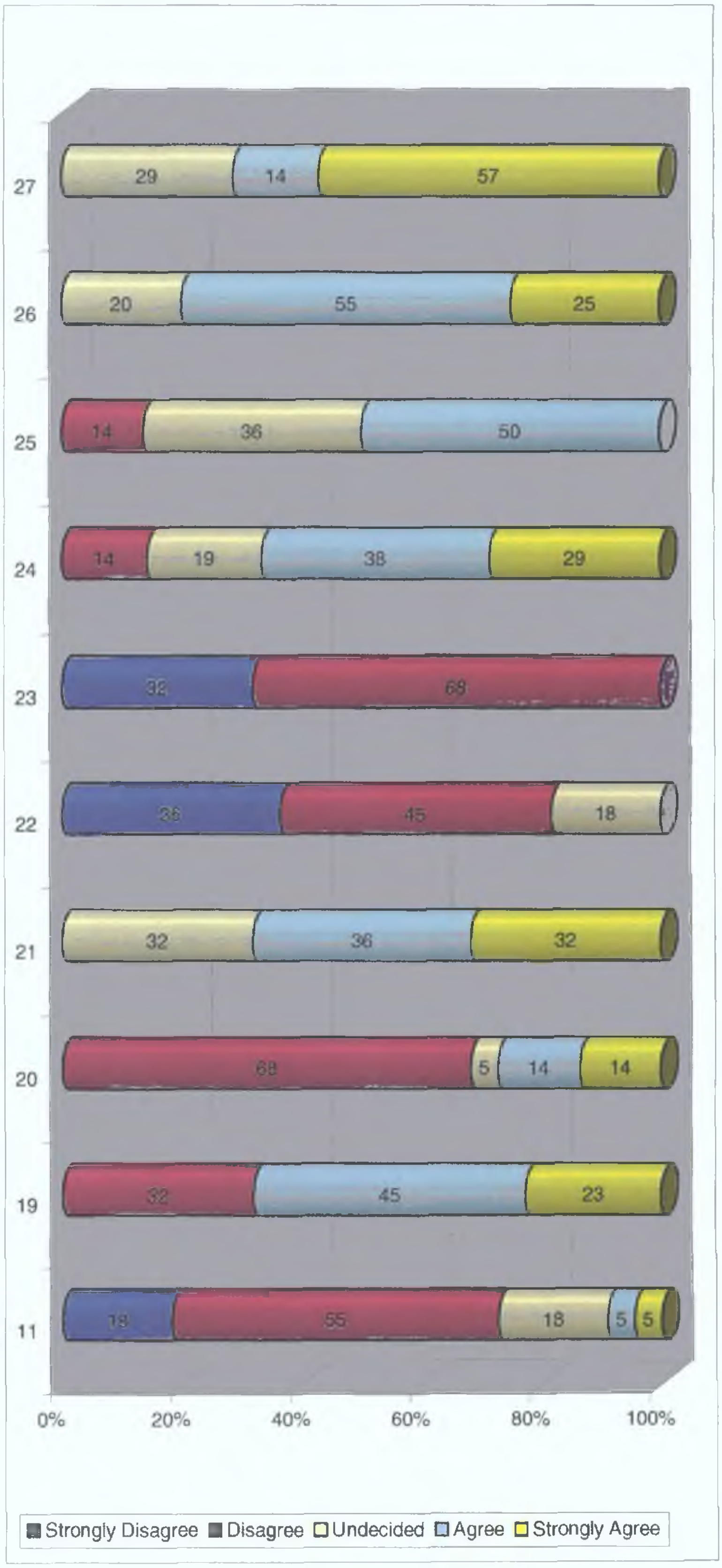
Qu. 24 In carrying out investigations, students are more likely to use the scientific process.

Qu. 23 Students are not comfortable using datalogging equipment.

Qu. 22 Datalogging has not helped them to develop a sense of enjoyment in the learning of science.

Qu. 21 The students' interpretation skills have improved since using datalogging.

Qu. 20 My students spend a lot of time interpreting graphs.



Qu 19	My students draw their graphs by hand	
Qu 11	The students found the datalogging system difficult to use	

Figure 4 5

Interestingly, two thirds of teachers still require students to draw graphs by hand (Qu 19) Similarly, the same number of teachers indicated that students did not spend a lot of time interpreting graphs It is clear that students were not encouraged to spend time analysing data This is in contrast to the response on the effect of datalogging where again, two thirds noted that interpretation skills had improved (Qu 21) although only half saw any improvement in observation skills (Qu 25)

Students improved in many of the fundamental scientific skills as a direct result of using datalogging Teachers noted an improved awareness of experimental error (Qu 27) possibly as a result of the pace that experiments are completed and of having the result displayed immediately Students are more critical of poor quality data when it is simple to re-run an experiment This leads on to the observation that students' expectation of accuracy has increased (Qu 26)

In general, the whole scientific process of planning and evaluating experiments was seen to have improved by most teachers (Qu 24) It is also important to note the improvement in student motivation where many teachers observed students displaying a sense of enjoyment in learning in the classroom (Qu 22) This willingness to be involved cannot be overstated Students take more of an interest when they have a sense of participation in the experiment and ownership of the data collected

Teachers' attitudes to students in this approach have been very positive with approximately two thirds of teachers noting an improvement is student response, skill levels and interest in the subject

4 4 5 Teacher attitudes to teaching Science

Teachers have shown an extremely positive attitude to teaching with the datalogging system [Fig 4 6] All teachers agree that using the hand-held technology has changed their attitude to its use as an instructional tool (Qu 4) There is a strong feeling of not needing to use a P C to get the desired results (Qu 6)

Although one third of teachers still prefer to design experiments for the students (Qu. 18) thereby retaining control of the learning situation, all teachers agreed that students' experiments were a necessary part of the science classroom (Qu. 17).

Qu. 18	I prefer to design experiments for the students.
Qu. 17	I am not comfortable in allowing students to conduct experiments in class.
Qu. 16	I now pose more open-ended questions.
Qu. 12	I am happy to allow pupils to conduct experiments.
Qu. 9	I have altered my teaching style as a result of using datalogging.
Qu. 6	I would have preferred to have used a PC to conduct my datalogging experiments.
Qu. 4	My attitude to using the graphing calculator as an instructional tool has improved.

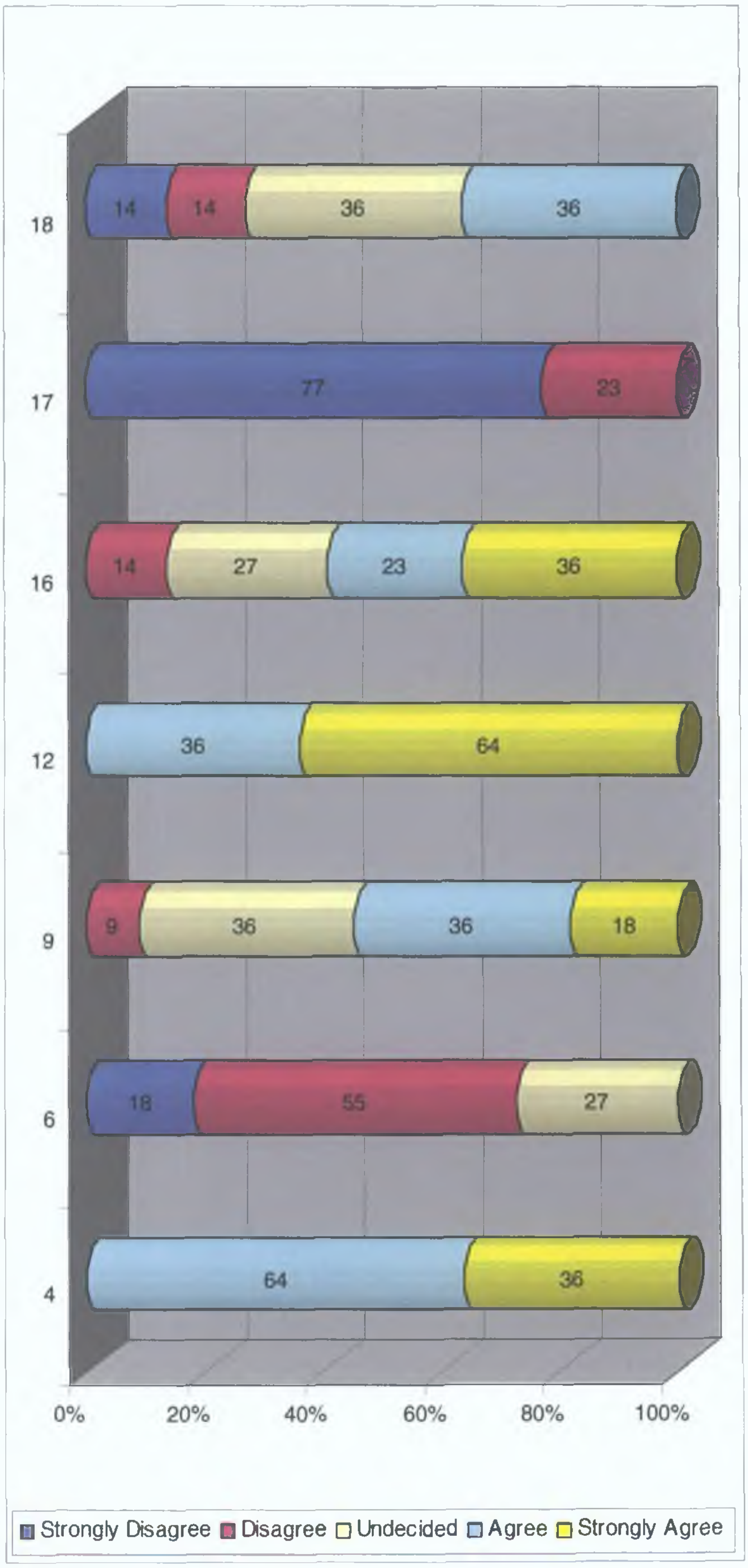


Figure 4.6

Teachers appear to be opening up other avenues of questioning to engage students more fully in the science learning process. More than half have altered their teaching style as a direct result of this technology (Qu. 9) and three-fifths admit to posing more open-ended questions in class (Qu. 16).

4.4.6 Student Attitudes to Science (as observed by teachers)

Qu. 29 Students have not improved in their ability to learn cooperatively.

Qu. 28 My students' formation of opinions and judgements based on evidence and experiment has not improved.

Qu. 15 My students enjoy science more with the technology.

Qu. 5 The students' attitude to using the graphing calculator in classroom as a learning tool has improved.

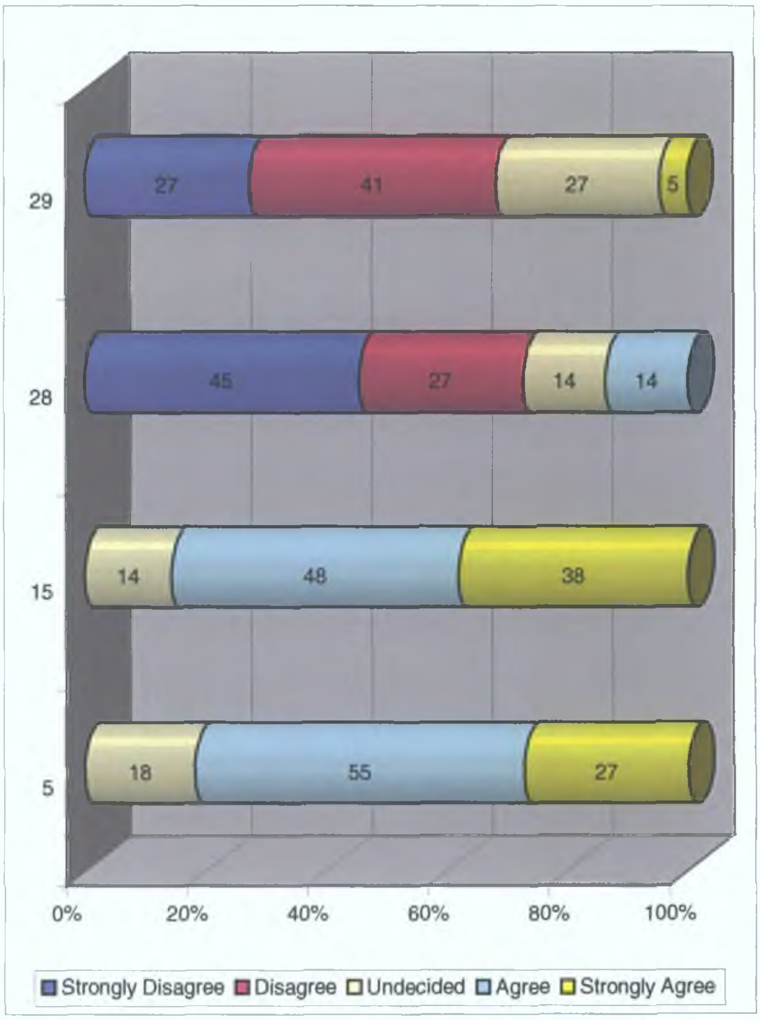


Figure 4.7

Part of the education process is allowing to students to develop socially and to develop skills required by society. The cooperative nature of the science experiment is an important aspect to that part of the education process. It is encouraging to note that only five percent of teachers noted that students had not improved their ability to work cooperatively (Qu. 29).

There was an improvement in attitude to hand-held technology (Qu. 5) and an associated improvement to the enjoyment of science (Qu. 15) by more than eighty percent of teachers. Only a small percentage of teachers have not observed any improvement in the students' ability to formulate an opinion and make judgements on evidence when conducting experiments using this technology (Qu 28) This is a positive feature of the system and is to be welcomed

4 4 7 Background to Teaching Groups

As expected from other research, optimal group size was observed to be 2 to 3 students This would allow for delegation and rotation of task to encourage full student participation (Appendix I, pg 124-132)

From this survey, it is apparent that teachers are using the datalogging system at Junior Certificate, Transition Year and Leaving Certificate This demonstrates versatility in the equipment and a willingness of teachers to attempt use of technology at all stages This is a positive outcome

Science teachers make more use of datalogging in the teaching of physics than chemistry or biology but sizeable numbers say that it is suitable for all the sciences Physical sciences show a strong representation with practical activities This is notable as it shows a divergence from the findings of the physical sciences task force who noted a lack of experimentation and suggested that more should be done to encourage it in the classroom It would appear this system does encourage more experimental and varied work at all stages

4.5 Summary

Both students and teachers find this system easy to use This coupled with its functionality, and the ability of every student to be involved in the investigation, all serve to highlight the teaching and learning potential of this system It is encouraging to note that the majority of teachers wish to embark on this style of learning in their classrooms, if they are not already doing so

Teachers have reported an increase in graph interpretation skills, and an increase in the amount of analysis that students undertake Teachers seem to be opening up other avenues of questioning to engage students more fully into the science learning process More than half of the teachers surveyed have altered their teaching style as a direct result of the technology

This is a positive response to a complicated situation as one of the difficulties often noted by teachers is being stretched by students mentally These results show that teachers are becoming more comfortable in allowing students to devise and conduct experiments (Qu 12)

In a time of reportedly increasing disruption in schools, it is important to encourage students into the learning environment and the learning process This technology serves to enhance the teaching and learning process as well as engaging students at all levels of ability

Chapter 5 Implications for Curriculum and Assessment

Issues remain for education in Ireland with respect to assessment It is evident that teachers agree that classroom practice should be reflected in assessment requirements at a national level Teachers, if they require a lead, would like to see changes to the assessment procedures which encourage a more investigative approach to the teaching and learning of science

As data-logging becomes more usual in our schools, and the operational skills have been acquired, we need to shift the emphasis of data-logging away from just collecting and gathering data, and more towards using the software to explore the data for scientific meaning Greater emphasis should be put on scientific evaluation of data to include scientific process skills as part of teaching and learning methodology

Technology is not magic and does not automatically make a powerful learning experience unless it is used with good teaching and curricula It is not a good idea to simply replace a traditional practical class with an equivalent one using handheld computers and/or sensors This kind of "substitution" is easiest to implement, but the inclusion of technology with little educational gain is detrimental to its long term implementation

Handheld computers and sensors add capacity and flexibility that, to be exploited, requires the focus of traditional laboratory work to be changed, giving students more opportunity to explore and learn through their investigations This, in turn, often requires a change in teaching style that takes time and commitment 'Outcomes' in the classroom are set by the curriculum, however, the teacher can influence the style of delivery and create successful or unsuccessful learning environments These changes are central to education reform

When any new technology is introduced, it is first used to put a new twist on what people were doing before It takes time for the technology to give rise to really new practices and the new cultures that support them In Ireland, datalogging technologies were introduced to schools in January 1999 Many teachers, once they overcame their initial reservations, used them purely as a way to collect data, they did not exploit the potential for analysis and open-ended investigation This is borne out by the questionnaire filled out by 22 teachers enthusiastic about the technology (Chapter 4) The reason given was that since analysis is not required in the assessment, students are not asked to plan or evaluate practical work, and the curriculum is still made up of "recipe" type investigations As the assessment does not support enquiry based learning, teachers do not spend time on it

The evidence that analysis is not required in the assessment of the 1988 Junior Science syllabus can be found in the three-year study of 44 students (Chapter 3) Although one group of students was taught in a constructivist manner using investigative processes and analysis, their Junior Certificate results were no better than those taught in a traditional manner It was evident that their ability to analyse graphs and data was better (see page 60), but the form of assessment used did not offer the students the opportunity to demonstrate those skills The current syllabus objectives clearly state that through the study of junior certificate science the student will develop a knowledge and understanding of

- procedural plans and the use of the scientific method in problem solving

- observation, measurement and the accurate recording of data

- obtaining and using information from a variety of sources

- numeracy, and the manipulation and interpretation of data in a variety of forms, including the use of symbols, charts and graphs

The present syllabus does not meet these objectives due to the nature of the assessment

Many educationalists have been urging reforms that reflect constructivist theories of learning One of the underpinning principles of constructivism is that it should support the student's efforts to "construct" their own understanding One way to deliver constructive education in science is through a "hands on" approach The flexibility, speed and analysis and storage capability of datalogging technology has caused educators to redefine "hands on" and rethink the traditional process of teaching

If technology is to be exploited to its best advantage, the introduction of new teaching methodologies must be supported with professional development This must also be coupled with changes in assessment structures Teachers are under increasing pressure to provide results, so if the mode of assessment does not support revised teaching methodologies it is reasonable to assume that teachers will not use them

Assessment of course work will go a long way towards encouraging teachers to develop investigative process skills in their students It is imperative that any investigations set by the examining body are open-ended enough to allow the student become involved in an authentic and meaningful learning experience during the investigation process Students must be allowed space to plan, predict, carry out and evaluate Without this, the investigation is in danger of becoming another recipe, with the student cooking the books

Chapter 6 Conclusions and recommendations

Interest in the history and development of datalogging technology has been stimulated by the Department of Education's choice of Datalogging system for Irish Education This history clearly shows that early users experienced many problems and difficulties with both software and hardware Nevertheless, quality research was completed by many people, although the results seldom left the academic domain

There is an apparent consciousness of the need to develop particular learning styles in education, commonly known as the constructivist approach This research highlights the way that use of datalogging supports a constructivist approach to science teaching This study also shows the positive aspects experienced when technology removes student frustration about graph production, thus enabling students of all abilities to engage in the science, encouraging both teachers and students to participate in effective questioning of the subject matter and most importantly, enhancing the classroom experience by making science thought provoking and interesting

Furthermore, the research clearly demonstrates the positive reinforcement gained by real-time graphing of events, and of the inductive nature of science when students are directly involved in the experiment This process worked best when the teacher allowed sufficient time for reflection and discussion of the events, encouraging students to both predict outcomes and then explain occurrences afterward

It is clear that much has been learned about the positive effects of datalogging However, discussions with teachers other than those surveyed in the course of this study indicate that there is limited usage of datalogging in the classroom To establish the factors affecting this situation consideration should be given to the current context of use of technology in science education If research is so positive about the development of scientific enquiry skills, why is it seldom seen in classrooms? Many believe it is because there is no reward in assessment for this approach to learning science, but it is more likely to be due to teacher's resistance to change

Social commentaries, comparative studies and similar educational media would suggest that science education in Ireland is experiencing difficulties in both content and the number undertaking study at third level This research highlights the opportunity afforded by the developments in teaching methodology stimulated by datalogging When students are allowed to develop their technological skills we enable them to reflect critically on the events in the classroom This is the essence behind the expected improvement in learning and teaching styles afforded by datalogging

The use of hand-held datalogging equipment allows a flexibility of approach and encourages all parties to engage in investigative thought and collaborative learning Students can be encouraged to design and develop new experiments based on initial findings The 'what if ' scenario empowers students to expand the thought processes, as well as encouraging the good teacher This aided opportunity for learning allows students and teachers to confirm each other's aims and objectives for lessons quickly and succinctly It serves to embellish lower order and enhance higher order skills of students It should become the norm in laboratories to find technology operating seamlessly with all other forms of teaching and learning systems

The study, over three years, of a group of students whose major experiences of science have been investigative, is both interesting and enlightening Control groups of students from similar backgrounds and abilities in the same school offer an interesting insight into the assessment processes used in education today

The fact that there was no appreciable difference in the performance of students in any class was noted in the state examination of June 2002 After a six month period this was found to no longer be the case The students taught through an investigative approach had shown understanding of the processes and concepts beyond that of the control groups This was further evidenced when the same students were invited to complete a test booklet on fundamental scientific skills These results are most likely because students understood the concepts rather than memorised a set of results or facts

Other factors were considered as influencing the results These included ability in mathematics and the further study of science into Transition Year All of these factors were considered and found in this study not to be significant Furthermore, no gender differences were evident in the figures, suggesting that both sexes are capable of developing under that system of learning Longer term studies would also be of interest in the numbers electing to continue the study of science beyond Junior Certificate level, as preliminary results in this study show an encouraging number of students continuing their interest in science

As has been discussed previously, the technology will not impact on education without the support of teachers A group of teachers who had not been using datalogging regularly was established in an effort to gauge their reaction to implementing this method of teaching and learning in their classrooms A workbook of experiments was prepared to allow them to integrate datalogging into their classes as easily as possible Their responses after a year were positive in a number of areas The majority found systems easy to use, students found it easy to use and the enjoyment of students, and indeed teachers, was noted They admitted to developing a more open-ended style of questioning of experiments and processes

More experienced dataloggers were interviewed to evaluate the views of practitioners Notably, they asked to see effective changes in curriculum and assessment to drive a change in teaching and learning methodology forward They commented on how students enjoyed practical opportunities to collect real-time data, the speed of the experiments and the ability of students to develop 'new' experiments to extend the concepts being taught

Both sets of teachers commented on the steep initial learning curve and about how the technology now saves time in the courses They further commented on the need for technical support in schools, a greater need for quality in-service training for teachers, and the requirements for the next generation of support materials which should extend the science and not be written around the recipe approach of which buttons to press

Implications for this level of development require that schools and teachers become aware of the possibilities afforded by technology in the teaching and learning of science It is important to embrace technology as a tool for enhancing science education and to avoid the artificial separation of the technology from the science it is supporting Allow laboratories to be seen as IT zones, where IT is embedded in the learning culture, rather than move science to the technology room

If we aim to take this seriously, quality staff development is fundamental to its success Many observers commend the quality and style of training offered by the physical sciences support teams around the country This would ideally be continued and supplemented

An important factor highlighted by the teacher interviews in chapter 4 was the importance of support from colleagues when implementing new teaching methodologies Teachers need opportunities to work and learn together Collaborative work helps teachers take advantage of each others expertise and overcome simple housekeeping problems that are often an obstacle to successful implementation of new technologies, such as access to laboratories and/or computers and availability of resources An organisation that values learning must view time for collaborative learning as critical One day workshops outside the school laboratory often fade into meaningless exercises that leave the teacher frustrated with a knowledge of what could be done if only we had time

Institutional support is also vital Successful teachers, like their students, need to be recognised and feel encouraged to try something new Because improvement implies change and change requires stepping outside ones comfort zone, it is important that the institution encourages risk taking to a certain extent Ideas and initiative are essential to school improvement and school leaders should find ways to reward them

It is evident from this research that an important factor in integrating datalogging technology seamlessly into the curriculum is that teachers must be not only technically proficient, but also aware of what the technology can do for their students' learning strategies within the curriculum Teachers brought up with chalk and talk followed by recipe-type practical work will have more difficulties in adapting to this change than newly-qualified teachers who still have the educational ideals of investigation and constructivism fresh in their minds

It is clear that enjoyment of science and engagement in the scientific process are crucial for the successful implementation of any science curriculum It is clear from this research that the use of datalogging in conjunction with a curriculum that encourages development of scientific process skills can do much to enhance children's experience of science at Junior Certificate level

The Department of Education and Science have provided Schools in Ireland with the tools and the In-Service training to facilitate an investigative problem solving approach to Science Education It is now up to teachers to take advantage of new technologies to give children an education through Science rather than an education in Science

Bibliography

Report of the task force on the physical Sciences (2002)
http //www sciencetaskforce ie/report/report pdf

Junior Certificate Science, final draft syllabus (2003) *http //www ncca ie/new htm*

Barton, R (1997) Computer Journal of Information Technology for Teacher Education, Vol 6, No 1

Barton, R and Rogers, L (1994) The computer as an aid to practical science Studying motion with a computer *Journal of Computer Assisted Learning, 7,* 104 -113

McRobbie, C J and Thomas, G P (2000) Epistemological and Contextual Issues in the Use of microcomputer-based Laboratories in a Year 11 Chemistry Classroom *Journal of Computers in Mathematics and Science Teaching* **19**(2), 137-160

Thornton, R K and Sokoloff, D R (1990) Learning motion concepts using real-time microcomputer-based laboratory tools *American Journal of Physics, 58,* 858

Newton, L R and Rogers, L (2001) Teaching science with ICT, *Continuum, London*

Flick, L B (1993) The meaning of hands-on science *Journal of Science Teacher Education, 4(1), 1-8*

Flick, L and Bell (2000) Preparing tomorrow's science teachers to use technology Guidelines for science educators *Contemporary issues in technology and teacher education Volume 1 (1)*

Pedretti, E , Mayer-Smith, J and Woodrow, J (1999) Teaming Technology Enhanced Instruction in the Science Classroom and Teacher Professional Development *Journal of Technology and Teacher Education* , **7**(2), 131-143

The role of Hand-held datalogging technology in Junior Certificate Science

Appendices

A thesis submitted for the degree of

Master of Science

September 2003

Appendices

Appendix A

Early Worksheets

WHY DATA LOGGING :endothermic/exothermic

With the proper data logging equipment, two probes are used simultaneously to record temperature changes in an endothermic reaction (citric acid and Sodium Hydrogen carbonate), and an exothermic reaction (HCl and magnesium).

With the use of data logging equipment, it is possible to record very small changes in temperature every second. This means that accurate results can be obtained using relatively small amounts of reagents, and that the practical can be completed in a short time.

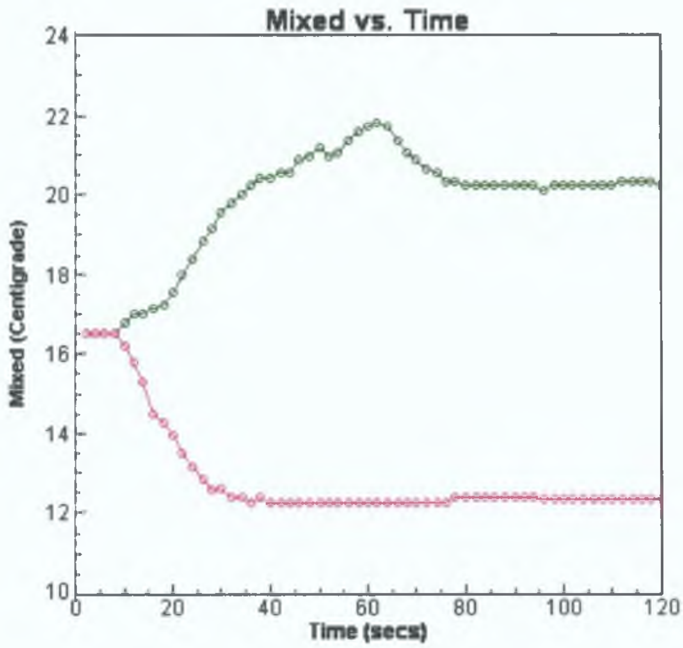
The fact that students no longer have to take temperatures allows them give all their attention to the teacher while the equipment records the data. In addition, completing the practical in such a short time allows for repetition, perhaps with several different reactions.

The facility to see the graph appear on the screen in real time is a powerful learning aid, especially for the weaker student. In this experiment, the student can observe the two reactions taking place simultaneously, as the theory is explained.

The main advantages of using data logging in this practical are:

1. Less time is spent with equipment. This allows more time for teaching
2. Results are accurate, and recorded in both list form and graph form
3. Both reactions can be done simultaneously
4. Students can watch the temperatures changing as the reactions are taking place
5. No risk of thermometers breaking.

The following is a sample of a student's graph.



Endothermic and Exothermic Reactions Heat changes during chemical reactions

INTRODUCTION

When a chemical reaction takes place, there is very often a heat change This is because there is a difference in the energy between the substances that are reacting, and the products of the reaction

Some reactions give out heat and these are known as *exothermic* reactions In exothermic reactions, the reactants have more energy than the products

Other reactions take in heat these and these are called *endothermic* reactions In these reactions, the products have more energy than the reactants Where do they get this extra energy? They get it by taking some heat away from the system Consequently, the system becomes colder

In this investigation, we will study one endothermic reaction, and one exothermic reaction

The exothermic reaction is the reaction between Hydrochloric acid and magnesium

$$2\ HCl + Mg \rightarrow MgCl_2 + H_2$$

The endothermic reaction is between citric acid (found in citrus fruits), and sodium hydrogen carbonate (baking soda) This is the reaction used in the manufacture of sherbet

This can be represented as

$$3\ NaHCO_3 + H_3Cit \rightarrow Na_3Cit + 3H_2O + 3CO_2$$

MATERIALS

CBL with 2 temp probes	10 grams sodium hydrogen carbonate
Graphing Calculator	2 cm strip magnesium ribbon
50 cm^3 graduated cylinder	50 cm^3 dilute HCl
2 Styrofoam cups	50 cm^3 water
2 250 cm^3 beakers	10 grams citric acid

METHOD

Put about 100 cm^3 dilute HCl in one beaker, and about 100 cm^3 citric acid in the other
Attach two temperature probes (channel 1 and channel 2) to the CBL
Check that the CBL is turned on

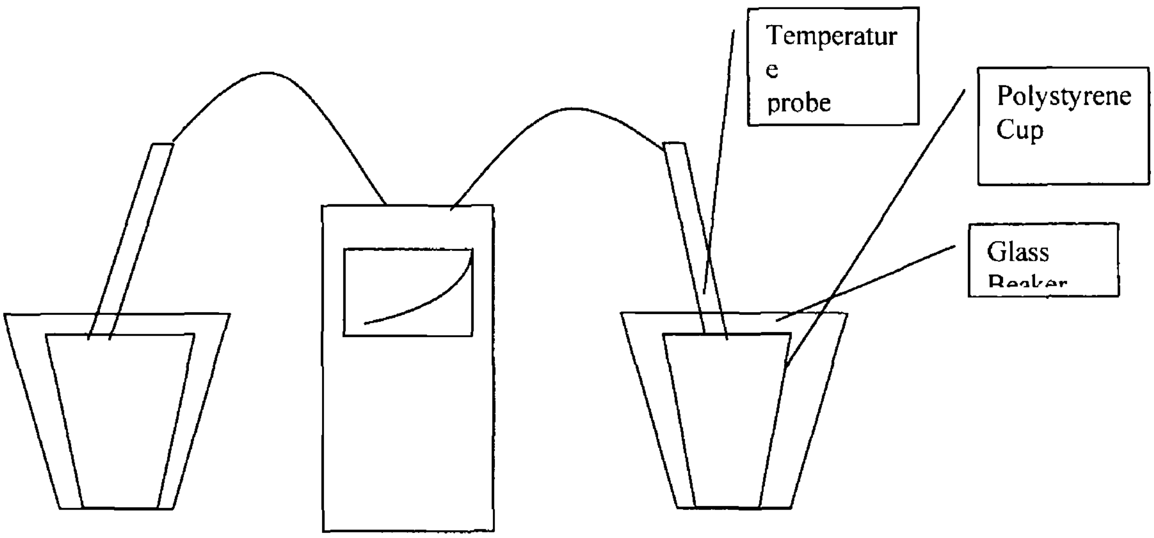
Press PRGM
CHEMBIO appears on the calculator Press enter
Choose SET UP PROBES

ENTER NUMBER OF PROBES	2
SELECT PROBE	TEMPERATURE
ENTER CHANNEL NUMBER	1
SELECT PROBE	TEMPERATURE

ENTER CHANNEL NUMBER	2
CALIBRATION	USE STORED
MAIN MENU	COLLECT DATA
DATA COLLECTION	TIME GRAPH
TIME BETWEEN SAMPLES	2
NUMBER OF SAMPLES	60
CONTINUE?	USE TIME SET UP
Y MIN	10
Y MAX	50
Y SCL	5

Pour 50cm^3 dilute HCl into one of the Styrofoam cups Dissolve the citric acid in 50 cm ^{3} of water in the other Styrofoam cup, and place them inside the glass beakers

Place a temperature probe into each of the cups



When everything is ready, commence data collection by pressing ENTER on the calculator

Once the temperatures in each beaker have stabilized, record the temperature in both beakers This is the initial temperature

After about 20 seconds, add the sodium hydrogen carbonate to the citric acid, and the magnesium ribbon to the dilute HCl Gently stir each of the mixtures

When the sampling is complete, examine the graph of temperature against time Record the final temperature of each solution

RESULTS

Temp	Citric Acid + $NaHCO_3$	HCl + Magnesium
Initial		
Final		
Change		

Print out a copy of the graph showing the changes in temperatures of each of the solutions, and answer the following questions

QUESTIONS

1 Calculate the heat change for each reaction

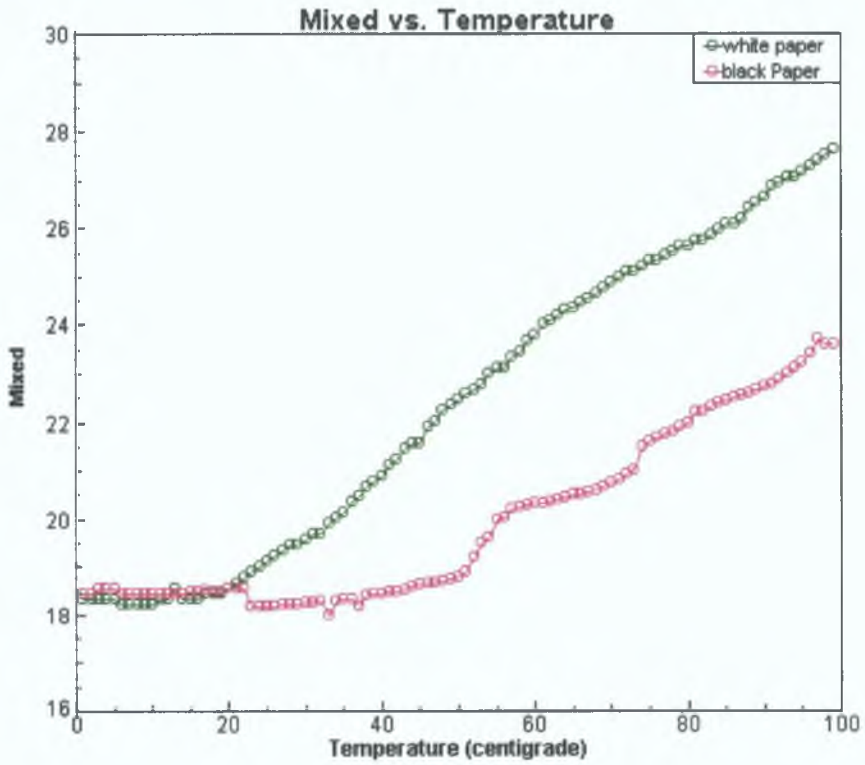
2 Which of these reactions is endothermic, and which is exothermic? Explain your answer

3 For each reaction, describe three ways in which you could tell that a chemical reaction was taking place

4 From your graph, is it possible to tell which reaction took place at a greater rate? Explain your answer

Absorption of radiant energy *teachers notes*

The object of this investigation is to measure the heat absorbed by different coloured surfaces. Students can substitute many different colours and explore how their heat absorbing properties differ. It is important not to switch on the light until the calculator has started recording temperatures.



This can be adapted to show the heat absorbed by different coloured cans filled with water (abs. of radiant energy.stu doc(2)). This is the experiment that appears in junior certificate text books and teachers may be more familiar with this method. The advantage of using pieces of paper is that it is quicker and much less messy, also, coloured paper is readily available, and students can explore heat absorption by many different colours.

The absorption of radiant energy

When heat is given out by an object without having to travel through a medium, we say that it is *radiated* This is how the heat from the sun travels almost 150,000,000 km towards the earth
Colour affects the absorption of radiant energy You can use the results of this experiment to decide which colour clothes to wear to keep cool in the summer, and warm in the winter

Apparatus

Calculator	Piece of white paper
CBL	Piece of black paper
2 temperature probes	Tape
	Lamp

PROCEDURE

Tape two temperature probes to the table *see the diagram* Put a piece of black, and a piece of white paper over the two probes Plug the probes into channel 1 and 2 of the CBL
Turn the CBL and the calculator on, press prgm on the calculator
CHEMBIO appears on the calculator Press enter

Choose	SET UP PROBES
ENTER NUMBER OF PROBES	2
SELECT PROBE	TEMPERATURE
ENTER CHANNEL NUMBER	1
SELECT PROBE	TEMPERATURE
ENTER CHANNEL NUMBER	2
CALIBRATION	USE STORED
MAIN MENU	COLLECT DATA
DATA COLLECTION	TIME GRAPH
TIME BETWEEN SAMPLES	2
NUMBER OF SAMPLES	60
CONTINUE?	USE TIME SET UP
Y MIN	10
Y MAX	50
Y SCL	5

Position a light bulb directly over the boundary between the two pieces of paper, and about 10 cm above the paper pieces The bulb should be the same distance from both probes

When everything is ready, begin collecting data by pressing ENTER After 20 seconds, a graph appears on the screen When this happens, switch the light on

A graph of the temperature under both the probes will appear on the calculator
When all the data has been recorded, DONE will appear on the screen
Press ENTER This will give a graph of the increase in temperature for the probe under the white paper You can examine the data points along the curve by moving the > button on the calculator
Press ENTER again This will give a graph for the probe under the black paper

To display both curves on the same graph, press ENTER again

1 Calculate the temperature change, for each color by subtracting the initial temperature from the final temperature

	Black	White
Initial temperature		
Final temperature		
Change in temperature		

2 Which color had the larger temperature increase?

3 Which color had the smaller temperature increase?

4 Why is it better to wear light-colored clothing in the summertime?

5 Solar collectors can be used to absorb the sun's radiation and change it to heat What color would work best for solar collectors? Explain

Appendix B

Research into Datalogging

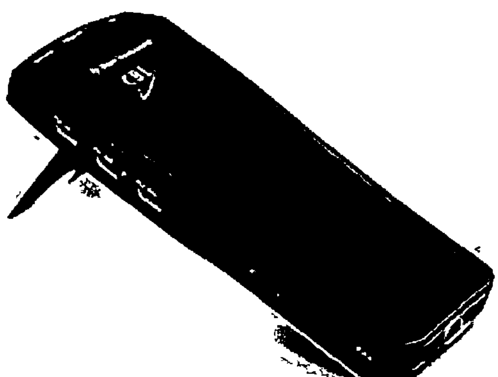
Research into Datalogging
Junior Certificate Science

A series of experiments using Datalogging with the CBL 2 and the TI 83+ calculator

Anna Walshe

Research into Datalogging
Junior Certificate Science

A series of experiments using Datalogging with the CBL 2 and the TI 83+ calculator



Anna Walshe

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RESEARCH INTO DATALOGGING
JUNIOR CERTIFICATE SCIENCE
TABLE OF CONTENTS

Introduction

The use of hand held technology offers teachers access to small portable machines that can be used to improve teaching and learning across a wide age and ability range

If used appropriately hand held technology has great potential value for mathematics and science education The last few years have seen rapid and significant change in handheld technology Such a situation sets challenges for education in terms of curriculum and assessment

The use of dataloggers in conjunction with graphics calculators means that real life data can easily be collected and analysed both in the classroom and elsewhere This method of collecting and analysing data is particularly useful for students who find science difficult Students can repeat experiments several times due to the speed at which data is collected, experiments are less cluttered with multiple manual measurements Students can concentrate on the significance of the data being collected, rather than worry about the equipment used to collect it

Graphics calculators provide a means of seeing, interpreting, exploring and communicating relationships graphically Teachers can use these calculators to introduce ideas and concepts where easily manipulated graphical representations can aid understanding Long and complex calculations can be carried out using this technology, thus enabling students and teachers to concentrate on the conceptual aspects of mathematics or science being studied

The use of data logging equipment improves the quality of information that students have to analyse It removes the inconsistencies produced by human error Students with limited skills of graphing can still produce an accurate graph An inaccurate graph can confuse the student, as it does not agree with the predicted result

As the graph appears in real time students are presented with the whole picture This moves students away from the belief that there must always be a straight-line relationship between the variables in an experiment When they plot a graph manually, students often try and make it fit their preconceived ideas Those students using graphing calculators have the advantage of seeing the graph appear on the screen before they try to interpret the shape

When students use datalogging equipment, they demand a much higher level of accuracy than when using traditional methods The ease with which experiments can be repeated enables them to think about possible reasons for their inaccuracy and find ways to remedy them Error analysis is a very important component of scientific investigation, but one which teachers generally do not spend much time on With this equipment, it can become an integral part of the lesson

Used in an investigative way, this technology allows students to visualise, verify, model and explore many what if ? situations Learning activities, which require a student to investigate the effect a change of one parameter with respect to another, have the power to give students much greater understanding of the mathematical or scientific concepts involved Through the outcomes of such activities and discussion of the process, students learn to work cooperatively and communicate effectively

The experiments in this book have mainly resulted from three years work with one particular class of students from Sutton Park School (now third year Lambay) They allowed me to use them as guinea pigs, and came up with many useful ideas on how datalogging could be used to enhance junior certificate science I would like to thank them for their patience, but most of all for their enthusiasm, they have been wonderful ambassadors for science and I have thoroughly enjoyed teaching them

Anna Walshe, January 2002

Using the DATAMATE program

The **DATAMATE** data collection program is used to collect, examine, analyse and graph data Make sure the calculator is connected to the CBL 2, and follow these steps to start the **DATAMATE** program

Press **APPS** then press the number on the calculator that precedes the **DATAMATE** program The main screen will now load

The top half of the screen will automatically identify the sensors attached to the CBL 2 The main screen supports a meter mode This can be turned on and off by using the + button on the calculator The advantage of turning off the battery is that it conserves battery power

SETUP

If you want to change the current set up, choose **SETUP** from the main menu From here you can change sensors, change the data collection mode, load or save an experiment and calibrate or zero the probes

Sometimes you may want to change the settings for the Y-axis For example, the range for the temperature probe is between -25^0C and $+125^0$C This range would not give a satisfactory graph if the temperature change being investigated were very small, for example in measuring heat of solution

To change the y scale, press **1 SETUP** from the main menu Move the black arrow down with the [▼] arrow until it is against the **MODE**

```
 CH 1
 CH 2
 CH 3
 DIG
▸MODE TIME GRAPH-9
----------------------
1 OK          3 ZERO
2 CALIBRATE
```

Press [ENTER] a list of modes will appear

Select **2 TIME GRAPH** to get the following screen

```
  TIME GRAPH SETTINGS
TIME INTERVAL      05
NUMBER OF SAMPLES  180
EXPERIMENT LENGTH  9
----------------------
1 OK        3 ADVANCED
2 CHANGE TIME SETTINGS
```

Select **3 ADVANCED**

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH LIGHT
YMIN    YMAX    YSCL
0       1       2
TRIGGERING NONE
----------------------
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Select **2 CHANGE GRAPH SETTINGS**

Select which graph you want to change, press [ENTER] and then enter whatever **Y MAX** and **Y MIN** you need The **Y SCL** refers to the number of divisions you want on the Y-axis

SENSORS

To change a sensor or add a sensor that is not auto ID use the [▼] key Position the cursor opposite the desired channel and press [ENTER] A list of sensors will be displayed

Select the appropriate sensor, or select **MORE** to see some more sensors

DATA COLLECTION MODES

To change modes, move the cursor to **MODE** and press [ENTER] This brings up the **SELECT MODE** screen

TIME GRAPH is the default mode The sensor you are using will set its own sample interval and length of run Selecting **CHANGE TIME SETTINGS** from the **TIME GRAPH**

SETTINGS screen can change the default settings

Time graphs will be displayed live unless the samples are taken at a greater rate than 10 samples a second or slower than one sample every 270 seconds If you are using multiple sensors and they are identical, all of the data will be shown live on one graph If they are not identical, only one set of data will be shown live, the other one will be recorded

LOG DATA - this is used for remote logging of data whilst the interface is not attached to the calculator

EVENTS WITH ENTRY - Data is collected one point at a time, and only when the [ENTER] button on the calculator is pressed The calculator will then prompt you to enter the corresponding value such as concentration, volume or trial This mode is used for things such as titration, Boyle's law, etc

SINGLE POINT - One average data point is displayed The interface will collect data for 10 seconds and report a single averaged value on the screen

SELECTED EVENTS - Data is collected one point at a time and only when the [ENTER] button on the calculator is pressed

START

The **START** option begins data collection using the current mode If for any reason you wish to end the sampling prematurely, press the [STO▸] button

GRAPH

This option allows you to manipulate your graph When chosen, the graph will be redrawn In the graph option, you can select a region for further analysis by choosing **SELECT REGION** The calculator will then ask you to define the region

Beware this will delete the portion of the data that was not selected

You can also rescale the axes with this option To rescale the graph select **3 ADVANCED**

One of the options in this menu is

ANALYSE

CURVE FIT - displays a list of curve fit options including linear, power, quadratic and exponential fits

ADD MODEL - allows manipulation of the coefficients of a function

STATISTICS - displays the mean, max, min, standard deviation, and number of data points of a selected region

INTEGRAL - integrates a region of the graph

TOOLS

STORE LATEST RUN - Temporarily stores the latest run

RETRIEVE DATA - Retrieves data stored on the interface from remote data collection

CHECK BATTERY - Displays the battery power of the interface

EXPERIMENTS IN PHYSICS

To investigate the relationship between depth and pressure in a liquid

Have you ever noticed how the water feels 'heavier' the further down you go?

That is because there is pressure at the bottom of a liquid due to its weight. The more liquid there is above you, the heavier it is, and the greater the pressure.

In this experiment, you will investigate the relationship between the pressure in a column of water and its depth.

A graduated cylinder is filled with water. The pressure is taken at different depths within the cylinder, and a graph of depth vs. pressure is drawn.

APPARATUS

Graphing calculator
CBL 2
Large cylinder
Thistle funnel

PROCEDURE

Attach the pressure sensor to the thistle funnel using a piece of plastic tubing. Ensure that all the connections are airtight.

Turn on the CBL 2 and calculator. Select the **DATAMATE** programme from the **APPS** menu.
Press [CLEAR] to reset the programme.
Press [ENTER] at the welcome screen. The CBL 2 will check for probes. Screen 1 will be shown.

```
CH 1:PRESS(KPA)     99.3

MODE:TIME GRAPH - 100
____________________
1:SETUP     4:ANALYSE
2:START     5:TOOLS
```

Screen

Select **1 : SETUP** and press the up arrow [▲] to highlight **MODE**.

Press [ENTER] to get screen 2

```
SELECT MODE
1:LOG DATA
2:TIME GRAPH
3:EVENTS WITH ENTRY
4:SINGLE POINT
5:SELECTED EVENTS
6:RETURN TO SETUP SCREEN
```

Screen 2

Select **3:EVENTS WITH ENTRY.**

At the next screen select **1 : OK** to get screen 3.

```
CH 1:GAS PRESSURE(K103.6

MODE:EVENTS WITH ENTRY
____________________
1:SETUP     4:ANALYZE
2:START     5:TOOLS
3:GRAPH     6:QUIT
```

Screen 3

TO COLLECT DATA

Place the top of the thistle funnel just over the top of the water in the cylinder

Select **2 START** to collect data Screen 4 will appear

```
PRESS [ENTER] TO
COLLECT OR [STO] TO
STOP
1      105
```

Screen 4

When the pressure reading on the calculator stabilizes, press [ENTER] The calculator will prompt you to enter a value Type in **0** as the value Press [ENTER] to store this data pair

Move the thistle funnel down 5 cm and repeat the procedure entering **5** as the value Repeat collection increasing the depth by 5 cm^3 up to 50cm Once the last data pair has been collected, Press [STO▶] to stop

PROCESSING THE DATA

The calculator will produce a graph of pressure vs depth

Print out this graph and answer the following questions

1 What is the relationship between depth and pressure in a liquid?

2 If you tried this experiment with a liquid that was less dense than water, do you think the slope of the line would be greater or less than the one obtained in this experiment?

3 Explain your answer to question 2)

4 Use your graph to work out a value for atmospheric pressure

Try repeating this experiment using different liquids

Is the relationship the same for all liquids?

If not, why not?

Time and distance graphs

Part 1 Match the graph

In this experiment, you will be asked to match a graph on the calculator by walking towards and away from a wall with a motion detector The motion detector will produce a graph of your distance from the wall versus time Time will be on the horizontal (X) axis, distance from the wall will be on the vertical (Y) axis

APPARATUS

TI 83+	Motion Detector

PROCEDURE

Attach the motion detector to the calculator Select the **RANGER** programme From the main menu select **APPLICATIONS** Select **METERS** as the units Select **DIST MATCH**

Follow the instructions on the screen

When you have attempted to match the graph, press [ENTER] again and select **NEW MATCH** Keep going until you have the hang of it

Part 2 Plotting a Distance-Time graph

In this part of the investigation, you will produce your own time and distance graph by using a toy car and a motion detector

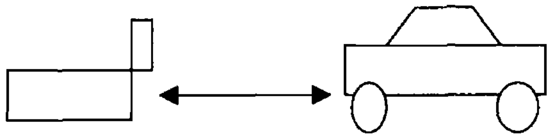
APPARATUS

Toy car	Piece of card
TI 83+	Motion detector

PROCEDURE

Attach the piece of card to the back of the toy car This gives the motion detector something to detect

Place the toy car on the ground about 50 cm away from the motion detector



Select the **RANGER** programme
Select **SET UP / SAMPLE** from the main menu
Then

REAL TIME	NO
TIME	5 SECONDS
DISPLAY	DISTANCE
BEGIN ON	ENTER
SMOOTHING	LIGHT
UNITS	METERS

Pressing [ENTER] can change each of these settings

Select **START NOW**
Press [ENTER] and follow the instructions on the screen

The motion detector will produce a graph of the distance travelled by the car over 5 seconds Repeat the activity until you have a nice straight line

Print your graph and answer the following questions

1 How far did the car travel in 5 seconds?

2 How long would it have taken the car to travel 5 meters, assuming that it kept up a constant velocity?

3 What speed was the car travelling at in m/s?

4 How far would the car have travelled in 1 minute? In 1 hour?

Investigating friction

Friction is a force that resists motion As it is a force, it is measured in newtons

Different surfaces in contact with each other exert different frictional forces In this investigation, you will measure the force required to drag a wooden block across different surfaces The more friction there is, the greater the force required to drag the block

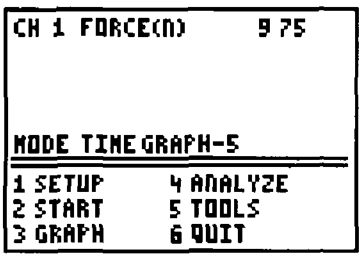
APPARATUS

TI 83+	1 Kg wooden Block
CBL 2	Material to provide different surfaces

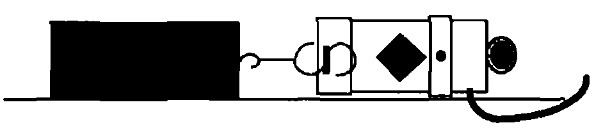
Student force sensor

PROCEDURE

Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu
Press [CLEAR] to reset the programme
Press [ENTER] at the welcome screen The CBL 2 will check for probes Screen 1 will be shown



Screen 1



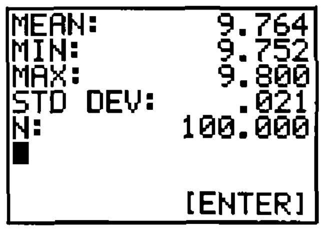
Place the block of wood on the first surface to be tested Attach the force sensor to it as in the diagram Pull the block slowly across the surface As soon as it is moving smoothly, press **2 START** on the calculator Continue to pull the wooden block, the calculator will take readings for 5 seconds

When the data collection is done, the calculator will produce a graph of the force experienced by the sensor over 5 seconds

Do not worry if you graph looks very uneven as you are going to calculate the average force over 5 seconds

When the graph appears on the screen, press **4 ANALYSE** to get to the **ANALYSE OPTIONS** menu The graph will reappear This time however, it will say **SELECT LEFT BOUND?** Press [ENTER] and the question will change to **SELECT RIGHT BOUND?**

Use the [▶] arrow to move the flashing cursor to the far right of the graph Press [ENTER] The calculator will ask you to wait while it calculates the average (This may take a few moments)



Screen 2

Record the mean (average) in the table below

Surface	Force (N)
1	
2	
3	
4	
5	

Represent this data in a bar chart

Which surface exerted the greatest frictional force?

Which exerted the least frictional force?

Give one instance where friction is useful?

Give one instance in which friction is a nuisance

Energy conversions

Energy is the ability to do work. Energy cannot be created or destroyed, it can only be converted from one form to another. The unit of measurement for energy is Joules.
In this experiment, you will investigate several different energy conversions.

Chemical energy into Food energy

Food contains chemical energy. When we eat, the energy in our food is converted into the energy we need to carry out our life processes. (There are roughly 4 joules in 1 Calorie). You will convert the energy contained in a walnut into heat energy in a test tube of water.

APPARATUS

TI 83+	50 cm^3 water
CBL 2	Walnut
Temperature probe	Candle
Boiling tube	Tongs

Place the temperature probe into the test tube of water, ensuring that it is close to the bottom, but not touching the glass.

Set up the calculator to take temperature readings over time.

PROCEDURE

Plug a temperature probe into channel 1 of the CBL 2. Turn on the CBL 2 and calculator. Select the **DATAMATE** programme from the **APPS** menu.

Press [ENTER] at the welcome screen. Press [CLEAR] to reset the programme. The CBL 2 will check for probes. Screen 1 will be shown.

```
CH 1 TEMP(C)        17.9


MODE TIME GRAPH-120
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen 1

Select 1 **SETUP** and press the up arrow [▲] to highlight **MODE**. Press [ENTER] to get screen 2.

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select 2 **TIME GRAPH** to get screen 3.

```
TIME GRAPH SETTINGS
TIME INTERVAL         3

NUMBER OF SAMPLES     80

EXPERIMENT LENGTH     240
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select 2 **CHANGE TIME SETTINGS**

Enter **2** as time between samples in seconds. Enter **60** as the number of samples. Press [ENTER] to get screen 4.

```
TIME GRAPH SETTINGS
TIME INTERVAL         2

NUMBER OF SAMPLES     60

EXPERIMENT LENGTH     120
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

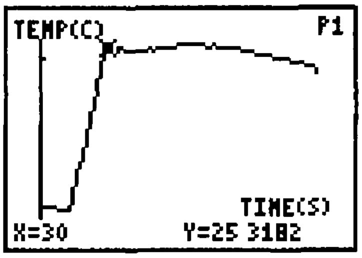
Select 1 **OK** to confirm settings. Select 1 **OK** again to return to the main menu.

Weigh the walnut and record the mass

Select **2 START** The calculator will start to record data Use a Bunsen to light the walnut Hold the walnut under the test tube

As soon as the data collection has finished, blow out the walnut

The calculator will auto scale the data As in Screen 5



Screen 5

Use the ◄► cursors to locate the minimum and maximum temperatures Record these values Re-weigh the walnut and record these values

RESULTS

Minimum temperature	
Maximum temperature	
Change in temperature	
Weight	
Change in temperature Per gram	

PROCESSING THE DATA

Print a graph of change of temperature with time, and answer the following questions

1 Is there more or less energy in the walnut before it was burned than after it was burned?

2 Where did the energy from the walnut go?

3 Is burning a walnut an exothermic or an endothermic reaction?

4 In this experiment, the _______________ energy in the walnut is changed to _______________ energy in the water

---

Sound energy to Electrical energy

When a sound is made, air molecules vibrate, and our ears pick up those vibrations A nerve called the auditory nerve runs from the ear to the brain, and we interpret the vibrations as sound
In this practical, you will use a tuning fork to produce the vibrations

These vibrations will be picked up on a microphone The microphone is attached to a CBL 2 and a graph representing the sound waves will appear on the calculator

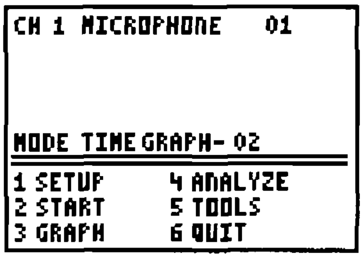
APPARATUS

TI 83 + CBL 2
Microphone
Tuning forks of different frequencies

PROCEDURE

Plug the microphone into channel 1 of the CBL 2
Press the **APPS** button on the calculator and select the **DATAMATE** programme
Press [CLEAR] to reset the programme

Screen 1 will be shown



Screen 1

Press [ENTER] to begin collecting data

Tap the tuning fork against the side of the table and place it in front of the microphone (See diagram)

The calculator will analyse the sound waves and produce a graph

Do this several times, using different frequencies of tuning forks

Repeat the whole process, except now, speak into the microphone instead of using the tuning fork

QUESTIONS

1. How does the pattern produced by your voice differ from the one produced with the tuning fork?
2. Why do you think this difference exists?
3. In this experiment, __________ energy from the tuning fork is converted into __________ energy in the calculator
4. Name some other examples of sound energy being converted into other forms of energy

---

Kinetic energy into Heat energy

APPARATUS

Litre beaker	CBL 2
Water	TI 83 +
Food mixer	

PROCEDURE

In this investigation, the kinetic energy generated by a food mixer is converted into heat energy in water

Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)        17 9

MODE TIME GRAPH-120
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen 1

Select 1 SETUP and press the up arrow [▲] to highlight MODE Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 8

Select 2 TIME GRAPH to get screen 3

```
TIME GRAPH SETTINGS
TIME INTERVAL        3

NUMBER OF SAMPLES   80

EXPERIMENT LENGTH  240
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select 2 CHANGE TIME SETTINGS

Enter 2 as time between samples in seconds
Enter 60 as number of samples
Press [ENTER] to get screen 4

```
TIME GRAPH SETTINGS
TIME INTERVAL        2

NUMBER OF SAMPLES   60

EXPERIMENT LENGTH  120
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

Select 1 OK to confirm settings Select 1 OK again to return to the main menu

Put a hand whisk into the water Press [ENTER] to begin collecting data Whisk the water as hard as you can, being careful not to damage the temperature probe

Select 2 START The calculator will start to record data

QUESTIONS

1 What happens to the temperature of the water?

2 Why does this happen?

Give two more examples of kinetic energy being converted into heat energy

To show that energy is conserved for a ball moving in freefall

When you throw a ball into the air several different types of energy are involved We will look at energy changes between *potential energy* and *kinetic energy*

When the ball is moving up and down it has kinetic and potential energy, when it reaches the top of the throw it becomes momentarily static and has only potential energy You will map the movement of a ball as you throw it up in the air The calculator will draw a graph of the movement

Then, you will use the calculator to graph the kinetic energy of the ball and the potential energy of the ball (It will work this out using the data you collected by throwing the ball in the air)

You have already learned that energy is neither created or destroyed, it just changes from one form to the other If this is the case, the total energy of the ball (kinetic + potential) should stay the same

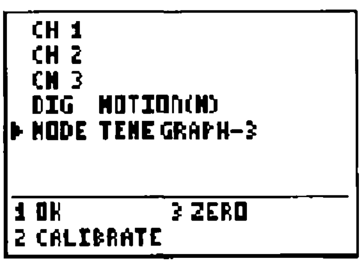
APPARATUS

Basketball, CBL 2, CBR, calculator

PROCEDURE

Select the **DATAMATE** programme from the **APPS** menu Press [CLEAR] to reset the calculator

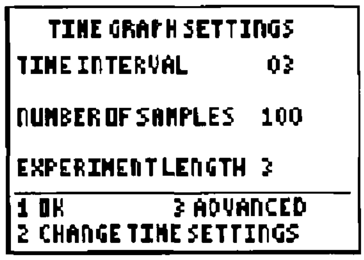
Select **1 SETUP** from the home screen



Screen1

Select **MODE** and press [ENTER] Select **TIME GRAPH** from the next screen Select **2 CHANGE TIME SETTINGS** from the next screen Type **0 03** for time between samples in seconds Press [ENTER]

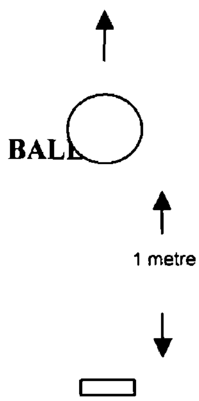
Type **100** for number of samples Press [ENTER] to get screen 2



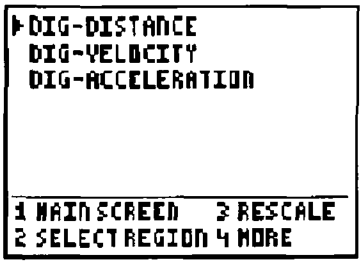
Screen 2

Press **1 OK** twice to return to the home screen

Measure the mass of the ball Place the motion detector on the ground Hold the ball by the sides about a meter above the detector Press **1 START** and at the same time throw the ball up, pulling hands and body away quickly

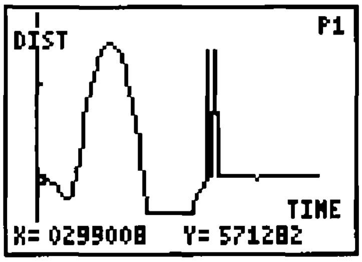


When the data has been collected the calculator will display **SAMPLING** Wait until the following screen is shown



Screen 3

Press [ENTER] Your graph will be similar to the one shown below If your curve is not smooth try again

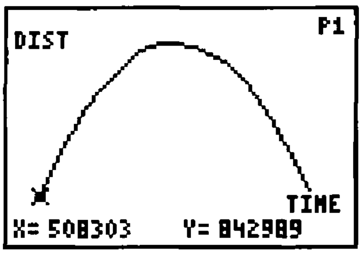


Screen 4

You need to select the curve from the rest of the data on the screen To do this press [ENTER] to see screen 3 again This time select **2 SELECT REGION**

The calculator will ask to select **LEFT BOUND?** Use the [◄][►] arrows to move the cursor to the bottom left point you want from your graph Press [ENTER] and a vertical line will appear

The calculator asks for the **RIGHT BOUND?** Use the arrows to move to the right end point and press [ENTER] After a short time screen 3 will appear again Press [ENTER] again and your selected data will be drawn as in screen 5

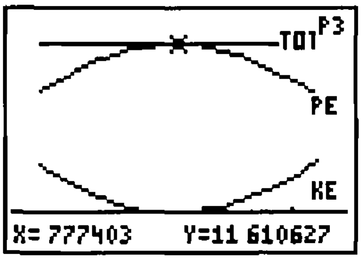


Screen 5

Exit the application be pressing [ENTER] , **1 MAIN SCREEN** and **6 QUIT**

Press [PRGM] and select **ENGYCONS**

You will be prompted for the weight of the ball in kg Enter your measured value and press [ENTER] You will then see a graph of Potential and Kinetic Energy as in screen 6



Screen 6

As potential energy increases, kinetic energy decreases and vice versa The total energy remains constant throughout This is shown by the **TOT** line at the top of the graph It is a constant value

Sketch graphs (labels / units)

CONCLUSION

Energy is Conserved for a ball under the pull of gravity

This is a simple and effective demonstration of a concept of huge importance in physics It would not be possible without the motion detector

To investigate the difference between heat and temperature

Heat is a form of energy Temperature is a measure of how hot something is In this investigation, you will give the same amount of energy to two different volumes of water, and record the increase in temperature that results

APPARATUS

TI 83+	2 Temperature probes
CBL 2	2 1L Beakers
2 Bunsen Burners	2 Tripods and Gauze

PROCEDURE

Put 800 cm^3 of cold water in one of the beakers Put 200 cm^3 of cold water in the other one Place each of the beakers on a tripod and gauze

Plug two temperature probes into channel 1 and channel 2 of the CBL 2 Turn on the CBL 2 and calculator Select **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)        19 6
CH 2 TEMP(C)        19 8

MODE TIME GRAPH-180
1 SETUP     4 ANALYZE
2 START     5 TOOLS
3 GRAPH     6 QUIT
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **2 TIME GRAPH**

```
TIME GRAPH SETTINGS
TIME INTERVAL        1
NUMBER OF SAMPLES    180
EXPERIMENT LENGTH    180
1 OK         3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Type **2** as the time between samples in seconds press [ENTER] Type **60** as the number of samples and press [ENTER] to get Screen 4

```
TIME GRAPH SETTINGS
TIME INTERVAL        2
NUMBER OF SAMPLES    60
EXPERIMENT LENGTH    120
1 OK         3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

To set the axes on the graph select **3 ADVANCED**

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX     YSCL
-25      125      25
TRIGGERING NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 5

The values on the Y axis (temperature) are set between –25 and +125 This range of values is too wide for the two reactions in this investigation

To change these values select **2 CHANGE GRAPH SETTINGS** to get screen 6

```
SELECT GRAPH
1 CH1-TEMP(C)
2 CH2-TEMP(C)
3 NONE
```

Screen 6

Select **1 CH1-TEMP(C)** and type **10** as **Y MIN** and press [ENTER] Type **100** as **Y MAX** and press [ENTER] type **10** as **Y SCL** and press [ENTER] to get screen 7

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX     YSCL
10       100      10
TRIGGERING NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 7

Select **1 OK** twice to return to the main menu

Place the two temperature probes in the beakers Select **2 START** on the calculator, light the two Bunsen burners and place them under the beakers

Stir the water in each beaker gently and observe the change in temperature for each

RESULTS

	$800\ cm^3$	$200\ cm^3$
Initial temp		
Final Temp		
Change in Temperature		

QUESTIONS

1 Which beaker showed the greatest temperature change?

2 The same amount of energy was supplied to both beakers of water, yet the temperature in each rose by different amounts Why?

3 Which loses more heat in cooling to 10^0C, a bath full of water at 20 ^0C or a cup of tea at 100 ^0C?

Absorption of radiant energy

When heat is given out by an object without having to travel through a medium, we say that it is *radiated* This is how the heat from the sun travels almost 150,000,000 km towards the earth

Colour affects the absorption of radiant energy You can use the results of this experiment to decide which colour clothes to wear to keep cool in the summer, and warm in the winter

APPARATUS

TI 83+ Calculator	White Paper
CBL 2	Black paper
2 temperature probes	Lamp

PROCEDURE

Tape two temperature probes to the table
Plug the probes into channel 1 and 2 of the CBL 2 Turn the CBL 2 and the calculator on Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)    19 6
CH 2 TEMP(C)    19 8

MODE TIME GRAPH -180

1 SETUP     4 ANALYSE
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP
```

Screen 2

Select **2 TIME GRAPH** for screen 3

```
TIME GRAPH SETTINGS

TIME INTERVAL    1

NUMBER OF SAMPLES    180

EXPERIMENT LENGTH    180

1 OK       3 ADVANCED
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Type **2** as the time between samples in seconds press [ENTER] Type **60** as the number of samples and Press [ENTER] to get Screen 4

To set the axes on the graph select **3 ADVANCED**

```
TIME GRAPH SETTINGS

TIME INTERVAL    2

NUMBER OF SAMPLES    60

EXPERIMENT LENGTH    120

1 OK  3 ADVANCED
```

Screen 4

The values on the Y-axis (temperature) are set between –25 and +125. This range of values is too wide for the temperature change in this investigation.

To change these values select

```
ADV  TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN        YMAX    YSCL
-25         125       25
TRIGGERING  NONE

1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 5

2 CHANGE GRAPH SETTINGS to get screen 6

```
SELECT GRAPH
1 CH1-TEMP(C)
2 CH2-TEMP(C)
3 NONE
```

Screen 6

Select **1 CH1-TEMP(C)** and type **10** as **Y MIN** and press [ENTER]. Type **50** as **Y MAX** and press [ENTER] type **2** as **Y SCL** and press [ENTER] to get screen 7

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX    YSCL
10       50      2
TRIGGERING NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 7

Select **1 OK** twice to return to the main menu.

Position a light bulb so that it shines equally onto both Pieces of paper.

When everything is ready, begin collecting data by pressing **2 START**.
A graph of the temperature under both pieces of paper will appear on the calculator. After about 20 seconds switch the light on.

When all the data has been recorded, a graph displaying Temperature against time for both probes will appear on the calculator.

You can examine the data points along the curve by moving the [►] button on the calculator.

Find the minimum and maximum temperature for each can and record them (you can switch the tracer between graphs by pressing the [▼] arrow on the calculator.

QUESTIONS

1. Calculate the temperature change, for each colour by subtracting the initial temperature from the final temperature.

	Black	white
Initial Temp		
Final Temp		

2. Which Piece of paper absorbed the most heat?

4. Why is it better to wear light-coloured clothing in the summertime?

5. Solar collectors can be used to absorb the sun's radiation and change it to heat. What colour would work best for solar collectors? Explain.

To show that there is no change of temperature during a change of state

In this investigation, we will look at the temperature changes that take place in a test tube of ice as you heat it

As you heat ice, its temperature gradually increases until it reaches 0^0C As you continue to heat it, the temperature remains at 0^0C until all the ice has melted The energy supplied during this change of state is not causing a rise in temperature, instead it is being used to break the bonds, which hold the molecules together in the solid state

If you continue to heat the melted ice (water) the energy supplied will cause a rise in temperature until it reaches 100^0C At this temperature, water turns to steam The energy supplied during this change of state is used to break the bonds that hold the molecules together in the liquid state
The temperature remains at 100^0C until all the water has been changed to steam
The energy supplied during these changes of state is called ***latent heat***

When the change of state is from a solid to a liquid, the latent heat is called latent heat of fusion, when the change of state is from liquid to vapour, it is called latent heat of vaporisation

APPARATUS

CBL 2 with 1 temp probe	Bunsen burner
TI 83 +	Ice
250 cm^3 beakers	5 spoons salt
	50 cm^3 water

PROCEDURE

Plug a temperature probe into channel 1 of the CBL Turn on the CBL 2 and calculator Select **DATAMATE** programme from the **APPS** menu Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)        17 9


MODE TIME GRAPH-120
1 SETUP       4 ANALYZE
2 START       5 TOOLS
3 GRAPH       6 QUIT
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **2 TIME GRAPH** to get screen 3

```
TIME GRAPH SETTINGS
TIME INTERVAL          3
NUMBER OF SAMPLES      80
EXPERIMENT LENGTH      240
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**
Enter **5** as time between samples in seconds and **120** as the number of samples Press [ENTER] to get screen 4

```
TIME GRAPH SETTINGS
TIME INTERVAL          5
NUMBER OF SAMPLES      120
EXPERIMENT LENGTH      600
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

The temperature probe has a default setting between -25^0C and $+125^0$ C While these settings will still give an accurate result, it is better to change the graph settings so that you can get a better picture of the change in temperature as the graph is appearing on the screen

To do this press **3 ADVANCED** to get screen 5

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX     YSCL
-25      125      25
TRIGGERING NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 5

Select **2 CHANGE GRAPH SETTINGS**
From the next screen, you will be asked to select which graph you want to change

Select **1 CH1-TEMP(C)** When prompted, type in **-5** for **Y MIN** then press [ENTER] (remember to use the [(-)] key on the calculator when typing -5) Type in **10** for **Y MAX**, press [ENTER] Type in **1** for **Y SCL**

The following screen should appear

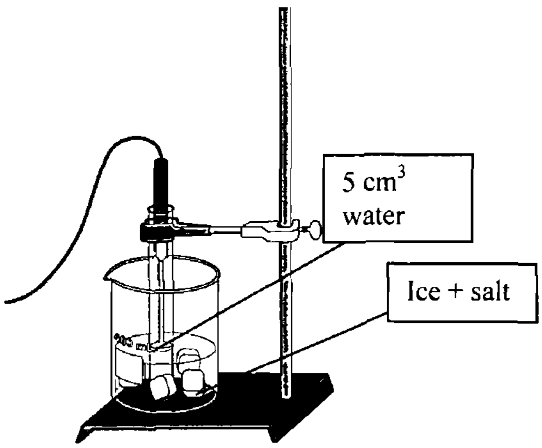
```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX     YSCL
-5       10       1
TRIGGERIRG NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHARGE TRIGGERING
```

Screen 6

Press **1 OK** three times until you get screen 7

```
CH 1  TEMP(C)          22 8

MODE  TIME GRAPH-1200
1 SETUP        4 ANALYZE
2 START        5 TOOLS
3 GRAPH        6 QUIT
```

Screen 7



Place about 5 cm^3 water in a test tube, and set up as in the diagram The calculator will give a live reading of temperature

When the temperature reaches about -2^0C press **2 START** on the calculator The calculator will begin to produce a graph of temperature vs time

Raise the test tube out of the ice bath and after about 5 minutes, lower it into a warm water bath Stir the warm water bath during the data collection period

Once data collection has finished, press [TRACE] on the calculator and move the [▶] arrow to the flat part of the graph Record the temperature of this region of the graph

Print a graph of temperature *vs* time If you have time, repeat the experiment, but this time, start off with water, place the test tube in some ice + salt, and investigate the temperature change as the water freezes

QUESTIONS

1 What is the energy involved in a change of sate called?

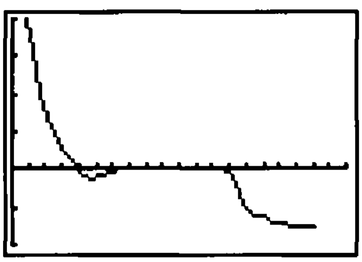
2 How does the melting point of water relate to the freezing point?

3 When ice at 0^0C is melted its temperature does not change until all the water has melted Why?

4 Why does it feel colder when snow is thawing than before it starts to thaw?

5 Examine the graph below, it shows the change in temperature as water freezes

Describe in words what the graph is showing



To demonstrate the effect of insulation

APPARATUS

Calculator	Cotton wool
CBL 2	2 250 cm^3 beakers
2 temperature probes	Hot water

PROCEDURE

Plug the probes into channel 1 and 2 of the CBL 2 Turn the CBL 2 and the calculator on Select **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)    19 6
CH 2 TEMP(C)    19 8

MODE  TIME GRAPH -180

1 SETUP       4 ANALYSE
2 START       5 TOOLS
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
```

Screen

Select **2 TIME GRAPH** for screen 3

```
TIME GRAPH SETTINGS

TIME INTERVAL    1

NUMBER OF SAMPLES    180

EXPERIMENT LENGTH    180

1 OK        3 ADVANCED
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Type **2** as the time between samples in seconds press [ENTER] Type **90** as the number of samples and press [ENTER] to get Screen 4

```
TIME GRAPH SETTINGS
TIME INTERVAL       2

NUMBER OF SAMPLES   90

EXPERIMENT LENGTH 180
1 OK           3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

To set the axes on the graph select **3 ADVANCED**

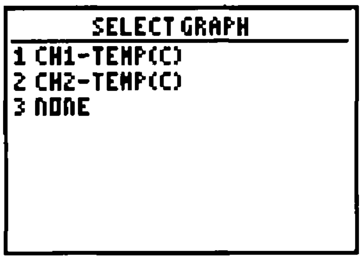
The values on the Y-axis (temperature) are set between –25 and +125 This range of values is too wide for the temperature change in this

```
ADV  TIME GRAPH SETTINGS
LIVE GRAPH  TEMP(C)
YMIN      YMAX    YSCL
-25       125     25
TRIGGERING  NONE

1 OK
2 CHANGE GRAPH SETTINGS
```

Screen 5

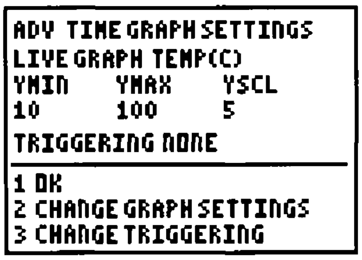
investigation

To change these values select **2 CHANGE GRAPH SETTINGS** to get screen 6



Screen 6

Select **1 CH1-TEMP(C)** and type **10** as **Y MIN** and press [ENTER] Type **100** as **Y MAX** and press [ENTER] type **5** as **Y SCL** and press [ENTER] to get screen 7



Screen 7

Select **1 OK** twice to return to the main menu

Wrap one of the beakers in cotton wool to insulate it Pour some boiling water into both beakers Place a temperature probe into each beaker

When everything is ready, begin collecting data by pressing **2 START** A graph of the temperature of the water in both beakers will appear on the calculator

When all the data has been recorded, a graph displaying Temperature against time for both probes will appear on the calculator You can examine the data points along the curve by moving the [►] button on the calculator

Find the minimum and maximum temperature for each beaker and record them (you can switch the tracer between graphs by pressing the [▲][▼] arrows on the calculator)

Calculate the temperature change for each beaker by subtracting the initial temperature from the final temperature

RESULTS

	Insulated	Not insulated
Initial temp ^{0}C		
Final temp ^{0}C		
Change in temperature		

1 Which beaker lost heat the fastest?

2 Why did the water in one beaker cool down faster than the other?

Sound is a wave motion

Sound is a wave motion These waves consist of a series of air pressure variations

The pressure variations caused by sound waves can be picked up by a microphone, and converted into an electrical signal

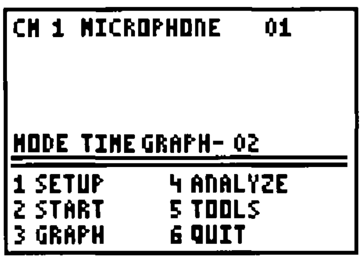
In this investigation, you will explore the properties of common sounds

APPARATUS

CBL 2 — 2 Tuning forks
TI 83+ — or electronic keyboard
Microphone

PROCEDURE

Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu Press [CLEAR] to reset the programme Press [ENTER] at the welcome screen The CBL 2 will check for probes Screen 1 will be shown



Screen 1

If the calculator does not display the microphone in Channel 1, you will need to set up the sensor manually

To do this

Select **SET UP** *from the main screen Press* [ENTER] *to select* **CH 1**

Chose **MICROPHONE** *from the select sensors list Select* **CBL, ULI,** *or* **MPLI** *depending on the type of microphone you are using*

Select **OK** *to return to the main screen*

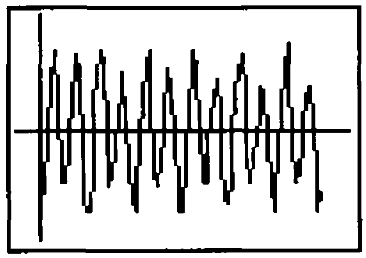
For best results, the microphone channel should be zeroed To do this

Select **SET UP** from the main screen
Select **ALL CHANNELS** from the **SELECT CHANNEL** screen

With the room quiet, press [ENTER] to zero the microphone

Produce a sound using a tuning fork or a keyboard

Select **2 START** from the main menu The calculator will collect data



Try this using tuning forks of different frequencies

Calculate the wavelength by counting the number of complete cycles on the graph and dividing by the time taken

EXPERIMENTS IN CHEMISTRY

Endothermic and exothermic reactions

When a chemical reaction takes place, there is very often a heat change This is because there is a difference in the energy between the substances that are reacting, and the products of the reaction

Some reactions give out heat and these are known as *exothermic* reactions In exothermic reactions, the reactants have more energy than the products

Other reactions take in heat these and these are called *endothermic* reactions In these reactions, the products have more energy than the reactants Where do they get this extra energy? They get it by taking some heat away from the system Consequently, the system becomes colder

In this investigation, we will study one endothermic reaction and one exothermic reaction

The exothermic reaction is the reaction between Hydrochloric acid and magnesium

$$2\,HCl + Mg \longrightarrow MgCl_2 + H_2$$

The endothermic reaction is between citric acid (found in citrus fruits), and sodium hydrogen carbonate (baking soda) This is the reaction used in the manufacture of sherbet

MATERIALS

CBL 2 with 2 temp probes	10 grams sodium hydrogen carbonate
TI 83+	5 cm strip magnesium ribbon
2 50 cm^3 graduated cylinder	50 cm^3 dilute (1M) HCl
2 Styrofoam cups	5 grams citric acid
2 250 cm^3 beakers	50 cm^3 water

PROCEDURE

Plug two temperature probes into channel 1 and channel 2 of the CBL 2 Turn on the CBL 2 and calculator Select **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)        19 6
CH 2 TEMP(C)        19 8

MODE TIME GRAPH-180
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **2 TIME GRAPH**

```
TIME GRAPH SETTINGS
TIME INTERVAL        1
NUMBER OF SAMPLES  180
EXPERIMENT LENGTH  180
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Type **2** as the time between samples in seconds press [ENTER] Type **60** as the number of samples and press [ENTER] to get Screen 4

```
  TIME GRAPH SETTINGS
TIME INTERVAL        2

NUMBER OF SAMPLES   60

EXPERIMENT LENGTH  120
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

To set the axes on the graph select
3 ADVANCED

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX     YSCL
-25      125      25
TRIGGERING NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 5

The values on the Y axis (temperature) are set between –25 and +125 This range of values is too wide for the two reactions in this investigation To change these values select
2 CHANGE GRAPH SETTINGS to get screen 6

```
      SELECT GRAPH
1 CH1-TEMP(C)
2 CH2-TEMP(C)
3 NONE
```

Screen 6

Select 1 CH1-TEMP(C) and type 10 as Y MIN and press [ENTER] Type 40 as Y MAX and press [ENTER] type 2 as Y SCL and press [ENTER] to get screen 7

```
ADV TIME GRAPH SETTINGS
LIVE GRAPH TEMP(C)
YMIN     YMAX     YSCL
10       40       2
TRIGGERING NONE
1 OK
2 CHANGE GRAPH SETTINGS
3 CHANGE TRIGGERING
```

Screen 7

Select 1 OK twice to return to the main menu

Pour 50 cm^3 dilute HCl into one of the Styrofoam cups Dissolve the citric acid in 50 cm^3 of water in the other Styrofoam cup, and place them inside the glass beakers

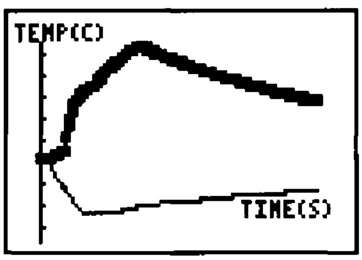
Place a temperature probe into each of the cups

When everything is ready, commence data collection by pressing **2 START**

Once the temperatures in each beaker have stabilized, record the temperature in both beakers This is the initial temperature

After about 10 seconds, add the sodium hydrogen carbonate to the citric acid, and the magnesium ribbon to the dilute HCl Gently stir each of the mixtures

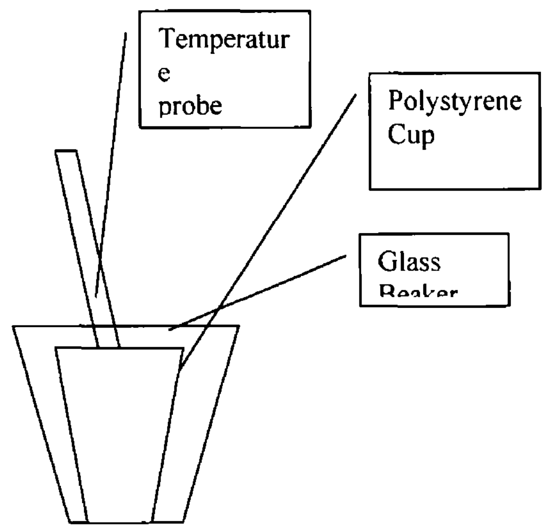
When the sampling is complete, the calculator will auto scale the data To view the graphs press [ENTER]



Screen 8

Examine the graph of temperature against time Record the maximum and minimum temperatures of each solution

RESULTS



Temp	**Citric Acid + $NaHCO_3$**	**HCl + Magnesium**
Initial		
Max/Min		
Change		

Ionic and covalent substances

The kind of bonding in a compound has a large effect on its properties Ionic compounds consist of ions joined by ionic bonds A covalent compound consists of groups of atoms joined together by covalent bonds

Because of their electric charge, the ions in an ionic substance can move in an electric field They conduct electricity when the compound is melted or dissolved Covalent compounds do not conduct electricity

APPARATUS

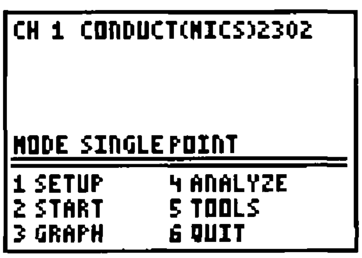
TI83+	Different solutions
CBL 2	Deionised water
Conductivity probe	

PROCEDURE

Check that the switch on the side of the conductivity probe is in the range 0-2000μS Attach a conductivity probe to Channel 1 of the CBL 2

Select the **DATAMATE** programme from the **APPS** menu Press [CLEAR] to reset the programme

Press [ENTER] at the welcome screen The CBL 2 will check for probes Screen 1 will be shown



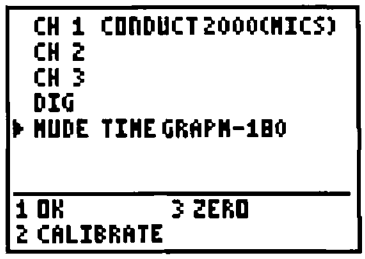
Screen 1

If the calculator does not display the conductivity probe in Channel 1, you will need to set up the sensor manually

__To do this__

Select **SET UP** *from the main screen*
Press [ENTER] *to select* **CH 1**
Chose **CONDUCTIVITY** *from the select sensors menu*
Select **CONDUCT 2000 (MICS)** *from the* **CONDUCTIVITY** *menu*
Select **1 OK** *to return to the main screen*

To set up the sensor for data collection
Press **1 SETUP**
Use the [▲] arrow to select **MODE** on the calculator screen to get screen 2



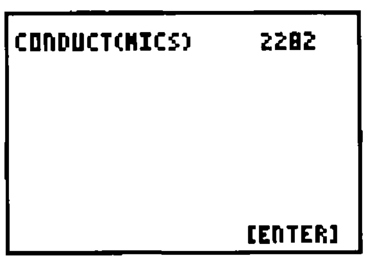
Screen 2

Press [ENTER] and select **4 SINGLE POINT** from the select mode menu

Select **1 OK** to return to the main menu

Place the probe into the first sample, ensuring that the tip of the probe is well under the surface of the water Move the probe gently in the sample

Press **2 START** The calculator will collect data for 10 seconds When Data collection is done, the conductivity in microsiemens will be displayed



Screen 3

Record this value and press [ENTER] to return to the main screen

Repeat for each of the samples

RESULTS

Sample	Conductivity (μS)	Ionic/covalent

QUESTIONS

1 Why do ionic substances conduct electricity while covalent compounds do not?

2 Why do ionic substances need to be melted or dissolved before they conduct electricity?

3 Give three other properties of ionic substances

4 Give three other properties of covalent substances

5 Why are ionic substances generally solid at room temperature whereas covalent substances are usually liquid or gas at room temperature?

Acids and bases

Many common household solutions contain acids and bases. Acids are responsible for giving some foodstuffs their sour taste. A test for acid is that it turns litmus red.

A base is the opposite of an acid. A base is often used to neutralise an acid. For example, indigestion tablets contain bases that neutralise the strong acid present in our stomachs.

The acidity of a solution can be expressed using the pH scale. Acidic solutions have pH values less than 7; basic solutions have pH values greater than 7, and neutral solutions have a pH value equal to 7.

In this experiment, you will use litmus and a pH Sensor to determine the pH values of household substances.

APPARATUS

CBL 2	Household solutions
TI 83+	7 small test tubes
pH probe	test-tube rack
wash bottle	red and blue litmus
distilled water	

PROCEDURE

Turn on the CBL 2 and calculator. Select **DATAMATE** programme from the **APPS** menu. Press [ENTER] at the welcome screen. Press [CLEAR] to reset the programme. The CBL 2 will check for probes. Screen 1 will be shown.

```
CH 1:PH              3.63

MODE: TIME GRAPH-120
1:SETUP       4:ANALYZE
2:START       5:TOOLS
3:GRAPH       6:QUIT
```

Screen 1

Select **1:SETUP.**

Use the down arrow [▼] to select **MODE**. Press [ENTER] to move to screen 2.

```
SELECT MODE
1:LOG DATA
2:TIME GRAPH
3:EVENTS WITH ENTRY
4:SINGLE POINT
5:SELECTED EVENTS
6:RETURN TO SETUP SCREEN
```

Screen 2

Select **4:SINGLE POINT** to get screen 3.

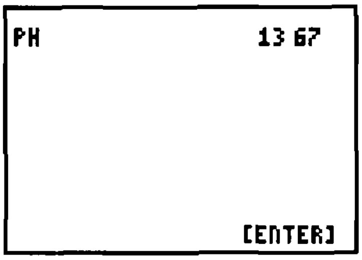
```
 CH 1:PH
 CH 2:
 CH 3:
 DIG :
▶ MODE: SINGLE POINT

1:OK          3:ZERO
2:CALIBRATE
```

Screen 3

Press **1:OK** to return to the main menu.

Remove the tip of the pH probe from the little soaking bottle that it is stored in and rinse the tip with distilled water.

Place the probe in the first solution to be tested and press **2 START** on the calculator The probe will sample for 10 seconds after which time it will display a pH reading on the calculator as in screen 4



Screen 4

Record this value

Dip some litmus paper in the solution and record the colour

Rinse the probe again and place in the next solution to be tested and repeat the procedure Continue doing this until all your solutions have been tested

RESULTS

Solution	***pH***	***Litmus***
Vinegar		
Ammonia		
Lemon juice		
Soft drink		
Drain cleaner		
Detergent		
Baking soda		

QUESTIONS

1 Which solutions were acidic?

2 Which solutions were basic?

3 An acid and a base make a ____________

and ____________________

4 What do we call a substance that is neither acidic nor basic?

The reaction between an acid and a carbonate

When Hydrochloric acid (HCl) reacts with Calcium Carbonate ($CaCO_3$) the acid neutralises the base and a salt and water is formed according to the equation

$$2HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O$$

In this investigation you will use a pH probe to monitor the change in pH as the carbonate neutralises the acid, and a CO_2 probe to monitor the evolution of CO_2 , one of the products of the reaction

APPARATUS

TI 83+	Dilute HCl (approx 0 1M)
CBL 2	Calcium Carbonate
pH probe	250 cm^3 beaker
CO_2 Gas probe	Water
	Litmus

PROCEDURE

Plug a pH probe into Channel 1 of the CBL 2 Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 PH                 3 63


MODE TIME GRAPH-120
1 SETUP       4 ANALYZE
2 START       5 TOOLS
3 GRAPH       6 QUIT
```

Screen 1

The default setting for the pH probe is fine for this experiment and does not have to be changed It is set to take a reading every 2 seconds for two minutes

Put 200 cm^3 Hydrochloric acid in the beaker with a small amount of litmus Put the pH probe into the acid Select **2 START** on the calculator and while stirring, add a spoonful of calcium carbonate powder

When the data has finished being recorded, a graph of pH vs time will appear on the calculator

Print out the graph and reset the calculator

Remove the pH probe from the CBL 2 and add a CO_2 gas probe into channel 1

Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes

Select **1 SETUP** from the main screen Move the black arrow down to **MODE • SETUP** by pressing the [▲] arrow once on the calculator Press [ENTER] to get screen 2

```
        SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **2 TIME GRAPH** to get screen 3

```
   TIME GRAPH SETTINGS
TIME INTERVAL         10
NUMBER OF SAMPLES     30
EXPERIMENT LENGTH    300
1 OK           3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Type in **5** when asked for the time between samples in seconds and press enter Type in **24** as the number in samples and press [ENTER] to get screen 4

```
  TIME GRAPH SETTINGS
TIME INTERVAL        5

NUMBER OF SAMPLES   24

EXPERIMENT LENGTH  120
----------------------
1 OK         3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

Press **1 OK** twice to return to the main screen

Put 200 cm^3 Hydrochloric acid in the beaker
Hold the CO_2 probe above the beaker

Select **2 START** on the calculator and while stirring, add a spoonful of calcium carbonate powder

The sensor will measure the amount of CO_2 that is evolved from the reaction between the carbonate and the acid and the calculator will draw a graph of CO_2 concentration vs time

QUESTIONS

1. What happened the pH of the solution once the carbonate was added?
2. What did you notice about the colour of the litmus once the carbonate was added?
3. What else did you notice about the solution once the carbonate was added?
4. What did that indicate about one of the products of the reaction?
5. Did the reaction between the acid and the carbonate result in a chemical or a physical change?
6. Give one piece of evidence to support your answer

To show that rusting is an oxidation process

About 20% of the air is made up of oxygen gas Many chemicals react with oxygen when they come into contact with it

Examples of common oxidation processes are burning, respiration and rusting

When metals react with oxygen in the air, they form a metal oxide A metal oxide that we are familiar with is Iron oxide, better known as rust Iron is a shiny grey solid, but when it reacts with oxygen it forms a new substance Iron oxide which is reddish brown and crumbly

The chemical equation for this reaction is

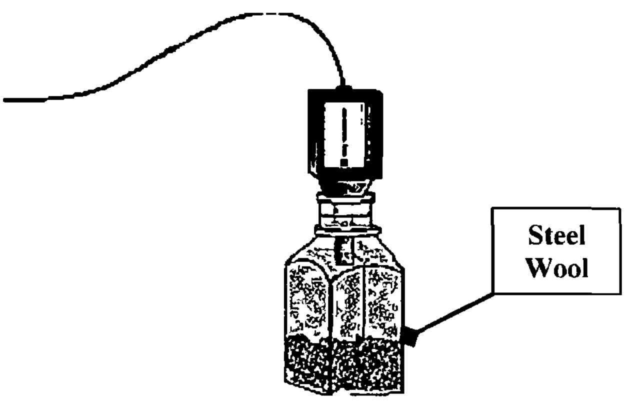
$$2Fe + O_2 \longrightarrow 2FeO$$

Iron + Oxygen → Iron Oxide

In this experiment, you will place some damp steel wool in a bottle with an oxygen gas sensor and leave it for 20 minutes During that time, the iron will react with the oxygen in the air and the level of oxygen inside the bottle will go down

APPARATUS

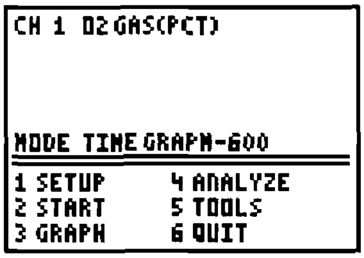
TI 83+	Gas probe bottle
CBL 2	Steel wool
O_2 Gas probe	Water



PROCEDURE

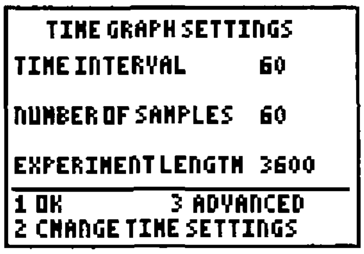
Place some damp steel wool in the bottom of the bottle that comes with the Oxygen gas probe

Plug an Oxygen gas probe into Channel 1 of the CBL 2 Select the **DATAMATE** programme from the **APPS** menu Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown



Screen 1

The calculator is set to take readings every 15 seconds for 10 minutes
Change these settings to take readings every minute for 1 hour
To do this select 1 SETUP press the [▲] arrow once to select TIME GRAPH press ENTER Select 2 TIME GRAPH Select 2 CHANGE TIME SETTINGS Enter 60 as time between settings press ENTER
Enter 60 as the number of samples Press ENTER Screen 2 will appear

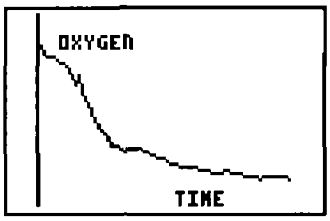


Screen 2

Select 1 O K three times to get back to the home screen

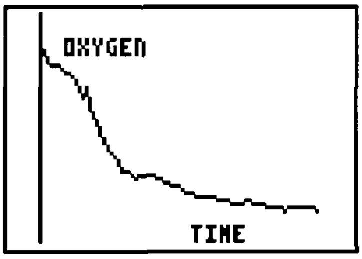
Put the probe into the bottle as on the diagram Select **2 START**

After 10 minutes, a graph showing the drop in oxygen levels over time will be shown As in screen 3



Screen 3

Put the probe into the bottle as on the diagram Select **2 START** After 10 minutes, a graph showing the drop in oxygen levels over time will be shown as in screen 2



Screen 2

QUESTIONS

1 Why did the oxygen level inside the bottle go down?

2 What chemical process was happening to the Steel wool?

3 Is the rusting of Iron a physical or a chemical change?

4 How do you think the shape of the graph would have changed if this had been done
a) At a much lower temperature?
b) At a much higher temperature?

To compare the hardness in different water samples

Hardness in water is caused by the presence of Mg^{++} and Ca^{++} ions The amounts of these ions present determine how hard the water is
In this experiment, you will use two methods to compare the hardness of water samples First, you will test their ability to form lather with soap flakes Hard water does not form lather, soft water does

Next, you will measure the ability of the water samples to conduct electricity If there are ions present in a solution, it will conduct electricity, if there are no ions present, it will not We can measure the ability of a solution to conduct electricity by using a conductivity probe The greater the conductivity, the harder the water

APPARATUS

TI 83+	4 Test tubes
CBL 2	Conductivity probe
Soap flakes	Water samples

PROCEDURE

Label four test tubes 1 - 4 Label each sample of water 1 - 4 Half fill each test tube with the corresponding number water sample

Add three or four soap flakes to each test tube and shake vigorously

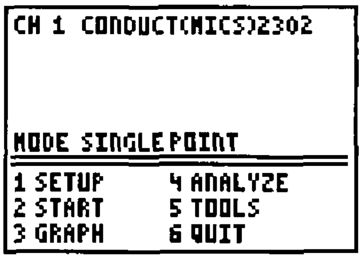
Record the height of the lather

Throw out the soapy water, and wash the test tubes Half fill the test tubes again with fresh water samples

Set up the conductivity probe to collect data Connect it to CH1 of the CBL 2 Switch the selector switch on the side of the conductivity probe to the 0-2000 range

Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu
Press [CLEAR] to reset the programme

Press [ENTER] at the welcome screen The CBL 2 will check for probes Screen 1 will be shown



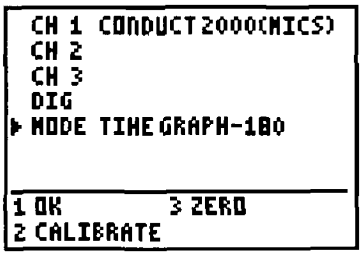
Screen 1

If the calculator does not display the conductivity probe in Channel 1 you will need to set up the sensor manually

To do this

Select **SET UP** *from the main screen*
Press [ENTER] to select **CH 1**
Chose **CONDUCTIVITY** *from the select sensors menu*
Select **CONDUCT 2000 (MICS)** *from the* **CONDUCTIVITY** *menu*
Select **OK** *to return to the main screen*

To set up the sensor for data collection
Press **1 SETUP**
Use the [▲] arrow to select **MODE** on the calculator screen to get screen 2



Screen 2

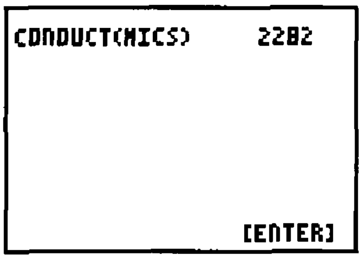
Press [ENTER] and select **4 SINGLE POINT** from the select mode menu

Select **1 OK** to return to the mam menu

Place the probe into the sample, ensuring that the tip of the probe is well under the surface of the water

Press **2 START** the calculator will collect data for 10 seconds

When data collection is done the conductivity in will be displayed in microsiemens (MICS) as in screen 3



Screen 3

Record this value and press [ENTER] to return to the main screen

Repeat for each of the water samples

RESULTS

Test tube number	Height of lather (cm)	Conductivity (µS)
1		
2		
3		
4		

PROCESSING THE DATA

Enter these results into graphic analysis on the computer (Conductivity can be entered automatically via the calculator, enter the height of the lather manually)

Produce two different bar charts, one with height of lather on the vertical axis, and one with Conductivity on the vertical axis Use the number of the water sample as the horizontal axis in each case

Alternatively, enter the height of the lather as L_3 in the calculator, and examine the graphs of L_1 L_2 and L_1 L_3 (in the Histogram option in **STAT PLOT**)

QUESTIONS

1 What was present in the water that enabled it to conduct electricity?

2 Why did their presence increase the conductivity of the water?

3 How would the height of lather produced by soapflakes compare in the boiled and unboiled water samples?

4 Which water sample was harder, the unboiled sample or the boiled sample?

5 Was this hardness due to temporary or permanent hardness?

Investigating temporary and permanent hardness of water

Hardness in water is caused by the presence of calcium and magnesium ions dissolved in water Hardness may be either temporary or permanent

Temporary hardness may be removed by boiling Calcium salts change when heated and forms lime scale The lime scale does not dissolve in water, and so comes out of solution This can sometimes be a problem as it can clog up hot water pipes

Permanent hardness cannot be removed by boiling, these salts do not change when heated, so remain dissolved in the water

The only way that permanent hardness can be removed is by passing it through something called an ion exchange resin This ion exchange resin holds on to the calcium and magnesium ions as the water passes through

In this investigation you will measure the hardness of a sample of water by measuring its ability to conduct electricity You will measure three samples of water

- Containing both temporary and permanent hardness,
- Containing just permanent hardness
- Both types of hardness removed

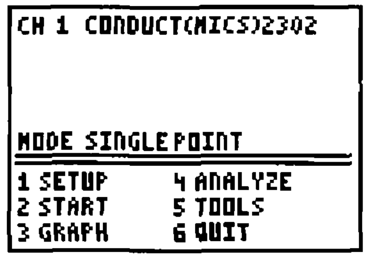
APPARATUS

TI83+	Hard water sample
CBL 2	Ion exchanger
Conductivity probe	Deionised water

PROCEDURE

Switch the selector switch on the side of the conductivity probe to the 0-2000 range

Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu Press [CLEAR] to reset the programme Press [ENTER] at the welcome screen The CBL 2 will check for probes Screen 1 will be shown



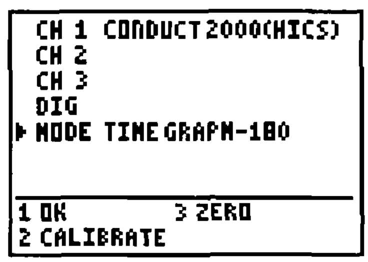
Screen 1

If the calculator does not display the conductivity probe in Channel 1 you will need to set up the sensor manually

To do this

Select SET UP *from the main screen*
Press [ENTER] to select CH 1
Chose CONDUCTIVITY *from the select sensors menu*
Select CONDUCT 2000 (MICS) *from the* CONDUCTIVITY *menu*
Select OK *to return to the main screen*

To set up the sensor for data collection
Press **1 SETUP** Use the [▲] arrow to select **MODE** on the calculator screen to get screen 2



Screen 2

Press [ENTER] and select **4 SINGLE POINT** from the select mode menu Select **1 OK** to return to the main menu

Place the probe into the sample of hard water, ensuring that the tip of the probe is well under the surface of the water

Press **2 START** the calculator will collect data for 10 seconds

When data collection is done the conductivity in will be displayed in microsiemens (MICS) as in screen 3

Screen 3

Record this value and press [ENTER] to return to the main screen Remove the conductivity probe from the sample and place in deionised water

Boil the hard water sample for one minute Allow it to cool down

Place the probe into the sample of cooled boiled water, ensuring that the tip of the probe is well under the surface of the water Press **2 START** the calculator will collect data for 10 seconds

When data collection is done the conductivity in will be displayed in microsiemens (MICS) Record this value and press [ENTER] to return to the main screen

Remove the conductivity probe from the sample and place in deionised water Pass the water sample through an ion exchanger Place the probe into the sample of water that comes out of the ion exchanger, ensuring that the tip of the probe is well under the surface of the water

Press **2 START** the calculator will collect data for 10 seconds When data collection is done the conductivity in will be displayed in microsiemens (MICS) Record this value

RESULTS

Sample	**Conductivity (μS)**
Hard water	
Boiled water	
Water after ion exchanger	

QUESTIONS

1 What causes hardness in water?

2 What is the difference between temporary and permanent hardness in water?

3 Give one advantage of hard water

4 Give one disadvantage of hard water

5 What is the name of the compound deposited on the inside of kettles in hard water areas?

6 How is permanent hardness removed from water?

To find the order of metals in the electrochemical series

In this experiment, the voltage produced by several different metals in a simple cell is investigated

A carbon electrode is used in a simple cell in conjunction with each of the other metals in turn

The electrochemical series is a list of elements in order of how readily they lose electrons The voltage produced by each of the metals in the simple cell will give us an indication of the ease with which they lose electrons The higher the voltage produced the higher up the electrochemical series the metal is

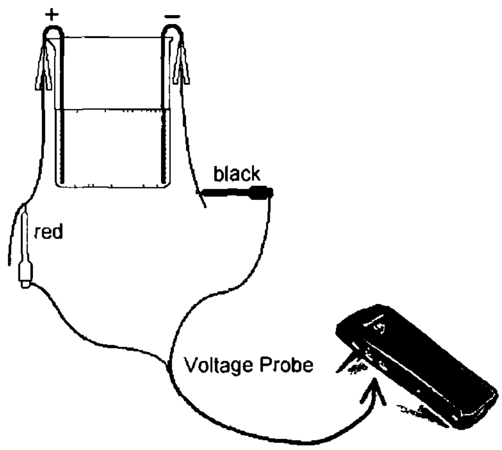
You will use a voltage probe to record and graph the voltages produced by each of the metals in turn

APPARATUS

TI 83+ graphing calculator	Zinc
CBL 2	
250 mL beaker	Copper
Voltage probe	Lead
Carbon rod	Aluminium
Dilute H_2SO_4	Sand paper
2 Crocodile clips	

PROCEDURE

Set up the apparatus as in the diagram Make sure there is a good connection between the crocodile clips and the electrodes

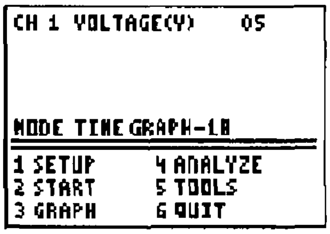


Prepare the data logging apparatus to record the voltage when triggered You will be taking the voltage produced by each of the metals, the metals will be labelled 1, 2, 3, 4

You will produce a bar chart of voltage against type of metal

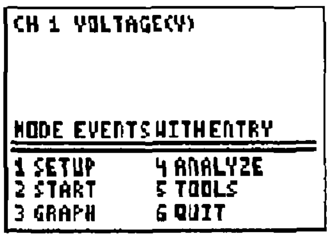
TO START COLLECTING DATA

Attach the voltage probe to Ch 1 on the CBL 2 Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu Press [CLEAR] to reset the programme Press [ENTER] at the welcome screen The CBL 2 will check for probes Screen 1 will be shown



Screen 1

Select **1 SETUP** and use the [▲] to select **MODE** Press [ENTER] and select **3 EVENTS WITH ENTRY** Press **1 OK** to confirm Screen 2 will be shown



Screen 2

Select **2 START** and press [ENTER] to store data as required

With the first metal in place, record the voltage by pressing [ENTER] When asked for a value, enter the number **1** on the calculator

Repeat these steps with the other metals, remembering to give each metal the value assigned to it by your teacher

Record the voltages in the space below

When all the voltages have been recorded, select **STOP AND GRAPH** on the calculator to graph the values

Produce this graph as a bar chart

Use this graph to place the metals in their correct order in the electrochemical series

RESULTS

Number	Metal	Voltage
1		
2		
3		
4		

ORDER OF METALS IN THE ELECTROCHEMICAL SERIES

NUMBER	METAL

EXPERIMENTS IN BIOLOGY

To show that food contains energy

Food contains chemical energy When we eat, the energy in our food is converted into the energy we need to carry out our life processes (There are roughly 4 joules in 1 Calorie) You will convert the energy contained in a walnut into heat energy in a test tube of water

APPARATUS

TI 83+	50 cm^3 water
CBL 2	Walnut
Temperature probe	Candle
Boiling tube	Tongs

Place the temperature probe into the test tube of water, ensuring that it is close to the bottom, but not touching the glass

Set up the calculator to take temperature readings over time

PROCEDURE

Plug a temperature probe into channel 1 of the CBL 2 Turn on the CBL 2 and calculator Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)         17 9


MODE TIME GRAPH-120
1 SETUP       4 ANALYZE
2 START       5 TOOLS
3 GRAPH       6 QUIT
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **2 TIME GRAPH** to get screen 3

```
TIME GRAPH SETTINGS
TIME INTERVAL          3
NUMBER OF SAMPLES      80
EXPERIMENT LENGTH      240
1 OK            3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Enter **2** as time between samples in seconds Enter **60** as number of samples Press [ENTER] to get screen 4

```
TIME GRAPH SETTINGS
TIME INTERVAL          2
NUMBER OF SAMPLES      60
EXPERIMENT LENGTH      120
1 OK            3 ADVANCED
2 CHANGE TIME SETTINGS
```

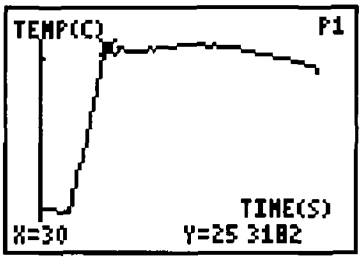
Screen 4

Select **1 OK** to confirm settings Select **1 OK** again to return to the main menu

Weigh the walnut and record the mass

Select **2 START** The calculator will start to record data Use a Bunsen to light the walnut Hold the walnut under the test tube As soon as the data collection has finished, blow out the walnut

The calculator will auto scale the data as in screen 5



Screen 5

Use the ◄ ► cursors to locate the minimum and maximum temperatures Record these values Reweigh the walnut and record these values

RESULTS

Minimum temperature	
Maximum temperature	
Change in temperature	
Weight	
Change in temperature Per gram	

PROCESSING THE DATA

Print a graph of change of temperature with time, and answer the following questions

1 Is there more or less energy in the walnut before it was burned than after it was burned?

2 Where did the energy from the walnut go?

3 Is burning a walnut an exothermic or an endothermic reaction?

4 In this experiment, the ______________ energy in the walnut is changed to ______________ energy in the water

To show that expired air has more carbon dioxide than inhaled air

The air that we breathe in contains oxygen Oxygen is needed for respiration Respiration is the process where oxygen is used to burn food and release energy The by-products of respiration are Carbon dioxide and water vapour Oxygen passes from the air into the blood, and carbon dioxide and water vapour pass from the blood into the air through a process called gaseous exchange This gaseous exchange takes place in the lungs

In this investigation, you will use a CO_2 gas sensor to measure CO_2 levels in the air that we breathe in, and CO_2 levels in the air that we breathe out, and compare them

APPARATUS

TI 83+
CBL 2
pH probe
CO_2 Gas probe
Gas probe bottle

PROCEDURE

Plug a CO_2 gas probe into Channel 1 of the CBL 2 Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen1 will appear

```
CH 1 CO2 GAS(PPM)   20

MODE TIME GRAPH-300
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen 1

Select **1 SETUP** from the main screen Move the black arrow down to **MODE · SETUP** by pressing the [▲] arrow once on the calculator

Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **4 SINGLE POINT** then select **1 OK** to get screen 3

```
CH 1 CO2 GAS(PPM)   40

MODE SINGLE POINT
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen3

Wait one minute, insert CO_2 gas probe into the bottle that comes with it then select **1 START** The calculator will sample data for 10 seconds, then show a value as in screen 4

```
CO2 GAS(PPM)        1740



                 [ENTER]
```

Screen 4

Record this value as inhaled air in the table below

Press [ENTER] to return to the main screen

Take a deep breath, hold it for a few seconds and then breathe into the bottle Place the probe into the bottle, select **2 START** The calculator will again sample data for 10 seconds Record this value as exhaled air

RESULTS

	CO_2 (ppm)
Inhaled air	
Exhaled air	

QUESTIONS

1. Why does the body need oxygen?

2. Why was there more carbon dioxide in the exhaled air than in the inhaled air?

3. Where did the extra carbon dioxide come from?

4. What chemical can you use to test for carbon dioxide?

5. What are the little sacs in the lungs called where gaseous exchange takes place?

To demonstrate the effect of exercise on heart rate

When we exercise, our body has an increased need for both oxygen and food The food is required for energy, and the oxygen is needed to burn the food to supply the energy

Both oxygen and food are transported around the body by the blood So, when we exercise, our pulse rate goes up so that blood is transported at a greater rate Our breathing also increases to meet the increased demand for Oxygen

In this investigation, you will monitor your heart rate before, during and after exercise

APPARATUS

TI 83+	Saline solution
CBL 2	Stopwatch
Exercise heart rate monitor	

PROCEDURE

Divide into pairs One person will do the exercise, the other one will record the data
The exercise heart rate monitor comes with a transmitter belt and a receiver

Wet each of the electrodes (the two grooved rectangular areas on the underside of the transmitter belt) with 3 drops of saline solution Position the belt so that the *Polar*™ logo is directly over the base of the rib cage, and in line with the chest centre The person whose heart rate is to be monitored holds the receiver in their right hand

Set up the calculator for recording data Plug the receiver module of the Exercise Heart Rate Monitor into Channel 1 of the CBL 2

Turn on the CBL 2 and calculator Select **DATAMATE** programme from the **APPS** menu Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 HEARTRT(BPM)


MODE TIMEGRAPH-900
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen 1

The default time for this sensor is 900 seconds (15 minutes) If you want to shorten this time, select **2 SETUP** to get screen 2

```
 CH 1 EXHEARTRATE(BPM)
 CH 2
 CH 3
 DIG
▸MODE TIMEGRAPH-900

1 OK        3 ZERO
2 CALIBRATE
```

Screen 2

Move the black arrow from **CH1 EXHEARTRATE(BPM)** to **MODE TIMEGRAPH** by pressing the [▲] button on the calculator once

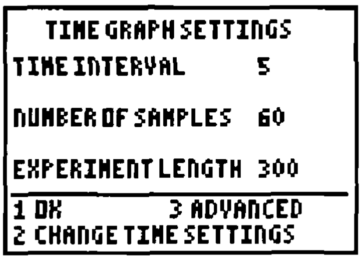
Select **2 TIMEGRAPH** from the next screen to get screen 3

```
  TIMEGRAPH SETTINGS
TIME INTERVAL        5
NUMBER OF SAMPLES  180
EXPERIMENT LENGTH  900
1 OK          3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

When prompted type **5** for the time interval then press [ENTER] The calculator will then ask for the number of samples Type **60** press [ENTER] Screen 4 will appear on the calculator



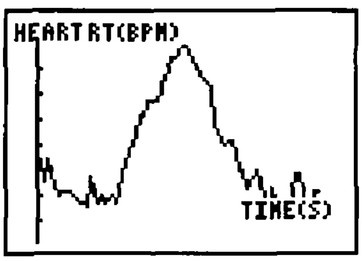
Screen 4

The calculator is now set up to monitor heart rate for 5 minutes

Press **1 OK** twice to get back to the main screen

The person whose heart rate is to be monitored should hold the receiver in their right hand Select **2 START**, a graph screen will appear on the calculator, with a live reading of heart rate in the top right hand corner

Remain still for one minute, exercise for two minutes and remain still for the last two minutes When data collection is complete, a graph of heart rate vs, time will be shown as in screen 5



Screen 5

QUESTIONS

1 Why did your heart rate increase when you started to exercise?

2 People who smoke generally have higher heart rates than if they did not smoke Can you think of a reason for this?

3 The heart is divided into two sides where does the right side of the heart pump blood?

4 Where does the left hand side of the heart pump blood?

5 Name three ways you could increase the efficiency of your blood circulation system

To show that respiration produces carbon dioxide

Respiration is the release of energy from food

When living organisms respire, they give off Carbon Dioxide

In this investigation you will look at the Carbon dioxide being given off by germinating peas as they respire

APPARATUS

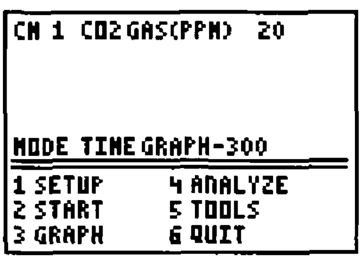
TI 83+
CBL 2
CO_2 Gas probe
Gas probe bottle
Germinating peas

PROCEDURE

Plug a CO_2 gas probe into Channel 1 of the CBL 2

Select the **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen1 will appear



Screen 1

The probe is set to take readings every 10 seconds for 5 minutes

Place the peas in the bottle supplied with the CO_2 probe Insert the CO_2 gas probe into the bottle that comes with it then select **1 START**

A graph of carbon dioxide concentration against time will appear on the calculator

Try doing this at different temperatures to see if temperature affects the rate of respiration

QUESTIONS

1 Define respiration

2 What is the name of the gas that reacts with the food in our bodies to produce energy?

3 What chemical can be used to test for carbon dioxide?

4 What would you expect to happen to the shape of the graph if the experiment were carried out at 0^0 C?

5 What would a suitable control for this experiment be?

Gaseous exchange during photosynthesis

Plants make sugar during photosynthesis by converting sunlight energy into chemical energy This chemical energy is then available to either themselves or other organisms to use during respiration

During this investigation, you will look at the changes in carbon dioxide levels as a plant goes between light and dark

The rate of uptake of Carbon dioxide can be used as a measure of the rate of photosynthesis

APPARATUS

TI 83+	CO_2 Gas probe
CBL 2	Gas probe bottle
PH probe	Green leaves

PROCEDURE

Plug a CO_2 gas probe into Channel 1 of the CBL 2 Select the **DATAMATE** programme from the **APPS** menu Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will appear

```
CH 1 CO2 GAS(PPM)  20


MODE TIME GRAPH-300
1 SETUP       4 ANALYZE
2 START       5 TOOLS
3 GRAPH       6 QUIT
```

Screen 1

The probe is set to take readings every 10 seconds for 5 minutes

Place the leaves in the bottle supplied with the CO_2 probe, cover the bottle with tin foil to ensure no light gets in Insert CO_2 gas probe into the bottle that comes with it then select
1 START

A graph of carbon dioxide concentration against time will appear on the calculator When the data collection is finished, save the information To do this, press [ENTER], this will return you to the main screen select **5 TOOLS** to get screen 2

```
TOOLS
1 STORE LATEST RUN
2 RETRIEVE DATA
3 CHECK BATTERY
4 RETURN TO MAIN SCREEN
```

Screen 2

Select **1 STORE LATEST RUN** The main screen will appear again

Remove the tinfoil from the bottle, shine a lamp on the leaves and select **2 START** Data will start to be recorded again

When the second data collection is finished, press [ENTER] This will return you to the main screen Select **3 GRAPH** from the main screen The most recent graph will reappear Press [ENTER] to get screen 3

```
▸ CH1-CO2 GAS(PPM)


1 MAIN SCREEN    3 RESCALE
2 SELECT REGION  4 MORE
```

Screen 3

Select 4 **MORE** to get screen 4

```
MORE GRAPHS
1 L3 VS L1
2 L3 VS L2
3 L2 VS L3
4 L4 VS L1
5 L3 VS L4
6 L2 AND L3 VS L1
7 L2,L3 AND L4 VS L1
8 RETURN TO GRAPH SCREEN
```

Screen 4

Select **6 L2 AND L3 VS L1**

Both graphs will be displayed on the same screen Print out the graphs

To show that living organisms produce heat energy during respiration

When living organisms respire, they produce heat energy

To demonstrate this, you will place some germinating peas in a flask and measure the temperature over 24 hours You will also monitor the temperature in a flask of dead peas These will not be respiring, so will act as a control

APPARATUS

TI 83+	Germinating peas
CBL 2	Two temperature probes
2 Thermos flasks	Disinfectant
	Dead (boiled) peas

Place the germinating peas into one of the thermos flasks Rinse the boiled peas with some disinfectant This will ensure that no micro-organisms are present which could respire and produce heat

Place the boiled peas in the other flask

PROCEDURE

Plug two temperature probes into channel 1 and channel 2 of the CBL 2 Turn on the CBL 2 and calculator Select **DATAMATE** programme from the **APPS** menu

Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 TEMP(C)        19 6
CH 2 TEMP(C)        19 8

MODE TIME GRAPH-180
1 SETUP    4 ANALYZE
2 START    5 TOOLS
3 GRAPH    6 QUIT
```

Screen 1

Select **1 SETUP** and press the up arrow [▲] to highlight **MODE** Press [ENTER] to get screen 2

```
SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **2 TIME GRAPH**

```
TIME GRAPH SETTINGS
TIME INTERVAL          1
NUMBER OF SAMPLES      180
EXPERIMENT LENGTH      180
1 OK           3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 3

Select **2 CHANGE TIME SETTINGS**

Type **3600** as the time between samples in seconds press [ENTER] Type **24** as the number of samples and press [ENTER] to get screen 4

```
TIME GRAPH SETTINGS
TIME INTERVAL          3600
NUMBER OF SAMPLES      24
EXPERIMENT LENGTH      86400
1 OK           3 ADVANCED
2 CHANGE TIME SETTINGS
```

Screen 4

Press **1 OK** twice to return to the main screen Press **2 START** The following screen will appear

```
COLLECTING DATA
CH 1          20 093

PRESS [STO] TO STOP
PRESS [ENTER] TO QUIT BUT
CONTINUE COLLECTING
```

Screen 5

The CBL 2 will continue to collect data for 24 hours

(It is probably a good idea to attach the CBL 2 to the mains electricity supply to avoid running out of battery)

By the end of the data collection period, the calculator will have timed out Press the on button, and when asked **DO YOU WISH TO CONTINUE?** say **NO**

Select the **DATAMATE** program again from the **APPS** menu

Screen 6 will appear

```
DATA COLLECTION IS DONE
CHOOSE THE TOOLS OPTION,
THEN CHOOSE RETRIEVE DATA
                  [ENTER]
```

Screen 6

Press [ENTER] to get screen 7

```
          TOOLS
1 STORE LATEST RUN
2 RETRIEVE DATA
3 CHECK BATTERY
4 RETURN TO MAIN SCREEN
```

Screen 7

Select **2 RETRIEVE DATA**

A graph of temperature vs time will appear

Respiration and photosynthesis in pond weed

Plants take in oxygen and give out carbon dioxide during respiration However, in the presence of light, they also undergo another very important process called photosynthesis

During photosynthesis, CO_2 and water are taken up by the plant, and, using the energy supplied by light, are converted into glucose A useful by-product of this reaction is oxygen

Photosynthesis

Carbon dioxide + water $\xrightarrow[\text{chlorophyll}]{\text{light}}$ *glucose + oxygen*

Respiration

glucose + oxygen ⟶ *Carbon dioxide + water + energy*

Respiration happens continuously in living plants, photosynthesis only happens in the presence of light

In this investigation you will look at the effect on carbon dioxide and oxygen levels in pond water containing pondweed when a light is switched on and off

APPARATUS

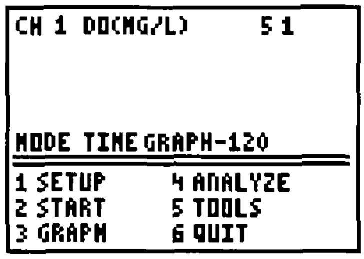
TI 83+	Pond weed
CBL 2	1 L beaker
Dissolved oxygen probe	$CaHCO_3$

PROCEDURE

Fill the 1 L beaker with water Place the pondweed in it and cover Leave for about an hour

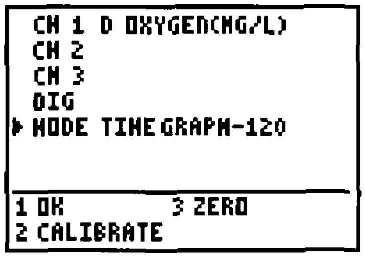
Turn on the CBL 2 and calculator Insert a dissolved oxygen probe into Channel 1 of the CBL 2

Select **DATAMATE** programme from the **APPS** menu Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown



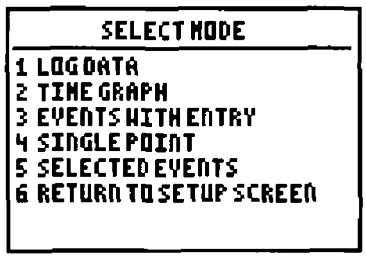
Screen 1

Select **1 SETUP** Press the [▲] arrow on the calculator once to select **MODE** as in screen 2



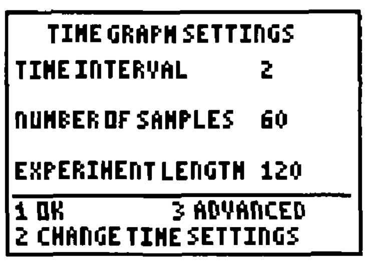
Screen 2

Press [ENTER] to get screen 3



Screen 3

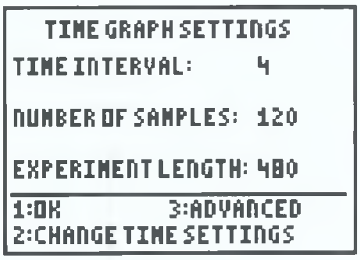
Select **2 TIME GRAPH** to get screen 4



Screen 4

Select **2 CHANGE TIME SETTINGS**

Enter **4** as the time between samples in seconds. Then press [ENTER]. Enter **120** as the number of samples. Press [ENTER] to get screen 5.



Screen 5

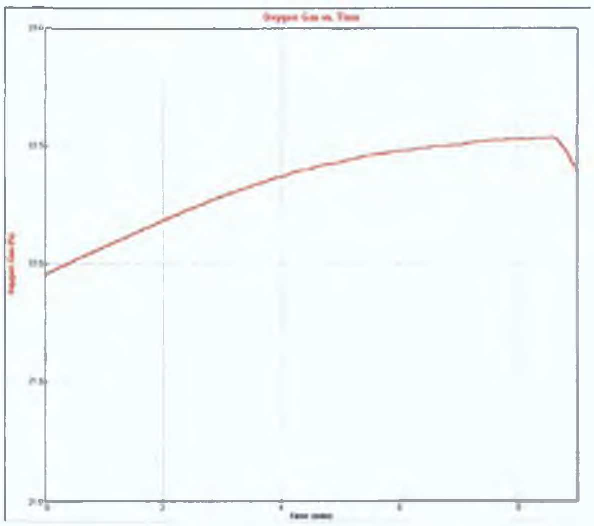
Press **1 : OK** twice to return to the main screen.

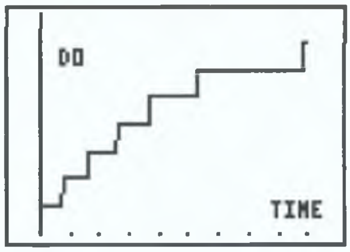
Put a couple of spoons of $CaHCO_3$ into the water, this ensures that there is enough CO_2 in the water for photosynthesis.

Put the probe into the 1L beaker and allow 30 seconds for it to warm up. Remove the cover from the beaker and shine a strong light on the pondweed.

Place the probe well under the surface of the water to be tested. Ensure that the probe is kept moving. Press **2 : START.** The CBL 2 will collect data for 10 minutes.

When the data collection is over, print the graph produced, either with graphical analysis or graph link.

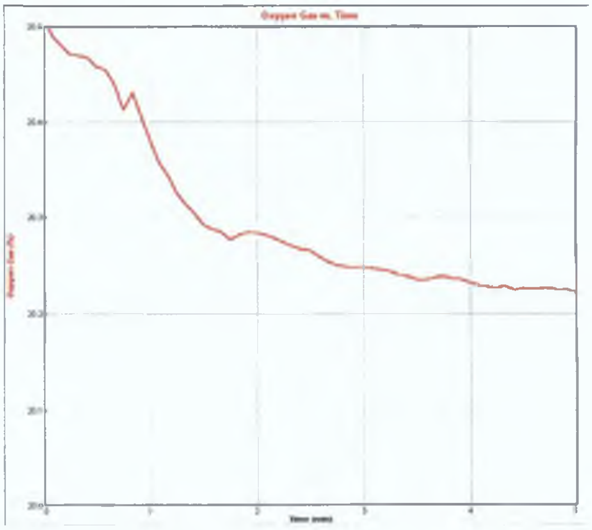


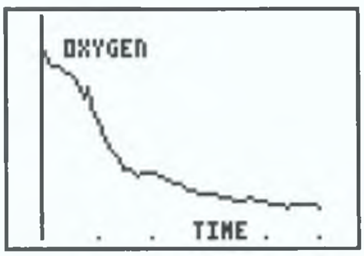


Return to the main screen by pressing [ENTER] or turn off the calculator. Select **DATAMATE** from the **APPS** button and the settings should still be there from the previous experiment.

Select **2 : START** again, this time cover up the beaker and repeat the process.

This time, the graph should look like this.





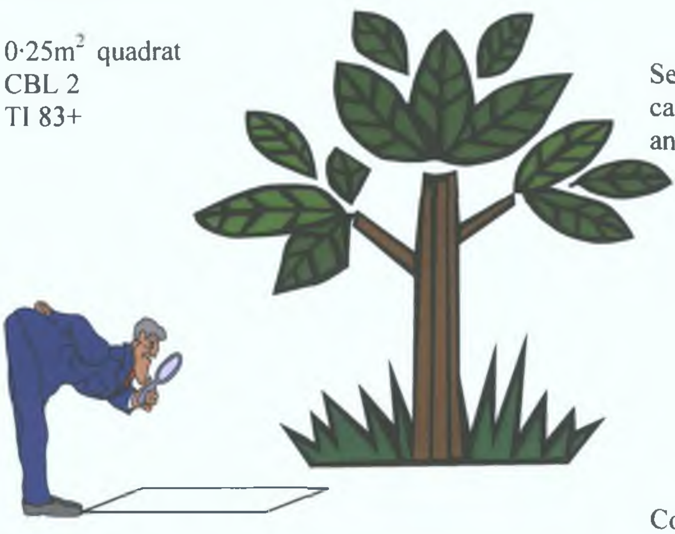
To investigate the effect of light intensity on the distribution of daisies

In any ecosystem, the distribution of organisms is affected by various *non-living* factors such as temperature, light intensity, available water and soil type. In this investigation, we will examine the affect on one of those factors on the distribution of daisies.

Daisies are sun-loving plants, so are more likely to grow where there is plenty of sunlight. Starting at the base of the tree, we will measure and record light intensity every 0·5m until we are outside the canopy of the tree. Using a 0·25m^2 quadrat, we will count the numbers of daisies at each point. There should be a correlation between the number of daisies and the light intensity.

APPARATUS

0·25m^2 quadrat
CBL 2
TI 83+



PROCEDURE

Select a suitable tree; one with a good canopy, and with plenty daisies growing around it.

Place the quadrat at the base of the tree.
At this point,the distance from the tree = 0.

Set up the CBL 2 to take light intensities when prompted.

Select the **DATAMATE** programme from the **APPS** menu. Keep pressing [ENTER] until the following screen appears.

```
CH 1:LIGHT          .009



MODE:TIME GRAPH-9
1:SETUP       4:ANALYZE
2:START       5:TOOLS
3:GRAPH       6:QUIT
```

Screen 1

Press **1:SETUP**.

```
 CH 1:
 CH 2:
 CH 3:
 DIG :
▸MODE:TIME GRAPH-9

1:OK          3:ZERO
2:CALIBRATE
```

Screen 2

Select **2:CALIBRATE.** Then, from the calibration screen select **2:CALIBRATE NOW** and screen 3 will appear.

```
   CALIBRATE SENSOR

MONITOR VOLTAGE, WHEN
STABLE, PRESS [ENTER].
         VALUE   VOLTAGE
POINT 1:         0
POINT 2:
```

Screen 3

Cover the end of the light probe. The voltage at point 1 on the calculator screen should be close to zero. Press [ENTER] .

Type in the value **0** when prompted, and then press [ENTER] again.

Hold the light probe out turned towards the sun. Press [ENTER] when the voltage reading at point 2 stabilises.

Type in the value **100** when prompted and then press [ENTER].

The following screen should appear

```
     CALIBRATION
LIGHT
CALIBRATION LINEAR
SLOPE        INT
675 18072    -2 300007
1 OK
2 CALIBRATE NOW
3 MANUAL ENTRY
```

Screen 4

To change the mode select 1 **OK**

The following screen should appear

```
▸ CH 1  TI LIGHT PROBE
  CH 2
  CH 3
  DIG
  MODE  TIME GRAPH-9

1 OK          3 ZERO
2 CALIBRATE
```

Screen 5

Move the black arrow down to **MODE** by using the blue [▲] arrow as in screen 6

```
  CH 1
  CH 2
  CH 3
  DIG
▸ MODE  TIME GRAPH-9

1 OK          3 ZERO
2 CALIBRATE
```

Screen 6

Press [ENTER] The select mode screen will appear

```
     SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 7

Select 3 **EVENTS WITH ENTRY** Then select 1 **OK** to return to the main screen

◆ Hold the light probe out turned towards the sky Make sure that it is directly over the centre of the quadrat

Press 2 **START** The following screen will appear

```
PRESS [ENTER] TO COLLECT
OR [STO] TO STOP
1      14 2
```

Screen 8

When the light intensity reading has stabilised, press [ENTER] The calculator will ask you to enter a value Type in the distance you are from the base of the tree and press [ENTER] Record the number of daisies in each quadrat

Move the quadrat out 50 cm and repeat the process from ◆

Keep going until you are well beyond the edge of the canopy When you are finished, press [STO▸] to stop and graph

RESULTS

Distance from tree (Meters)	Number of daisies In Quadrat
0 0	
0 5	
1 0	
1 5	
2 0	
2 5	
3 0	
3 5	
4 0	

Transfer your graph of light intensity vs distance to the computer, or use the values on the calculator to draw a graph manually of light intensity vs distance

Using the same graph paper, plot a graph of numbers of daisies vs distance

Examine relationship between numbers of daisies and light intensity

To test the pH of a soil sample

pH is a measure of the degree of acidity or alkalinity of a substance Soil pH is very important as plants will only be able to absorb all the nutrients they need if they are grown in soil of a suitable pH

Different plants have different pH ranges Some plants like an acidic soil, but most crops grown by farmers cannot tolerate acid soils, so farmers often neutralise acid in soil with lime (a base)

In this investigation, you will measure the pH of different soil samples It is a good idea to collect samples from different areas

APPARATUS

CBL 2	Soil samples
TI 83+	test tubes
pH probe	test-tube rack
wash bottle	Barium Sulfate
deionised water	

PROCEDURE

Turn on the CBL 2 and calculator Select **DATAMATE** programme from the **APPS** menu Press [ENTER] at the welcome screen Press [CLEAR] to reset the programme The CBL 2 will check for probes Screen 1 will be shown

```
CH 1 PH                3 63


MODE TIMEGRAPH-120
1 SETUP      4 ANALYZE
2 START      5 TOOLS
3 GRAPH      6 QUIT
```

Screen 1

Select **1 SETUP**

Use the down arrow [▲] to select **MODE** Press [ENTER] to move to screen 2

```
        SELECT MODE
1 LOG DATA
2 TIME GRAPH
3 EVENTS WITH ENTRY
4 SINGLE POINT
5 SELECTED EVENTS
6 RETURN TO SETUP SCREEN
```

Screen 2

Select **4 SINGLE POINT** to get screen 3

```
  CH 1 PH
  CH 2
  CH 3
  DIG
▸ MODE SINGLE POINT

1 OK           3 ZERO
2 CALIBRATE
```

Screen 3

Press **1 OK** to return to the main menu

Remove the tip of the pH probe from the little soaking bottle that it is stored in and rinse the tip with distilled water

Place a small amount of soil in a test tube Half fill the test tube with deionised water Stopper the test tube and shake it vigorously Add some Barium Sulfate to clear the clay from the solution

Place the probe in the solution to be tested and press **2 START** on the calculator The probe will sample for 10 seconds after which time it will display a pH reading on the calculator As in screen 4

```
PH                  13 67




                  [ENTER]
```

Screen 4

Record this value

Rinse the probe and repeat the procedure with the next soil sample

Continue doing this until all your samples have been tested

RESULTS

Sample	pH

QUESTIONS

1 Why do farmers add lime to soil?

2 Why do plants need to be grown at a suitable Ph?

APPENDIX

APPARATUS LIST

Experiments in Physics

EXPERIMENT		APPARATUS
To investigate the relationship between depth and pressure in a liquid		TI 83 +, CBL 2, Large Cylinder, Thistle funnel
Time and distance graphs		TI 83 + , Motion Detector, Toy car, Piece of card
Investigating friction		TI 83 + , CBL 2, Student force sensor, 1 Kg wooden block, Material to provide different surfaces
Energy Conversions	Chemical energy into Food energy	TI 83 +, CBL 2, Walnut , Temperature probe, Candle, Boiling tube ,Tongs, 50 cm^3 water
	Sound energy to Electrical energy	TI 83 + , CBL 2, Microphone, Tuning forks of different frequencies
	Kinetic energy into Heat energy	TI 83 + , CBL 2, 1 Litre beaker, Water , Food mixer
To show that energy is conserved for a ball moving in freefall		TI 83 +, CBL 2, CBR, Basketball,
To investigate the difference between heat and temperature		TI 83 +, CBL 2, 2 temperature probes, 2 1L Beakers, 2 Bunsen Burners, 2 Tripods and Gauze
Absorption Of Radiant Energy		TI 83 +, CBL 2, Shiny can, Dull black can, 2 temperature probes,
To show that there is no change of temperature during a change of state		TI 83 +, CBL 2, temperature probes, Bunsen burner, Ice, 5 spoons salt, 250 cm^3 beakers, 50 cm^3 water
To demonstrate the effect of insulation		TI 83 +, CBL 2, Cotton wool, 2 250 cm^3 beakers, 2 temperature probes, Hot water
Sound is a wave motion		TI 83 +, CBL 2, Microphone, 2 Tuning forks or electronic keyboard

Experiments in Chemistry

EXPERIMENT	APPARATUS
Endothermic and Exothermic Reactions	TI 83 +, CBL 2 , 2 temperature probes, 10 grams sodium hydrogen carbonate, 5 cm strip magnesium ribbon, 2 50 cm^3 graduated cylinder, 50 cm^3 dilute (1M) HCl, 2 Styrofoam cups, 10 grams citric acid, 2 250 cm^3 beakers, 50 cm^3 water
Ionic and covalent substances	TI83 +, CBL 2, Conductivity probe, Different solutions, Deionised water
Acids and bases	TI 83 +, CBL 2, pH probe, Household solutions, 7 small test tubes, test-tube rack, wash bottle, red and blue litmus, distilled water
The reaction between an acid and a carbonate	TI 83 +, CBL 2, pH probe, CO_2 Gas probe, Dilute HCl, Calcium Carbonate, 250 cm^3 beaker, Water, Litmus
To show that rusting is an oxidation process	TI 83 +, CBL 2, O_2 Gas probe, Gas probe bottle, Steel wool, Water
To compare the hardness in different water samples	TI 83 +, CBL 2, Conductivity probe, 4 Test tubes, Soap flakes Water samples
Investigating temporary and permanent hardness of water	TI 83 +, CBL 2, Conductivity probe, Hard water sample, Ion exchanger, Deionised water
To find the order of metals in the electrochemical series	TI 83 +, CBL 2, Voltage probe, 250 mL beaker, Dilute H_2SO_4 , Zinc, Copper, Lead, Carbon rod, Aluminium, 2 Crocodile clips, Sand paper

Experiments in Biology

EXPERIMENT	APPARATUS
To show that food contains energy	TI 83 +, CBL 2, Temperature probe, 50 cm^3 water, Walnut, Candle, Boiling tube, Tongs
To show that expired air has more carbon dioxide than inhaled air	TI 83 +, CBL 2, pH probe, CO_2 Gas probe, Gas probe bottle
To demonstrate the effect of exercise on heart rate	TI 83 +, CBL 2, Exercise heart rate monitor, Stopwatch, Saline solution
To show that respiration produces Carbon Dioxide	TI 83 +, CBL 2, CO_2 Gas probe, Gas probe bottle, Germinating peas
Gaseous exchange during photosynthesis	TI 83+, CBL 2, pH probe, CO_2 Gas probe, Gas probe bottle, Green leaves
To show that living organisms produce heat energy during respiration	TI 83 +, CBL 2, Two temperature probes, 2 Thermos flasks, Germinating peas, Disinfectant, Dead (boiled) peas
Respiration and Photosynthesis in Pond weed	TI 83 +, CBL 2, Dissolved oxygen probe, 1 L beaker, Pond weed, $CaHCO_3$
To investigate the effect of light intensity on the distribution of daisies	TI 83 +, CBL 2, 0 25m^2 quadrat
To test the pH of a soil sample	TI 83 +, CBL 2, pH probe, Soil samples, test tubes, test-tube rack, wash bottle, Barium Sulfate, deionised water

Appendix C

Test Booklet

You have been given a research number. Please note that number in the space below.

Research Number ____________________

Information to Students

This booklet contains questions related to graphs and charts relevant to your experiences in science and other subject areas

The answers you give to the questions will be used in scientific study to assist the researcher in determining which skills and processes you have acquired during Junior Certificate work in school

Your answers will remain strictly confidential and will not be made available to other parties in this or any other school No individual feedback will be given, although the researcher may offer some general comments on particular areas of excellence visible in the data

Each section has some general information which you should read carefully.

Enjoy the process and good luck!

Section A

Interpreting Data

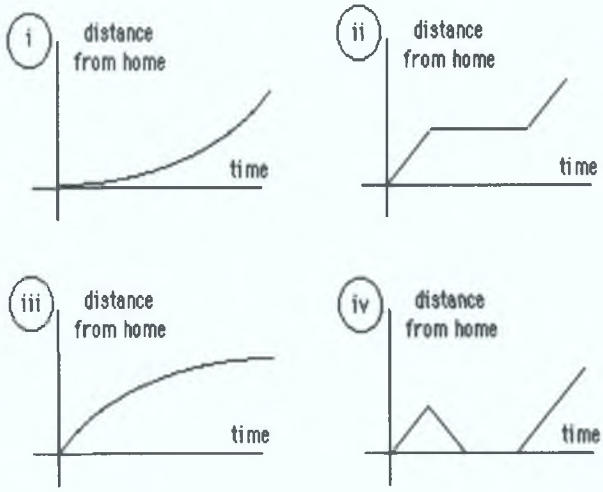
This section of questions is about interpreting graphs and data in tables and charts

If you think a graph scale is not clear, make your best attempt with the scale as drawn That may be part of the difficulty of the question

Complete your answers in the spaces provided Read each question carefully as there may be more then one possible answer If you think there is more than one answer then give the answer you feel is' best'

Interpreting data

1. Identify the graph that matches each of the following stories:



a) I had just left home when I realized I had forgotten my books so I went back to pick them up.

Ans: ___________________

b) The battery on my electric car started to run down.

Ans: ___________________

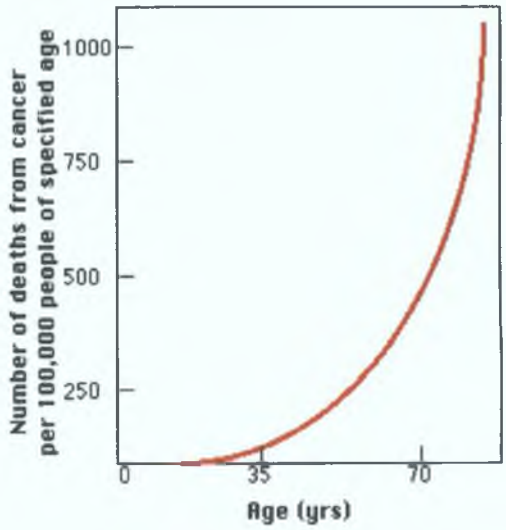
c) Things went fine until I had a flat tyre.

Ans: ___________________

d) I started out calmly, but sped up when I realized I was going to be late.

Ans: ___________________

2. Which of the following hypotheses are best represented by this graph?



a) Smoking causes cancer.

b) Cancer is dangerous.

c) One out of a thousand people will get cancer during their lifetime.

d) Young people don't get cancer.

e) The probability of getting cancer increases with age.

Ans: ___________________

3. The graph at the right represents the typical day of a teenager. Answer these questions:

a) What percent of the day is spent watching TV?

Ans: ___________________

b) How many hours are spent sleeping?

Ans: ___________________

c) What activity takes up the least amount of time?

Ans: ____________________

d) What activity takes up a quarter of the day?

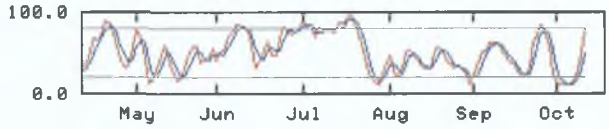
Ans: ____________________

e) What two activities take up 50% of the day?

Ans: ____________________

f) What two activities take up 25% of the day? **Ans:**____________________

4. Answer these questions about the graph at the right:



a) How many sets of data are represented?

Ans: ____________________

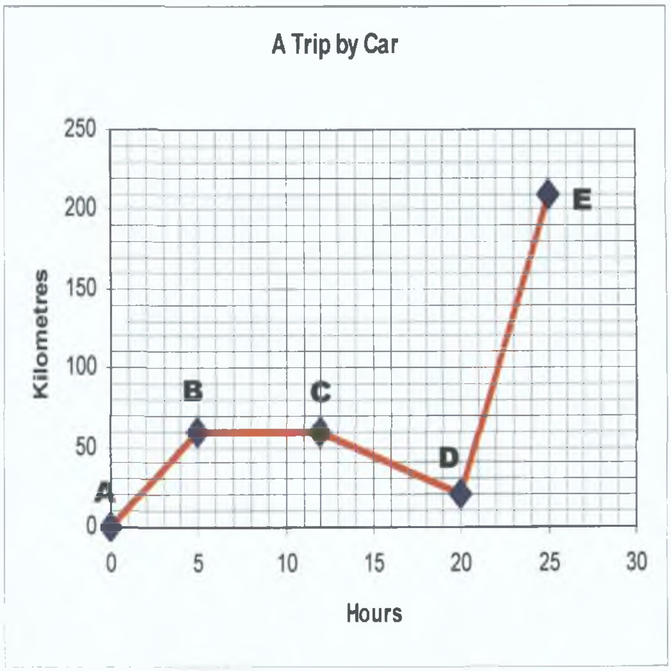
b) On approximately what calendar date does the graph begin?

Ans: ____________________

c) In what month does the graph reach its highest point?

Ans: ____________________

5. Answer these questions about the graph on the right:



a) How many total kilometres did the car travel?

Ans: ____________________

b) What was the average speed of the car for the trip?

Ans: ____________________

c) Describe the motion of the car between hours 5 and 12?

Ans: ____________________

d) What direction is represented by line CD?

Ans: ____________________

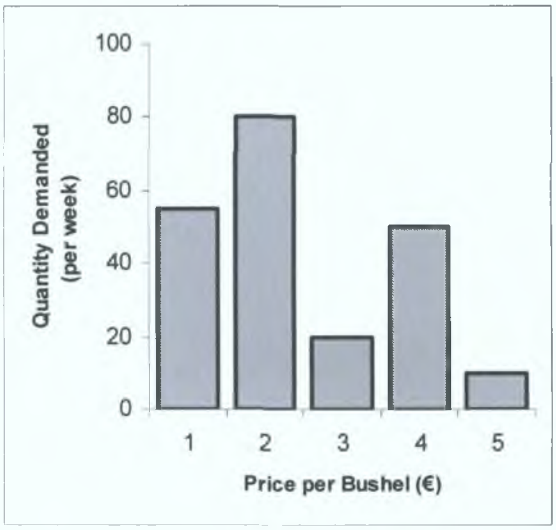
e) How many kilometres were travelled in the first two hours of the trip?

Ans: ____________________

f) Which line represents the fastest speed?

Ans: ____________________

6. Answer these questions about the graph at the right:



a) What is the dependent variable on this graph?

Ans: ____________________

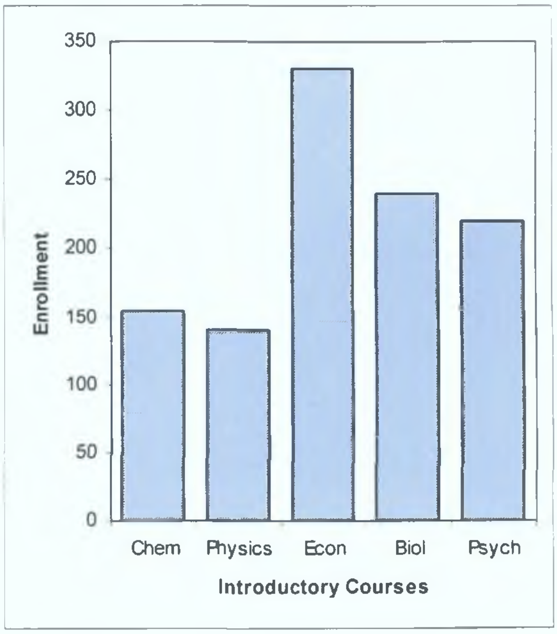
b) Does the price per bushel always increase with demand?

Ans: ____________________

c) What is the demand when the price is $5 per bushel?

Ans: ____________________

7. The bar graph at right represents the declared courses of students enrolling at a university. Answer the following questions:



a) What is the total student enrolment of the university?

Ans: ____________________

b) What percent of the students are in physics?

Ans: ____________________

c) How many students are in economics?

Ans: ____________________

d) How many more students are in biology than in psychology?

Ans: ____________________

8. This graph represents the number of A's earned in a particular Junior Certificate Science class. Answer the following questions:

a) How many A's were earned during the autumn and spring of 1990?

Ans: ____________________

b) How many more A's were earned in the autumn of 1991 than in the spring of 1991?

Ans: ____________________

c) In which year were the most A's earned?

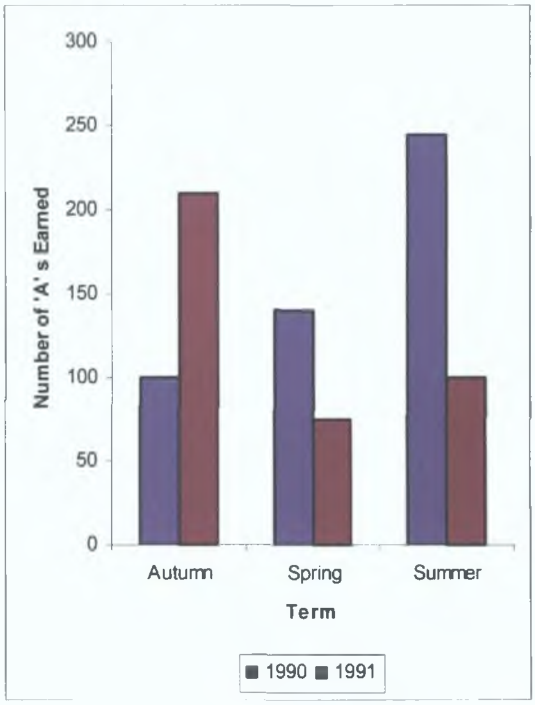
Ans: ____________________

d) In which term were the most A's earned?

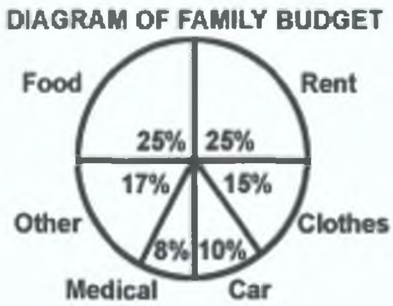
Ans: ____________________

e) In which term and year were the fewest A's earned?

Ans: ____________________



9. Using the graph at right, which of these questions is true for a family of five with a monthly income of €1000?



a) They can afford a car payment of €200.

b) They spend over €100 on clothes each month.

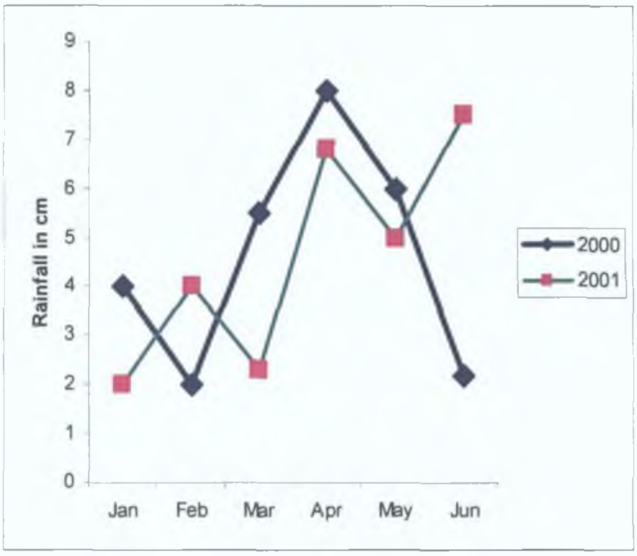
c) They spend €50 each on food each month.

d) They have €100 left over each month for savings.

e) They pay €25 each month for rent.

Ans: ____________________

10. Answer these questions about the graph at the right:



a) How much rain fell in Mar of 2000?

Ans: ____________________

b) How much more rain fell in Feb of 2001 than in Feb of 2000?

Ans: ____________________

c) Which year had the most rainfall?

Ans: ____________________

d) What is the wettest month on the graph?

Ans: ____________________

11. *Answer these questions about the data table:*

a) What is the independent variable on this table?

Ans: ____________________

b) What is the dependent variable on this table?

Ans: ____________________

Atomic Number	Ionisation Energy (mV)
2	24.46
4	9.28
6	11.22
8	13.55
10	21.47

c) How many elements are represented on the table?

Ans ____________________

d) Which element has the highest ionization energy?

Ans ____________________

e) Describe the shape of the line graph that this data would produce?

Ans ____________________

12 Answer the following using the data table

Solar System Data Table				
Name	Orbits	Distance (000 km)	Radius (km)	Mass (kg)
Sun			697000	1.99×10^{30}
Jupiter	Sun	778000	71492	1.90×10^{27}
Saturn	Sun	1429000	60268	5.69×10^{26}
Uranus	Sun	2870990	25559	8.69×10^{25}
Neptune	Sun	4504300	24764	1.02×10^{26}
Earth	Sun	149600	6378	5.98×10^{24}
Venus	Sun	108200	6052	4.87×10^{24}
Mars	Sun	227940	3398	6.42×10^{23}
Ganymede	Jupiter	1070	2631	1.48×10^{23}
Titan	Saturn	1222	2575	1.35×10^{23}
Mercury	Sun	57910	2439	3.30×10^{23}
Callisto	Jupiter	1883	2400	1.08×10^{23}
Io	Jupiter	422	1815	8.93×10^{22}
Moon	Earth	384	1738	7.35×10^{22}
Europa	Jupiter	671	1569	4.80×10^{22}
Triton	Neptune	355	1353	2.14×10^{22}
Pluto	Sun	5913520	1160	1.32×10^{22}

a) How many planets are represented?

Ans ____________________

b) How many moons are represented?

Ans ____________________

c) Which moon has the largest mass?

Ans ____________________

d) Which planet has a radius closest to that of Earth?

Ans ____________________

e) How many moons are larger than the planet Pluto?

Ans ____________________

f) Which of Jupiter's moons orbits closest to the planet?

Ans ____________________

g) Which planet is closest to Earth?

Ans ____________________

13 Use the graph at right to answer the following

a) Most tornadoes in Oklahoma occur between the hours of?

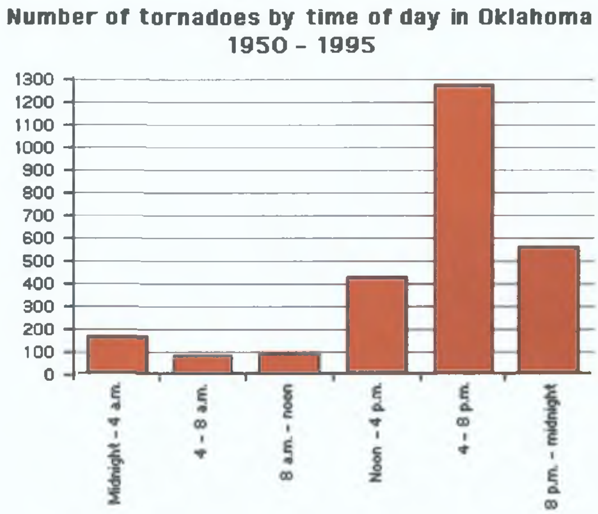
Ans: ____________________

b) Rounded to the nearest fifty, how many tornadoes occurred in Oklahoma between 1950 and 1995?

Ans: ____________________

c) What four hour period has the fewest tornadoes?

Ans: ____________________



END OF QUESTIONS IN THIS SECTION

Section B

Kinematics

This section of questions is about motion – time graphs and velocity – time graphs

The motion-time graphs have been drawn by moving an object towards or away from a wall

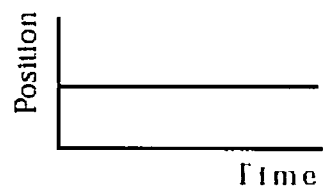
The velocity-time graphs represent the change in speed in a straight line measured by a person observing the movement

Complete your answers in the spaces provided Read each question carefully as there may be more then one possible answer

Motion Time Graphs

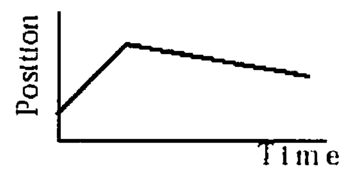
ANSWER THE FOLLOWING QUESTIONS

1 What do you do to create a horizontal line on a position vs time graph?



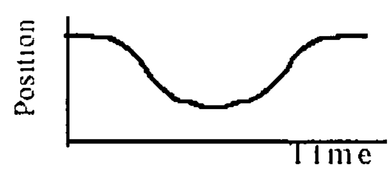
Ans

2 How do you move so the graph goes up steeply at first, and then goes down gradually?



Ans

3 How do you walk to create a u-shaped graph?

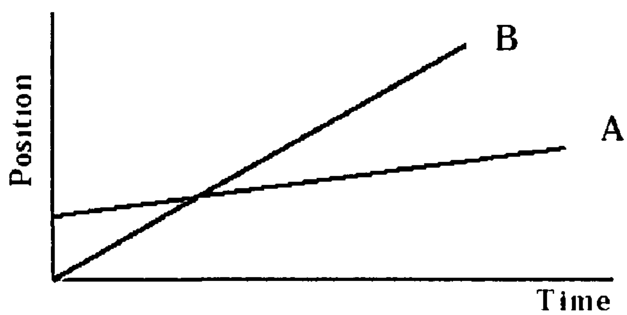


Ans

ANSWER THE FOLLOWING QUESTIONS ABOUT TWO OBJECTS, A AND B, WHOSE MOTION IS REPRESENTED BY THE GRAPHS SHOWN BELOW

4

a) Which object is moving faster, A or B?



Ans ____________________

b) Which object starts ahead? What do you mean by ahead?

Ans

c) What does the intersection mean?

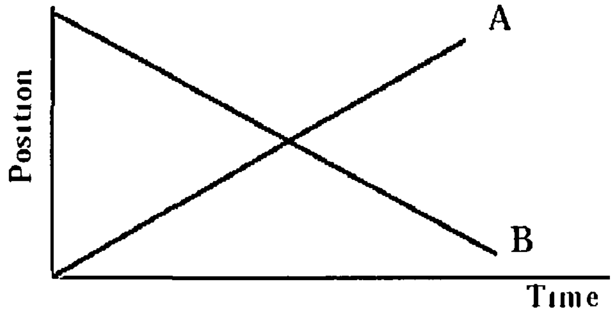
Ans

5 (a) From the graph on the right, which object is moving faster, A or B?

Ans ____________________

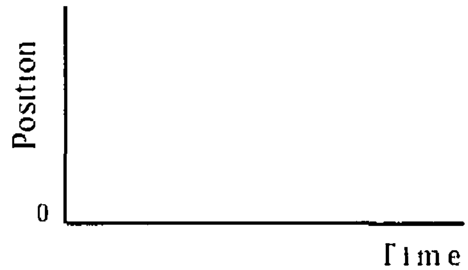
(b) Which object has negative velocity according to the convention we have set?

Ans ____________________



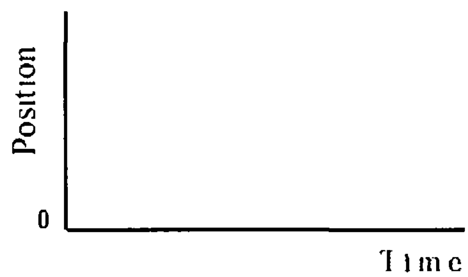
SKETCH THE POSITION-TIME GRAPH CORRESPONDING TO EACH OF THE FOLLOWING DESCRIPTIONS OF THE MOTION OF AN OBJECT MARK THE TIME SCALE ON THE GRAPHS FOR QUESTIONS 7 AND 8

6 The object moves with a steady velocity away from the origin



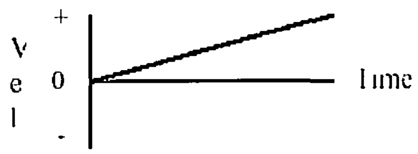
7 The object moves toward the origin with a steady velocity for 5 seconds and then stands still for 5 seconds

8 The object moves away from the origin for 5 seconds and then reverses direction and moves with the same speed toward the origin for 5 seconds



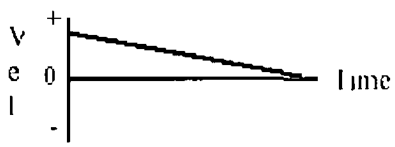
Velocity Graphs

9 How do you move to create a straight-line velocity-time graph that slopes up from zero, as shown below?



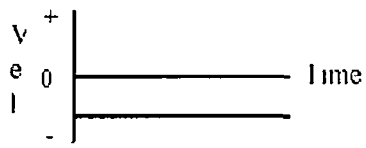
Ans

10 How do you move to create a straight-line velocity-time graph that slopes down, as shown below?



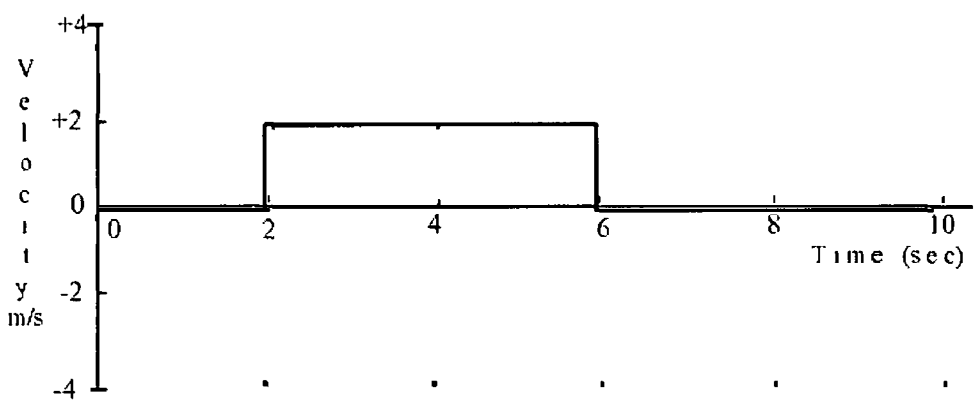
Ans

11 How do you move to make a horizontal line in the negative part of a velocity/time graph, as shown below?



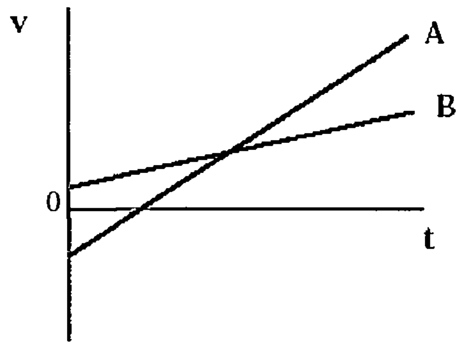
Ans

12 The velocity-time graph of an object is shown below Figure out the total change in position (*displacement*) of the object **Show your work!**



Ans Displacement = ____________ meters

THE *VELOCITY* GRAPH BELOW SHOWS THE MOTION OF TWO OBJECTS, A AND B ANSWER THE FOLLOWING QUESTIONS EXPLAIN YOUR ANSWERS WHEN NECESSARY



13 a) Is one object moving at a greater speed (i e moving faster) than the other? If so, which one is faster? (A or B)

Ans ____________________

b) What does the intersection of the two graphs mean?

Ans

c) Can one tell which object is "ahead"? (define "ahead")

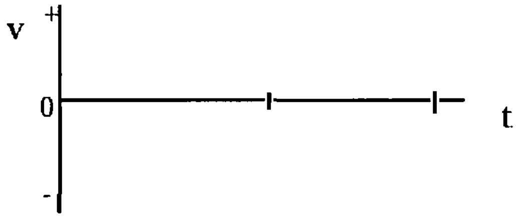
Ans

d) Does either object A or B reverse direction? Explain

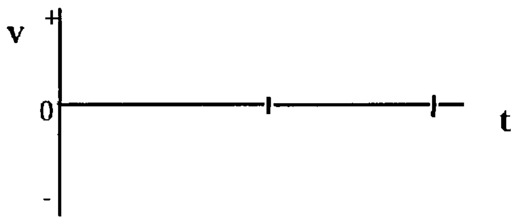
Ans

SKETCH THE VELOCITY-TIME GRAPH CORRESPONDING TO EACH OF THE FOLLOWING DESCRIPTIONS OF THE MOTION OF AN OBJECT

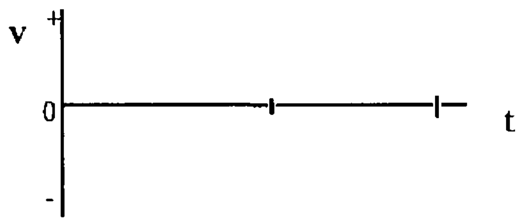
14 The object is moving away from the origin at a steady velocity



15 The object moves toward the origin at a steady (constant) velocity for 10 seconds, and then stands still for 10 seconds



16 The object moves away from the origin at a steady (constant) velocity for 10 seconds, reverses direction and moves back toward the origin at the same speed for 10 seconds



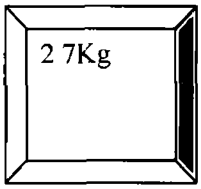
END OF QUESTIONS IN THIS SECTION

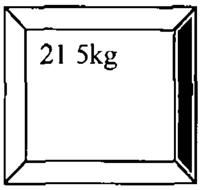
Section C

The Scientific Process

This section of questions is about constructing your own experiments and considering possible outcomes

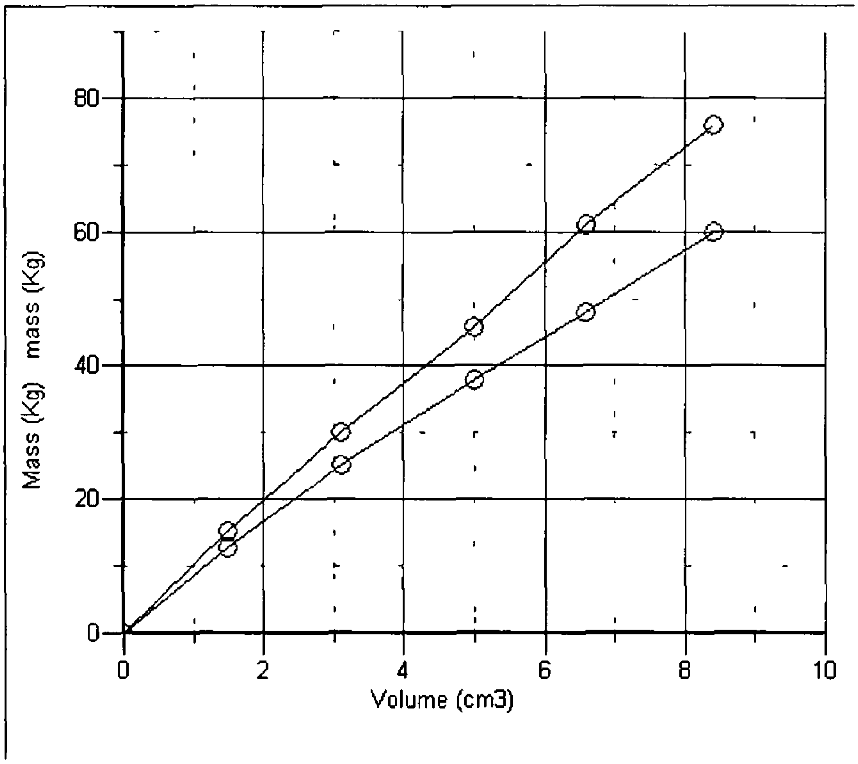
Complete your answers in the spaces provided Read each question carefully as there may be more then one way of approaching a situation





These two metal blocks may look the same, but their weights are very different That is because one is made of Aluminium and one is made of platinum
The reason for their difference in weights is due to their different densities The density of an object is a measure of the mass divided by the volume

The following graph shows the masses of different volumes of pennies The pennies depicted by the red line were all minted before 1983 Those depicted by the blue line were all minted after 1983

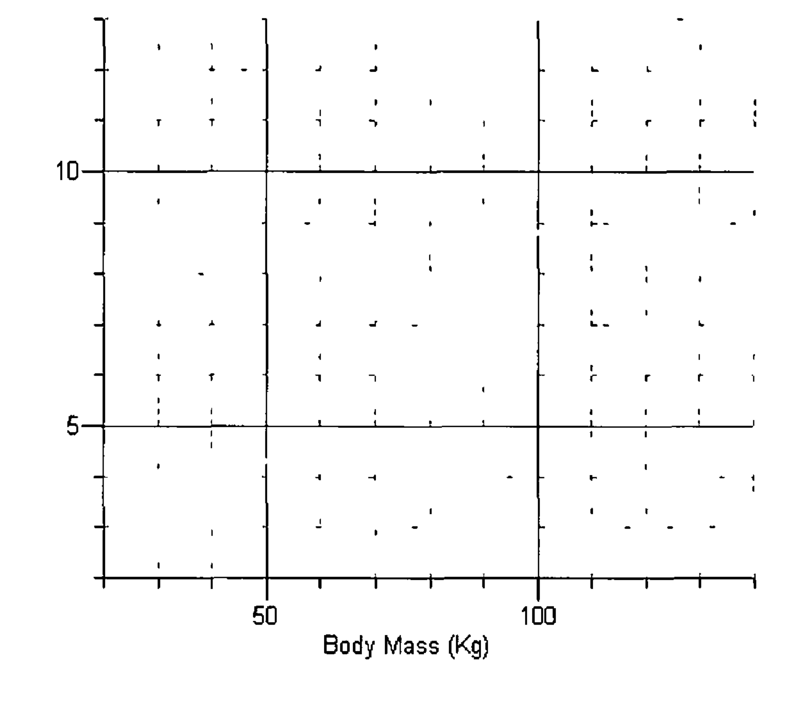


What does the slope of each of the lines represent?

Which pennies are the densest, explain your answer in terms of the graph

The following is a data table showing the relationship between body mass and blood volume

Data Set	
mass (Kg)	Vol (L)
30 000	2 500
40 000	3 400
50 000	4 300
60 000	5 200
70 000	6 100
80 000	7 000
90 000	7 900
100 000	8 800
110 000	9 700
120 000	10 600
130 000	11 500



1 According to the data table, what is the relationship between body mass and blood volume?

2 What is the change in mass from data point to data point? This is also known as ∩X Is the ∩X the same between each two successive X-values? (you may use a calculator)

3 What is the change in blood volume from data point to data point? This is also known as ∩Y Is the ∩Y the same between each two successive Y-values?

4 What is the significance of your answers to Q 2 and Q 3?

5 Can you write a mathematical formula for determining the volume of blood if you know your mass? (hint it will be in the form y= mx + c)

6 Using the formula, or by drawing a graph (using the axes above) estimate the volume of blood ***you*** have in ***your*** body How did you make your estimation?

7 How much blood would there be in a person who had a mass of 75 kg?

8 Estimate the mass in kg of a person who has 5 4 litres of blood in her body

9 How much blood would a 3 2 kg newborn baby have?

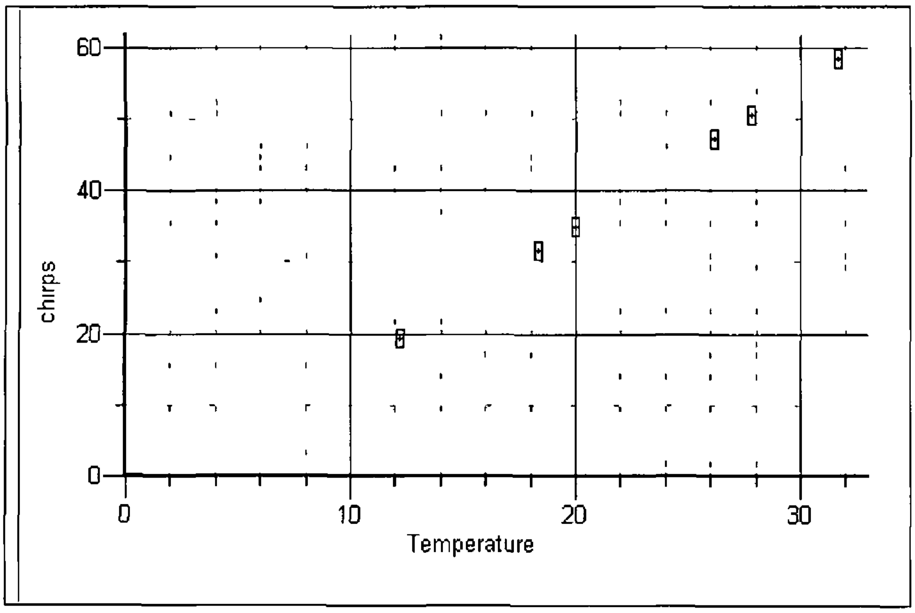
10 If this mass/blood volume relationship were true for other animals, too, how many litres of blood would there be in a horse that had a mass of 500 kg?

11 Estimate the mass of a person who has 7 6 litres of blood in her body

Cricket thermometers

Crickets make a chirping sound These chirping patterns convey different messages and are different from species to species
Crickets are insects, and like all insects are ectothermic That means that their body temperature rises or falls when the temperature of the environment rises or falls The metabolism of an insect fluctuates with its body temperature
Is a cricket's rate of metabolism reflected in the frequency of its chirps? In this activity you will examine the relationship between cricket chirps and temperature

Crickets were recorded and the number of chirps every 15 seconds was noted A graph of Chirps/15 seconds against temperature was drawn



1 A cricket was recorded chirping at a rate of 25 chirps in 15 seconds, estimate what the temperature was when this recording was taken

2 What is the relationship between temperature and the number of chirps per second?

3 How many chirps per second would have been recorded at 0^0C ?

4 How many chirps per second would have been recorded at 100 ^0C ?

5 Briefly describe how you might carry out this investigation

Surface Area

Surface area is a one of the moist important concepts to understand in the biomedical sciences. For example, when you breathe, you must be able to absorb enough oxygen into your blood. Your lungs provide 70 square metres of surface area for oxygen absorption. That is about the size of the floor in your classroom. The surface area of the lining of your small intestine is about 300 square metres, which is about the size of a tennis court. That allows you to absorb nutrients efficiently from the food that you digest.

Surface area adaptations are found throughout the living world. Root hairs provide a very large surface area for water and mineral absorption, and the large surface area of leaves allows them to absorb sunlight efficiently. Measuring the surface area of irregularly shaped objects provides quite a challenge.

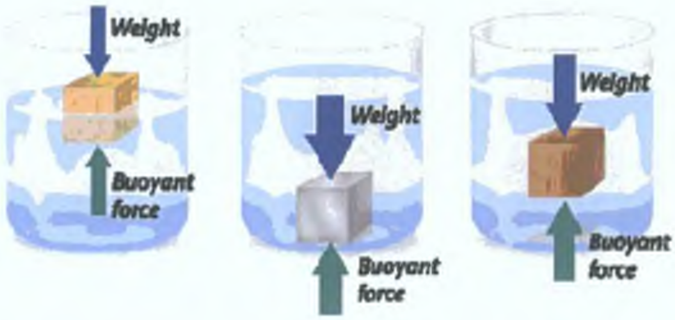
Problem:

There are formulas for finding the surface area of geometric figures such as a square a rectangle, a triangle or a circle. However, there are no such formulas for finding the surface area of an irregularly shaped object such as a hand or a leaf. Only using the materials listed below can you accurately find the surface area of your hand or a leaf?

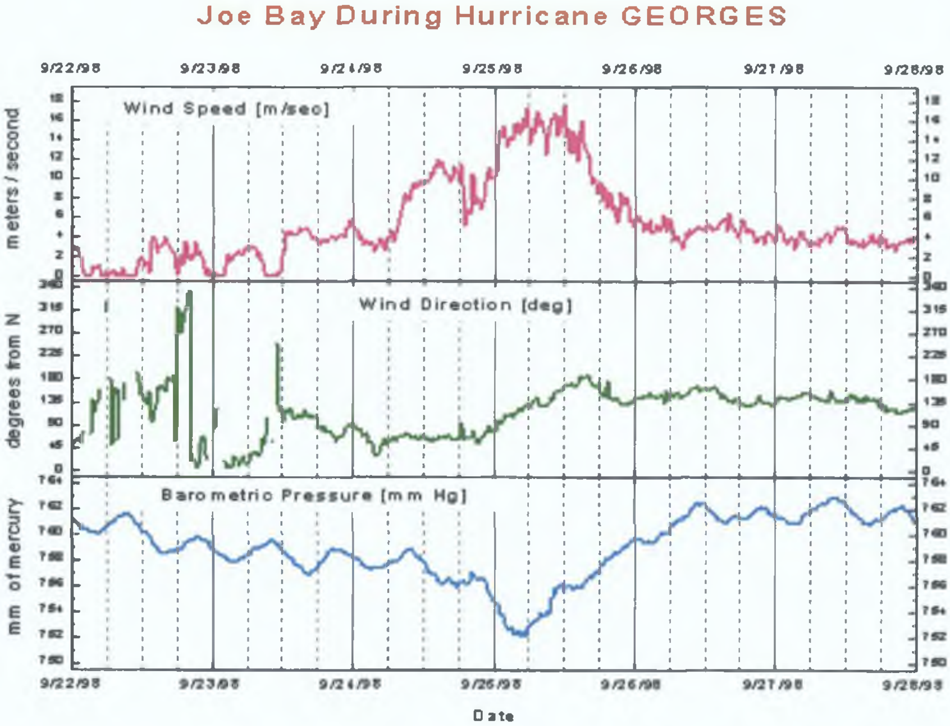
Given: Cardboard, scissors, weighing scale that weighs in grams, ruler that measures in centimetres and an irregularly shaped leaf, devise a way that you could collect data that would enable you to accurately measure the area of the leaf.

(Hint: you will collect data using the materials above, graph it, and use the graph to estimate the area.)

Looking at graphs



Describe the relationship between the buoyant force and the weight of the three objects in the pictures above.



In this data collected during Hurricane George, The top graph represents the wind speed in Metres/second, the middle graph represents the wind direction and the bottom represented the atmospheric pressure.

Write three sentences describing the relationship between these three things during the hurricane.

Appendix D

Test Booklet Marking Scheme

Answers to Section A **2 points per answer**

1a	iv	**1b**	iii	**1c**	ii
2	e				
3a	13%	**3b**	24/3 = 8	**3c**	Studying
3e	sleep + phone	**3f**	phone + eating		
4a	2	**4b**	1st May	**4c**	July
5a	190+40+60 = 290	**5b**	290/25 = 12	**5c**	Stationary
5e	2*(60/5)=24	**5f**	DE		
6a	Quantity	**6b**	No	**6c**	~10
7a	~1100	**7b**	140/(a)=~13%	**7c**	~330
8a	~240	**8b**	~130 / 140	**8c**	1990
8d	Summer	**8e**	Spring '91		
9	b				
10a	5 5 cm	**10b**	2 cm	**10c**	same (~27 5)
11a	Atomic No	**11b**	Energy	**11c**	5
12a	9	**12b**	7	**12c**	Ganymede
12e	all 7	**12f**	Io	**12g**	Venus
13a	4 - 8 pm	**13b**	~2650	**13c**	4 - 8 am

1d	I		
3d	going to school		
5d	travel towards start		
7d	~20		
10d	April		
11d	Atomic No 2	**11e**	scattergr aph
12d	Venus		
		TOTAL	**104**

Answers to Section B

Position Graphs — **4 points per answer**

1 Remain Stationary

2 Walk away with high speed
return with a lower speed

3 Remain still, walk towards sensor slowing to a momentary stop move away from sensor getting quicker, slow to a stop

4a B

4b B - farthest away from sensor at t=0

4c same point in space at same time

5a same speed
different direction

5b B

6

7

8

Velocity Graphs

9 Const Accel away from sensor

10 Const accel towards sensor

11 Const velocity towards sensor

12 Area under graph = 8m

13a A - greatest velocity

13b same velocity at same time

13c No

14

15

16

Answers to Section C — **4 points per**

13d B - Change of sign =
change of direction

Appendix D

1a	Density	**1b**	answer Red Line - Steepest line		
2a	Volume is directly related to Body mass	**2b**	10 Kg	**2c**	0 9 L
2e	y = 0 09x - 0 2	**2f**	answer from own Body Mass	**2g**	6 55
2i	0 088 L	**2j**	44 8 L	**2k**	86 7 Kg
3a	~12 5 C	**3b**	C = 2T - 4	**3c**	hibernation?
3e	record temp record chirps vary temp				
4	Method that compares weight of a known area with the total irregular leaf				
5	graph 1 - boy Force > weight graph 2 - boy force < weight graph 3 - boy force = weight				
6	wind speed greatest at lowest pressure direct/press/wind speed constant after storm direction change gradual at change of pressure				

2d Allows slope of line to be found

2h 57 8 Kg

3d boiling point?

Total **84**

Appendix E

Point Matrix Allocation

Certificate Points banding

Percentage Band for Grades	90-100	85-89	80-84	75-79	70-74	65-69	60-64	55- 59	50-54	45-49	40-44
Leaving Certificate Examination Grades	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3
Points allocated to grades in Leaving Certificate Papers - HIGHER LEVEL	100	90	85	80	75	70	65	60	55	50	45
Points allocated to grades in Leaving Certificate Papers - ORDINARY LEVEL	60	50	45	40	35	30	25	20	15	10	5

Percentage Allocation to Banding Scores.

Higher	Percentage Allocated
A1	95
A2	87
B1	82
B2	77
B3	72
C1	67
C2	62
C3	57
D1	52
D2	47
D3	42
E	35

Ordinary	Percentage Allocated
A	35
B	30
C	25
D	20

These scores were used as percentage scores obtained by students with band scores allocated by the Department in the Junior Certificate exams in Maths and Science in June 2002. They form the basis for comparison between Maths and Science in Chapter 4.

Appendix F

Subject Choice Data

Science Uptake	Figure 3 12	and	Figure 3 14	
Group A				**Group B**
		Number	**%**	
Science Choices Module 1 September 2002	Chemistry	**8**	61 5%	Science Choices Module 1 September 2002
	Physics	**8**	61 5%	
	Biology	**6**	46 2%	
Science Choices Module 2 Leaving Certificate 2003	Chemistry	**5**	38 5%	Science Choices Module 2 Leaving Certificate 2003
	Physics	**3**	23 1%	
	Biology	**2**	15 4%	
Maths Junior Cert level	Higher	**11**	84 6%	Maths Junior Cert level
	Ordinary	**2**	15 4%	
Science Junior Cert level	Higher	**13**	100 0 %	Science Junior Cert level
	Ordinary	**0**	0 0%	
	Pupil Roll	**13**		
Year Group (n=44)	Chemistry	**43 2%**		
	Physics	**27 3%**		
	Biology	**22 7%**		***Figure 3 12 September Uptake***
Class Constituents - Chemistry	Group C	**52 6%**		Chemistry
n=19	Group B	**21 1%**		Physics
	Group A	**26 3%**		Biology
Class Constituents - Physics	Group C	**58 3%**		
n=12	Group B	**21 1%**		***Figure 3 14***
	Group A	**26 3%**		***Leaving Certificate Uptake*** Chemistry
Class Constituents - Biology	Group C	**60 0%**		Physics
n=10	Group B	**20 0%**		Biology
	Group A	**20 0%**		

Subject Choice Data

	Number	%	Group C		Number	%
Chemistry	**6**	54 5%	Science Choices Module 1 September 2002	Chemistry	**9**	60 0%
Physics	**2**	18 2%		Physics	**4**	26 7%
Biology	**6**	54 5%		Biology	**10**	66 7%
Chemistry	**4**	36 4%	Science Choices Module 2 Leaving Certificate 2003	Chemistry	**10**	66 7%
Physics	2	18 2%		Physics	**7**	46 7%
Biology	2	18 2%		Biology	**6**	40 0%
Higher	**8**	72 7%	Maths Junior Cert level	Higher	**12**	80 0%
Ordinary	**3**	27 3%		Ordinary	**3**	20 0%
Higher	**11**	100 0%	Science Junior Cert level	Higher	**14**	93 3%
Ordinary	**0**	0 0%		Ordinary	**1**	6 7%
Pupil Roll	**11**			Pupil Roll	**15**	

Group A	**Group B**	**Group C**
8	**6**	**9**
8	**2**	**4**
6	**6**	**10**

Group A	**Group B**	**Group C**
5	**4**	**10**
3	**2**	**7**
2	**2**	**6**

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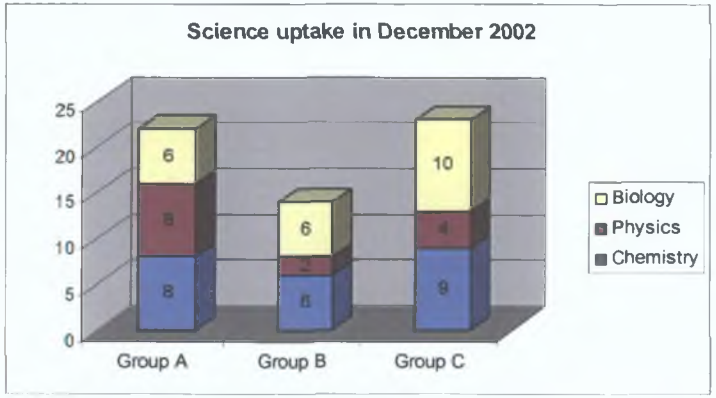
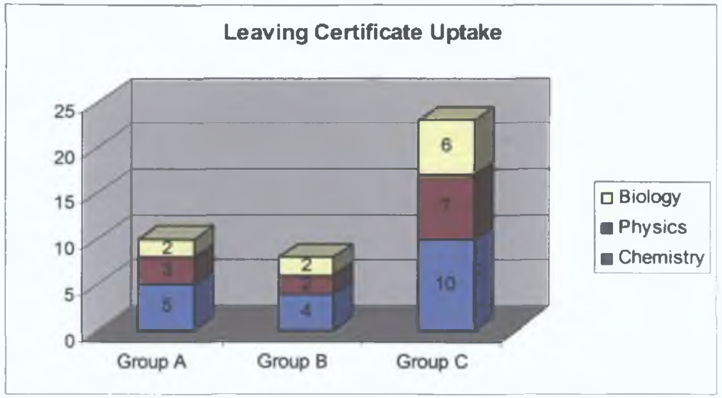
Table 16 figures as % Based all LC Science Candidates

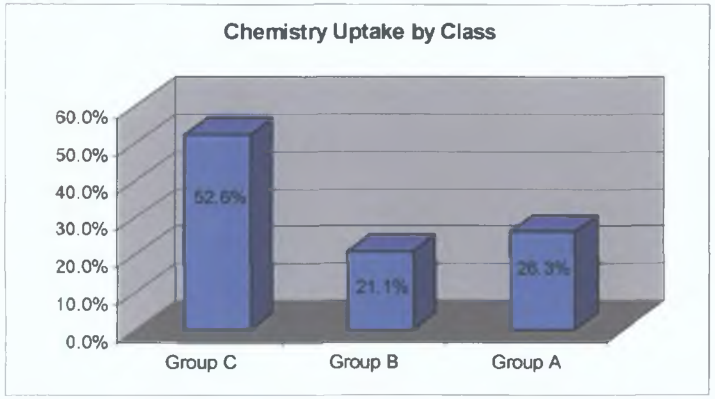
LC SCIENCE SUBJECT	1985	1990	1995	2000
Biology	51	54	57	58
Physics	20	21	20	19
Chemistry	21	17	15	15
Ag Science	4	4	4	6
Physics & Chemistry	4	4	3	2

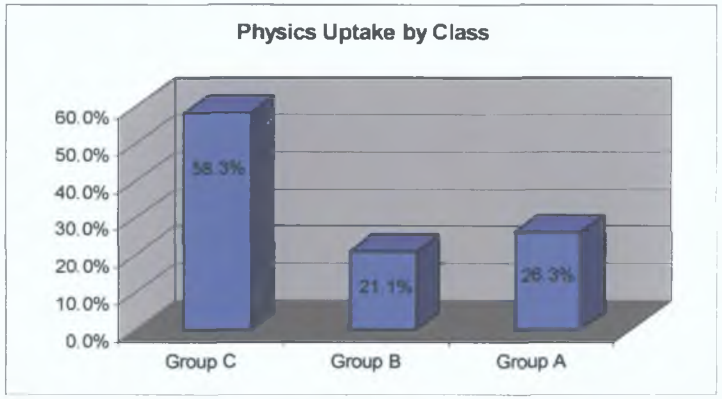
Table 17 figures as % Based all LC Candidates

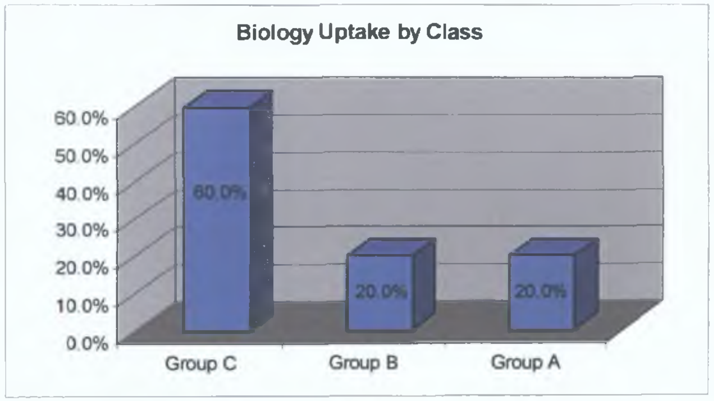
LC SCIENCE SUBJECT	1985	1990	1995	2000
Biology	52	52	52	46
Physics	21	20	18	15
Chemistry	21	17	14	12
Ag Science	4	4	4	5
Physics & Chemistry	4	4	3	2

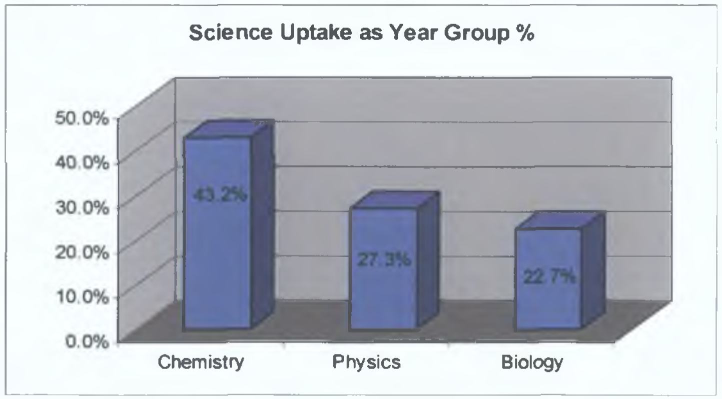

Science uptake in December 2002
25
20
15
10
5
0
6
8
8
6
2
6
10
4
9
Group A
Group B
Group C
Biology
Physics
Chemistry


Leaving Certificate Uptake
25
20
15
10
5
0
2
3
5
2
2
4
6
7
10
Group A
Group B
Group C
Biology
Physics
Chemistry


Chemistry Uptake by Class
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
52.6%
21.1%
26.3%
Group C
Group B
Group A


Physics Uptake by Class
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
58.3%
21.1%
26.3%
Group C
Group B
Group A


Biology Uptake by Class
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
60.0%
20.0%
20.0%
Group C
Group B
Group A


Science Uptake as Year Group %
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
43.2%
27.3%
22.7%
Chemistry
Physics
Biology

Retention of learned information **Table 3 1**

Junior Cert Comparison - June to December

Teaching Group	Dec Score	June Score	Difference
Group A	73%	80	-7%
Group A	32%	65	-33%
Group A	50%	65	-15%
Group A	57%	80	-23%
Group A	50%	65	-15%
Group A	40%	90	-50%
Group A	32%	50	-18%
Group A	61%	80	-19%
Group A	73%	80	-7%
Group A	48%	80	-32%
Group A	67%	80	-13%
Group A	88%	90	-3%
Group A	61%	65	-4%
Group A	73%	25	48%
Group B	54%	80	-26%
Group B	77%	80	-3%
Group B	57%	65	-8%
Group B	54%	65	-11%
Group B	49%	65	-16%
Group B	74%	90	-16%
Group B	54%	80	-26%
Group B	77%	80	-3%
Group B	61%	65	-4%
Group B	93%	90	3%
Group B	30%	50	-20%
Group B	40%	50	-10%
Group C	93%	80	13%

Retention of learned information **Table 3 1** **& Fig 3 7**

Graphical Representation

Group A		Group B		Group C	
1	-7%	1	-26%	1	13%
2	-33%	2	-3%	2	-14%
3	-15%	3	-8%	3	7%
4	-23%	4	-11%	4	-9%
5	-15%	5	-16%	5	-19%
6	-50%	6	-16%	6	-2%
7	-18%	7	-26%	7	3%
8	-19%	8	-3%	8	6%
9	-7%	9	-4%	9	-15%
10	-32%	10	3%	10	48%
11	-13%	11	-20%	11	31%
12	-3%	12	-10%	12	22%
13	-4%			13	8%
14	48%			14	-23%

	Size	Difference in performance	Average Gain/Drop
Group C	14	55%	**3 92%**
Group A	14	-190%	**-13 61%**
Group B	12	-140%	**-11 66%**
Total	***40***		

Appendix F

Group C	36%	50	-14%
Group C	57%	50	7%
Group C	81%	90	-9%
Group C	71%	90	-19%
Group C	78%	80	-2%
Group C	93%	90	3%
Group C	86%	80	6%
Group C	65%	80	-15%
Group C	88%	40	48%
Group C	81%	50	31%
Group C	72%	50	22%
Group C	73%	65	8%
Group C	42%	65	-23%

Subject Choice Data

Appendix F

Subject Comparisons - June 2002 *Figure 3.13*

Junior Cert Test Scores - June '02

Teaching Group	Junior Cert Science (*x1*)	Mathematics Result (*y1*)	x1y1	x1^2	y1^2
Group C	80	65	5200	6400	4225
Group C	80	80	6400	6400	6400
Group C	50	40	2000	2500	1600
Group C	65	40	2600	4225	1600
Group C	50	40	2000	2500	1600
Group C	50	40	2000	2500	1600
Group C	65	80	5200	4225	6400
Group C	90	90	8100	8100	8100
Group C	50	50	2500	2500	2500
Group C	80	65	5200	6400	4225
Group C	90	80	7200	8100	6400
Group C	90	90	8100	8100	8100
Group C	40	40	1600	1600	1600
Group C	80	90	7200	6400	8100
Other	80	90	7200	6400	8100
Other	90	80	7200	8100	6400
Other	90	90	8100	8100	8100
Other	80	80	6400	6400	6400
Other	65	50	3250	4225	2500
Other	80	65	5200	6400	4225
Other	65	50	3250	4225	2500
Other	65	65	4225	4225	4225
Other	65	40	2600	4225	1600
Other	80	65	5200	6400	4225
Other	80	80	6400	6400	6400
Other	80	80	6400	6400	6400
Other	25	25	625	625	625
Other	50	50	2500	2500	2500
Other	80	80	6400	6400	6400
Other	90	80	7200	8100	6400
Other	65	25	1625	4225	625

Subject Comparisons - June 2002

Figure 3.13

	Science	Maths
Mean Score	70.375	63.625
sum	2815	2545
variance	260.7532	391.0096154
std deviation	16.14785	19.77396307

Pearson Product Moment
Correlation coefficient

r =	0.758503
r^2	0.575327
Slope	0.9288
Y Intercept	-1.7393
Std Error of Estimate	13.055

Confidence Intervals

	Lower Limit	Upper Limit
95%	0.586	0.865
99%	0.515	0.888

Appendix F

Other	65	65	4225	4225	4225
Other	90	90	8100	8100	8100
Other	80	65	5200	6400	4225
Other	80	40	3200	6400	1600
Other	50	65	3250	2500	4225
Other	65	40	2600	4225	1600
Other	50	65	3250	2500	4225
Other	65	50	3250	4225	2500
Other	80	80	6400	6400	6400
count	**40**	**sum**	188550	208275	177175

Subject Choice Data

Science Uptake Dec-02 **Figure 3 12**

Group A

Science Choices December		Number	%
	Chemistry	8	61 5%
	Physics	8	61 5%
	Biology	6	46 2%
	Roll	13	

Group C

Science Choices December		Number	%
	Chemistry	9	60 0%
	Physics	4	26 7%
	Biology	10	66 7%
	Roll	15	

Science Uptake Jun-03 **Figure 3 15**

Group A

Science Choices Module 2	Chemistry	5	38 5%
	Physics	3	23 1%
	Biology	2	15 4%

Group C

Science Choices Module 2	Chemistry	10	66 7%
	Physics	7	46 7%
	Biology	6	40 0%

Group B

		Number	%
Science Choices December	Chemistry	**6**	54 5%
	Physics	**2**	18 2%
	Biology	**6**	54 5%
	Roll	**11**	

Group B

Science Choices Module 2	Chemistry	**4**	36 4%
	Physics	**2**	18 2%
	Biology	**2**	18 2%

Appendix G

Junior Certificate Test Scores

t-Test for the Significance of the Difference between the Means of Two independent Samples

Note that this test makes the following assumptions and can be meaningfully applied only insofar as these assumptions are met:

That the two samples are independently and randomly drawn from the source population(s).

That the scale of measurement for both samples has the properties of an equal interval scale.

That the source population(s) can be reasonably supposed to have a normal distribution.

Step 1. For the two samples, A and B, of sizes of N_a and N_b respectively, calculate

$\mathbf{M_{Xa}}$ and $\mathbf{SS_a}$	the mean and sum of squared deviates of sample A
$\mathbf{M_{Xb}}$ and $\mathbf{SS_a}$	the mean and sum of squared deviates of sample B

Step 2. Estimate the variance of the source population as

$$\{s^2_p\} = \frac{\mathbf{SS_a+SS_b}}{(N_a-1)+(N_b-1)}$$

Note that "source population" in this context means "the population of measures that the null hypothesis assumes to have been the common source of the measures in both groups."

Step 3. Estimate the standard deviation of the sampling distribution of sample-mean differences (the "standard error" of $\mathbf{M_{Xa}-M_{Xb}}$) as

$$\text{est. } \sigma_{M-M} = \mathbf{sqrt}\left[\frac{\{s^2_p\}}{N_a} + \frac{\{s^2_p\}}{N_b}\right]$$

Step 4. Calculate **t** as

$$\mathbf{t} = \frac{\mathbf{M_{Xa}-M_{Xb}}}{\text{est. } \sigma_{M-M}}$$

Pearson product-moment correlation coefficient

In its underlying logic, the Pearson product-moment correlation coefficient comes down to a simple ratio between (i) the amount of covariation between X and Y that is actually observed, and (ii) the amount of covariation that *would* exist if X and Y had a perfect (100%) positive correlation Thus

$$\mathbf{r} = \frac{\text{observed covariance}}{\text{maximum possible positive covariance}}$$

As it turns out, the quantity listed above as "maximum possible positive covariance" is precisely determined by the two separate variances of X and Y This is for the simple reason that X and Y can **co**-vary, together, only in the degree that they vary separately If either of the variables had zero variability (for example, if the values of X_i were all the same), then clearly they could not **co**-vary Specifically, the maximum possible positive covariance that can exist between two variables is equal to the *geometric mean* of the two separate variances

So the structure of the relationship now comes down to

$$\mathbf{r} = \frac{\text{observed covariance}}{\mathbf{sqrt[}(\text{variance}_X) \times (\text{variance}_Y)\mathbf{]}}$$

Which can be simplified mathematically to

$$\mathbf{r} = \frac{\mathbf{SC_{XY}}}{\mathbf{sqrt[SS_X} \times \mathbf{SS_Y]}}$$

Where SCxy is the sum of the co-deviates and SSx and SSy are the variability of X and Y

Test for the Significance of the Pearson Product-Moment Correlation Coefficient

If the true correlation between X and Y within the general population is **rho**=0 and if the size of the sample, **N**, on which an observed value of **r** is based is equal to or greater than 6, then the quantity

$$\mathbf{t} = \frac{\mathbf{r}}{\text{sqrt}[(1-\mathbf{r}^2)/(\mathbf{N}-2)]}$$

is distributed approximately as **t** with **df**=**N**−2 Application of this formula to any particular observed sample value of **r** will accordingly test the null hypothesis that the observed value comes from a population in which **rho**=0

Appendix G

t-Test for Independent Samples

Figure 3 5 Comparison of all groups in June 2002

Values entered

count	Xa	Xb
1	80	90
2	50	50
3	90	80
4	90	50
5	25	50
6	65	80
7	80	65
8	80	90
9	65	40
10	80	80
11	65	80
12	65	90
13	80	
14	80	
15	50	
16	65	
17	65	
18	80	
19	50	
20	80	
21	80	
22	65	
23	65	
24	50	
25	90	
26	90	
27	80	

Summary Values

Values	Xa	Xb
n	27	12
sum	1905	845
mean	70 5556	70 4167
sumsq	140825	63225
SS	6416 66	3722 91
variance	246 794	338 447
st dev	15 7097	18 3969

Variances and standard deviations are calculated
with denominator = n 1

Junior Certificate Test Scores

MeanA - MeanB	t	df
0 1389	0 0242	37
P	**one-tailed**	0 49041
	two-tailed	0 98083

t-Test for Independent Samples

Figure 3.6 Comparison of all groups in December 2002

Values entered:

count	X_a	X_b
1	65	73
2	72	32
3	81	32
4	42	88
5	71	73
6	88	57
7	93	61
8	88	40
9	93	61
10	78	73
11	73	67
12	36	50
13	81	50
14	86	48
15		72
16		57
17		54
18		30
19		40
20		49
21		77
22		30
23		61
24		77
25		54
26		57
27		93
28		54
29		54
30		74

Summary Values

Values	X_a	X_b
n	14	30
sum	1045	805
mean	74.7857	57.9333
sumsq	679376	901211
SS	32226	66210.167
variance	302.026	276.753
st. dev.	17.3789	16.6359

Variances and standard deviations are calculated with denominator = n-1.

$Mean_A$ - $Mean_B$	t	df
16.8524	3.086	42
P	one-tailed	0.001852
	two-tailed	0.003642

t-Test for Independent Samples

Comparison of groups A & B in June 2002

Values entered

count	Xa	Xb
1	80	50
2	50	65
3	90	65
4	90	80
5	25	50
6	65	80
7	80	80
8	80	65
9	65	65
10	80	50
11	65	90
12	65	90
13	80	80
14	80	

Summary Values

Values	Xa	Xb
n	14	13
sum	995	910
mean	71 0714	70
sumsq	74625	66200
SS	3908 92	2500
variance	300 686	208 333
st dev	17 3403	14 4338

Variances and standard deviations are calculated with denominator = n 1

Junior Certificate Test Scores

MeanA - MeanB	t	df
1 0714	0 1737	25
P	**one-tailed**	0 43173
	two-tailed	0 86347

t-Test for Independent Samples

Comparison of groups A & B in December 2002

Values entered

count	X_a	X_b
1	73	57
2	32	54
3	32	30
4	88	40
5	73	49
6	57	77
7	61	30
8	40	61
9	61	77
10	73	54
11	67	57
12	50	93
13	50	54
14	48	54
15	72	74

Summary Values

Values	X_a	X_b
n	15	15
sum	876	861
mean	58 4667	57 4
sumsq	455504	445707
SS	30798 93	35349 6
variance	269 4095	303 258
st dev	16 4137	17 4143

Variances and standard deviations are calculated with denominator = n-1

Junior Certificate Test Scores

$Mean_A$ - $Mean_B$	**t**	**df**
-1 0006	-0 1726	28
P	**one-tailed**	0 4321
	two-tailed	0 8642

Appendix H

Test Booklet Scores

t-Test for Independent Samples

Test Booklet *Scores for* Groups A & B

Values entered:

count	X_a	X_b
1	33	89
2	80	89
3	100	89
4	108	93
5	115	100
6	118	102
7	122	106
8	131	106
9	132	114
10	132	122
11	144	124
12	145	127
13	150	150
14	159	179
15	163	224

Summary Values

Values	X_a	X_b
n	15	15
sum	1832	1814
mean	122.133	120.933
sumsq	239306	239390
SS	15557.7	20016.9
variance	1111.27	1429.78
st. dev.	33.3357	37.8124

Variances and standard deviations are calculated with denominator = n-1.

$Mean_A$ - $Mean_B$	t	df
1.2	0.0922	28
P	**one-tailed**	0.4636
	two-tailed	0.9272

t-Test for Independent Samples

Figure 3 8 Test Booklet Scores for All Groups

Values entered

count	X_a	X_b
1	112	33
2	131	80
3	152	100
4	157	108
5	158	115
6	160	118
7	167	122
8	169	131
9	171	132
10	179	132
11	179	144
12	184	145
13	188	150
14	189	159
15		163
16		89
17		89
18		89
19		93
20		100
21		102
22		106
23		106
24		114
25		122
26		124
27		127
28		150
29		179
30		224

Summary Values

Values	X_a	X_b
n	14	30
sum	2296	3646
mean	164	121 533
sumsq	382716	478696
SS	6172	35585 5
variance	474 769	1227 09
st dev	21 7892	35 0298

Variances and standard deviations are calculated with denominator = n 1

Test Booklet Scores

$Mean_A$ - $Mean_B$	**t**	**df**
42 4667	4 1611	42
P	**one-tailed**	< 0001
	two-tailed	0 00015

t-Test for Independent Samples

Figure 3 9 Section A Test Scores - Interpreting Data

Values entered

count	X_a	X_b
1	86	66
2	83	57
3	79	90
4	82	78
5	93	68
6	78	84
7	85	78
8	94	70
9	80	33
10	91	68
11	84	60
12	81	72
13	58	71
14	86	69
15		54
16		61
17		59
18		80
19		64
20		72
21		59
22		49
23		66
24		70
25		62
26		66
27		95
28		60
29		61
30		84

Summary Values

Values	X_a	X_b
n	14	30
sum	1160	2026
mean	82 8571	67 5333
sumsq	97102	141290
SS	987 714	4467 47
variance	75 978	154 051
st dev	8 7165	12 4117

Variances and standard deviations are calculated with denominator = n 1

Test Booklet Scores

$Mean_A$ - $Mean_B$	t	df
15 3238	4 1542	42
P	**one-tailed**	< 0001
	two-tailed	0 00016

t-Test for Independent Samples

Figure 3 10 Section B Test Scores - Motion/Time Graphs

Values entered

count	X_a	X_b
1	35	14
2	37	25
3	26	18
4	35	26
5	40	26
6	21	27
7	36	16
8	36	16
9	25	16
10	33	25
11	36	34
12	34	27
13	34	0
14	25	24
15		26
16		18
17		25
18		17
19		37
20		25
21		25
22		17
23		31
24		18
25		21
26		21
27		18
28		18
29		18
30		21

Summary Values

Values	X_a	X_b
n	14	30
sum	453	650
mean	32 3571	21 6667
sumsq	15075	15482
SS	417 214	1398 67
variance	32 0934	48 2299
st dev	5 6651	6 9448

Variances and standard deviations are calculated with denominator = n 1

Test Booklet Scores

$Mean_A - Mean_B$	t	df
10 6905	5 0232	42
P	one-tailed	< 0001
	two-tailed	< 0001

t-Test for Independent Samples

Figure 3 11 Section C Test Scores - Scientific Process

Values entered

count	X_a	X_b
1	37	35
2	29	14
3	50	33
4	39	15
5	44	34
6	12	35
7	29	4
8	40	37
9	37	0
10	42	29
11	48	26
12	45	27
13	27	32
14	38	31
15		4
16		10
17		16
18		22
19		10
20		21
21		14
22		6
23		0
24		8
25		26
26		0
27		70
28		38
29		38
30		48

Summary Values

Values	X_a	X_b
n	14	30
sum	517	683
mean	36 9286	22 7667
sumsq	20387	23193
SS	1294 93	7643 37
variance	99 6099	263 564
st dev	9 9805	16 2347

Variances and standard deviations are calculated with denominator = n-1

Test Booklet Scores

$Mean_A$ - $Mean_B$	**t**	**df**
14 1619	2 9993	42
P	**one-tailed**	0 00227
	two-tailed	0 00454

Characteristics of Science teaching groups in Sutton Park School

Groups A, B & C

Degrees of Freedom 42 t score at (p<0 01) 2 418 t score at (p<0 05) 1 682

Characteristics by mean score	Group C	Other Pupils	Value of
N =	14	30	t
Booklet Data			
Interpreting Data	82 9	67 5	4 59
Kinematics			
Position	32 4	21 7	5 26
Velocity	11 9	9 6	1 47
Combined	44 2	31 2	4 23
Scientific Process	36 9	22 8	3 46
Booklet Total	164 0	121 5	4 78
December Test			
Recall of Learned Facts			
Short Qus	120 2	101 3	2 47
Physics	32 6	20 4	3 75
Chemistry	29 6	22 0	1 76
Biology	32 6	23 1	2 85
Booklet Total	215	166 8	2 93
Complete Test Total	379 0	288 4	4 00

Groups A & B

Degrees of freedom	28	t score at (p<0 01)	2 467	t score at (p<0 05)	1 701

Characteristics by mean score	Group A		Group B		Value of
N =	15		15		t
Booklet Data					
Interpreting Data	67 9		67 2		**0 14**
Kinematics					
Position	21 3		22 0		**-0 25**
Velocity	9 2		9 9		**-0 30**
Combined	30 5		31 9		**-0 31**
Scientific Process	23 7		21 8		**0 31**
Booklet Total	**290 4**		**286 3**		**0 14**
December Test					
Recall of Learned Facts					
Short Qus	105 9		96 8		**1 12**
Physics	20 4		20 5		**-0 02**
Chemisrty	21 2		22 7		**-0 32**
Biology	20 8		25 4		**-1 04**
Booklet Total	**168 3**		**165 4**		**0 16**
Complete Test Total	**290 4**		**286 3**		**0 14**

Characteristics of Science teaching groups in Sutton Park School
Individual Question Comparisons

Degrees of Freedom 42 t score at (p<0 01) 2 7 t score at (p<0 05) 2 02

Characteristics by mean score		Group C	Other Pupils	Value of	Significance	
	N =	14	30	t	1%	5%
Section A					15	16
Qu	1c	1 786	1 000	3 923	**	
Qu	5c	1 571	0 800	2 847	**	
Qu	5d	1 214	0 367	2 811	**	
Qu	6a	1 000	0 333	2 081		*
Qu	7d	1 857	1 500	2 030		*
Qu	8a	2 000	1 667	2 370		*
Qu	8b	1 857	1 100	3 267	**	
Qu	9	2 000	1 267	4 029	**	
Qu	10d	2 000	1 733	2 077		*
Qu	11a	0 714	0 067	2 280		*
Qu	11c	2 000	1 733	2 077		*
Qu	11e	1 786	1 200	2 738	**	
Qu	12a	1 857	1 333	2 261		*
Qu	12b	1 714	1 133	2 113		*
Qu	12c	0 857	0 133	2 412		*
Qu	13a	2 000	1 733	2 077		*
Qu	13b	1 929	1 467	2 623		*
Qu	13c	2 000	1 500	3 127	**	
Section B						
Qu	1	3 857	2 133	4 256	**	
Qu	2	2 929	1 567	2 949	**	
Qu	3	2 857	1 400	3 122	**	
Qu	4a	4 000	2 867	3 555	**	
Qu	5a	2 714	1 067	3 738	**	
Qu	9	1 214	0 767	2 026		*

	Qu	*10*	1 500
	Qu	*13a*	4 000
Section C			
	Qu	*1a*	2 500
	Qu	*2b*	4 000
	Qu	*2c*	3 714
	Qu	*2g*	3 143
	Qu	*4*	1 357

Test Booklet Scores

0 933	**2 622**		*
3 067	**3 067**	**	
1 067	**2 595**		*
1 933	**5 568**	**	
1 667	**4 347**	**	
1 667	**2 478**		*
0 600	**2 606**		*

Appendix I

Questionnaire & Analysis

Experiences in the use of Datalogging technology

Please read each question carefully and select your answer on the scale provided Note that the logic of some questions may not be consistent with those posed before them

Your help and assistance with this research are greatly appreciated

Question		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	I regularly used technology in my classroom before using datalogging					
2	I now intend to use datalogging regularly in my classroom					
3	I have improved my I T skills as a result of using this technology					
4	My attitude to using the graphing calculator as an instructional tool has improved					
5	The students' attitude to using the graphing calculator in classroom as a learning tool has improved					
6	I would have preferred to have used a PC to conduct my datalogging experiments					
7	I have altered my teaching style as a result of using datalogging					
8	My students seldom did experiments pre-datalogging					
9	I demonstrated most experiments pre datalogging?					
10	I found the datalogging systems difficult to use					
11	The students found the datalogging system difficult to use					
12	I am happy to allow pupils to conduct experiments					
13	My training was adequate					
14	I need more training					

Question		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
15	My students enjoy science more with the technology					
16	I now pose more open ended questions					
17	I am not comfortable in allowing students to conduct experiments in class					
18	I prefer to design experiments for the students					
19	My students draw their graphs by hand					
20	My students spend a lot of time interpreting graphs					
21	The students' interpretation skills have improved since using datalogging					
22	Datalogging has not helped them to develop a sense of enjoyment in the learning of science					
23	Students are not comfortable using datalogging equipment					
24	In carrying out investigations students are more likely to use the scientific process [hypothesise / predict / plan /analyse/evaluate/conclude]					
25	Students' observation skills have improved since using datalogging					
26	Students have increased expectations of accuracy					
27	Students' awareness of experimental error has increased					
28	My students' formation of opinions and judgements based on evidence and experiment has not improved					
29	Students have not improved in their ability to learn cooperatively					

Please enter a single answer to the following questions

	Question	Answer
30	Did you observe an optimum group size?	
31	Which age group did you work with most?	
32	Did you use it more in any particular discipline? (Phys, Chem, Biol)	

Thank you for participating in this research I will be sure to make the results and information available to you if you wish to see it

Anna Walshe
Researcher

Questionnaire Data

		Strongly Disagree	Disagree	Un decided	Agree	Strongly Agree
Previous Practice	1	4	8	2	4	4
	8	16	4	0	2	0
	9	11	11	0	0	0
Teacher Science	3	0	0	2	14	6
	10	4	12	2	2	2
Student Science	11	4	12	4	1	1
	19	0	7	0	10	5
	20	0	15	1	3	3
	21	0	0	7	8	7
	22	8	10	4	0	0
	23	7	15	0	0	0
	24	0	3	4	8	6
	25	0	3	8	11	0
	26	0	0	4	11	5
	27	0	0	6	3	12
Teacher Science Teaching	4	0	0	0	14	8
	6	4	12	6	0	0
	7	0	2	8	8	4
	12	0	0	0	8	14
	16	0	3	6	5	8
	17	17	5	0	0	0
	18	3	3	8	8	0
Student Science Education	5	0	0	4	12	6
	15	0	0	3	10	8
	28	10	6	3	3	0
	29	6	9	6	0	1
Teacher Prof Dev	13	0	4	2	12	4
	14	0	1	2	14	4

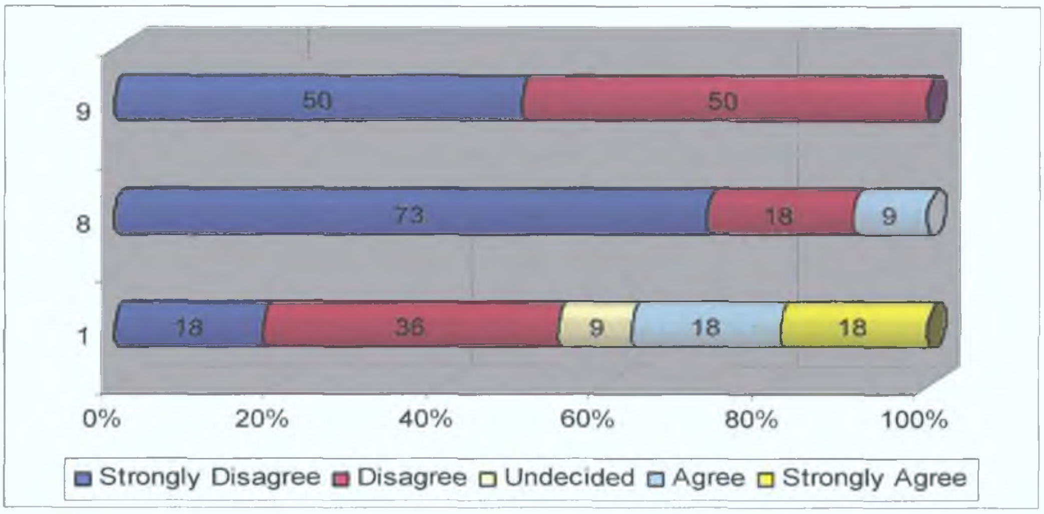
Percentages

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
11	18	55	18	5	5
19		32		45	23
20		68	5	14	14
21			32	36	32
22	36	45	18		
23	32	68			
24		14	19	38	29
25		14	36	50	
26			20	55	25
27			29	14	57

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4				64	36
6	18	55	27		
9		9	36	36	18
12				36	64
16		14	27	23	36
17	77	23			
18	14	14	36	36	

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
5			18	55	27
15			14	48	38
28	45	27	14	14	
29	27	41	27		5

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
13		18	9	55	18
14		5	10	67	19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8
1
50
50
73
18
9
18
36
9
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18
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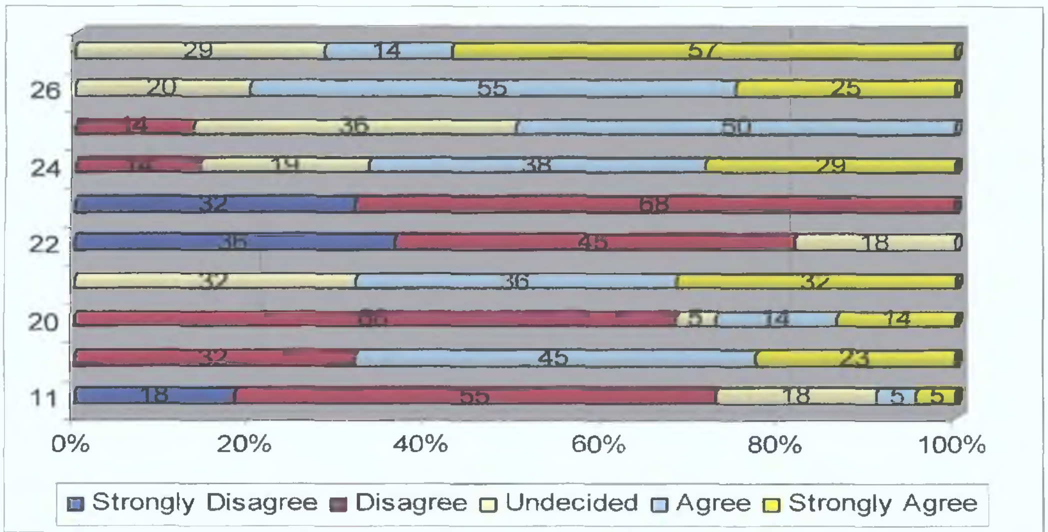
20%
40%
60%
80%
100%
Strongly Disagree
Disagree
Undecided
Agree
Strongly Agree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32
36
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20%
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80%
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Strongly Disagree
Disagree
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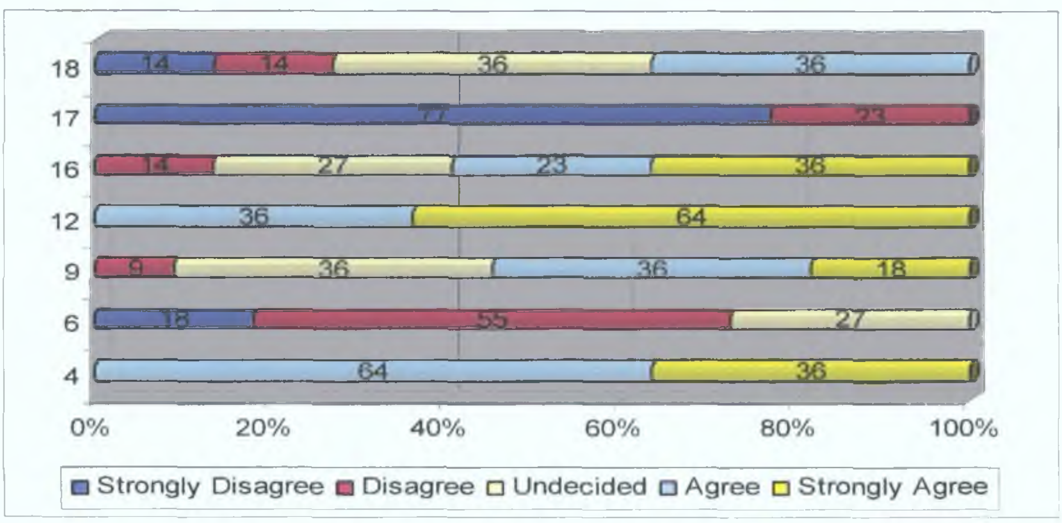
Agree
Strongly Agree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20%
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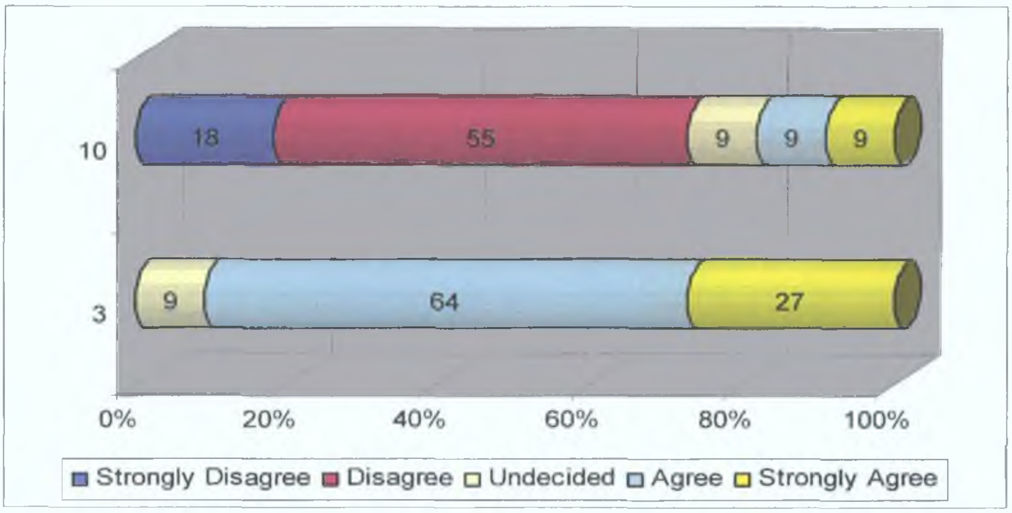
60%
80%
100%
Strongly Disagree
Disagree
Undecided
Agree
Strongly Agree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20%
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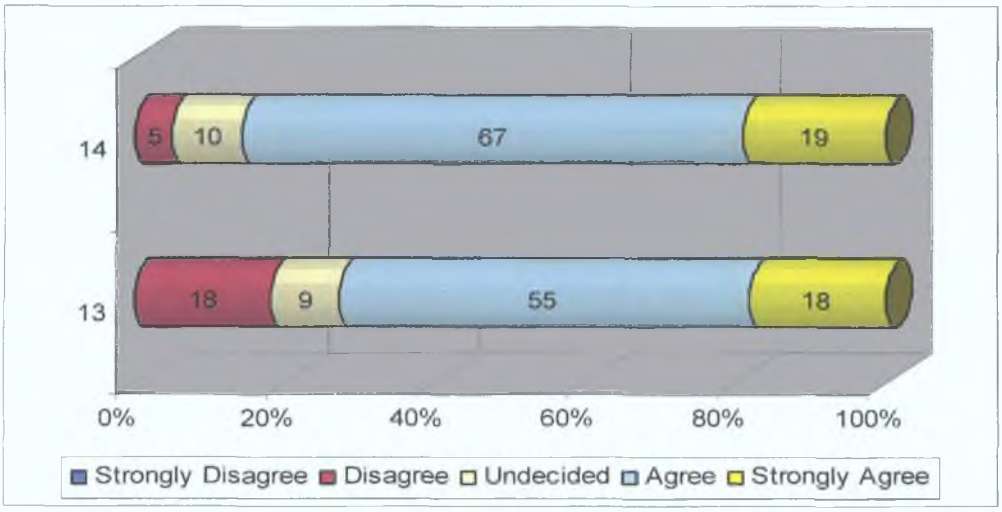
80%
100%
Strongly Disagree
Disagree
Undecided
Agree
Strongly Agree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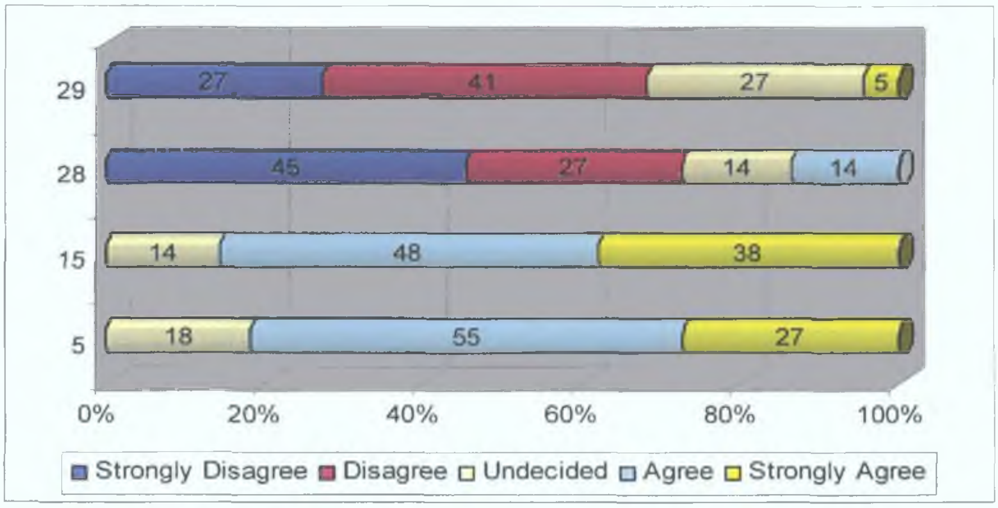
20%
40%
60%
80%
100%
Strongly Disagree
Disagree
Undecided
Agree
Strongly Agree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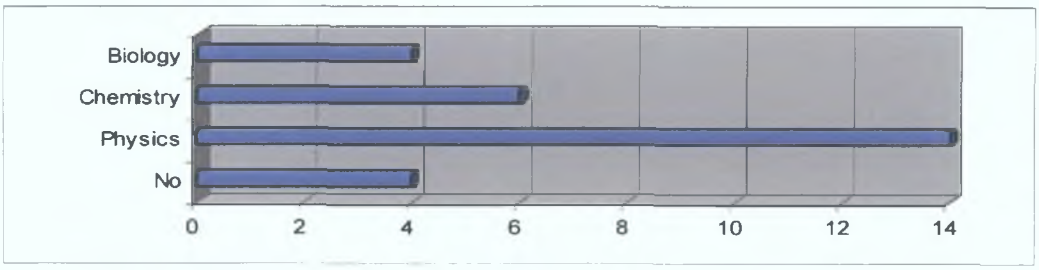
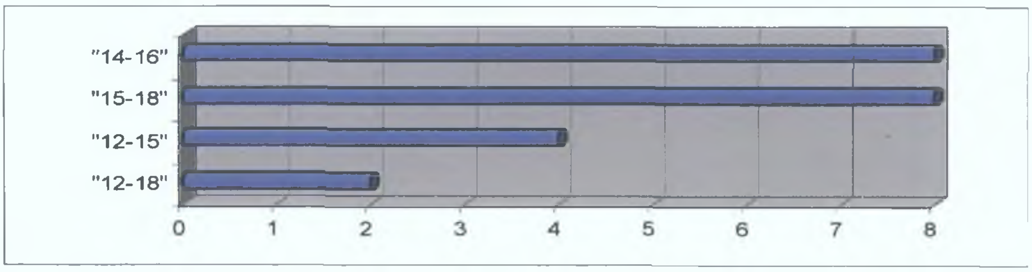
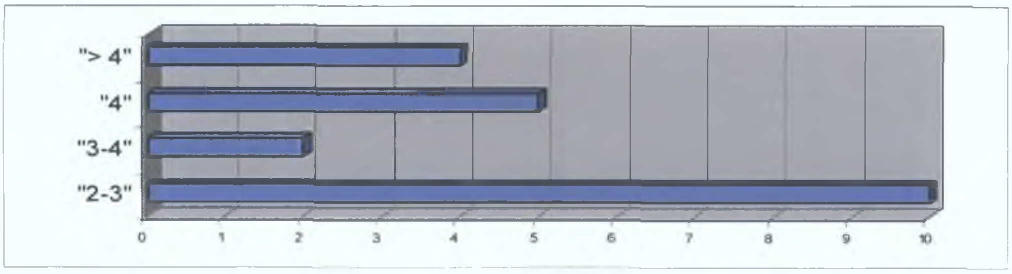
14
48
38
5
18
55
27
0%
20%
40%
60%
80%
100%
Strongly Disagree
Disagree
Undecided
Agree
Strongly Agree

30	"2-3"	10	**31** "12-18"	2	**32** No	4
	"3-4"	2	"12-15"	4	Physics	14
	"4"	5	"15-18"	8	Chemistry	6
	"> 4"	4	"14-16"	8	Biology	4







Appendix X

Test Analysis by Gender

t-Test for Independent Samples

Gender Scores for Groups A & B in December Tests

Values entered:

count	X_a	X_b
1	210	93
2	165	144
3	210	144
4	252	114
5	210	93
6	165	176
7	156	138
8	165	192
9	155	176
10	156	222
11	177	141
12		213
13		222
14		267
15		86
16		114

Summary Values

Values	X_a	X_b
n	11	16
sum	2021	2535
mean	183.727	158.438
sumsq	381505	445125
SS	10192.2	43485.9
variance	1019.22	2899.06
st. dev.	31.9252	53.8429

Variances and standard deviations are calculated with denominator = n-1.

Test Analysis by Gender

$Mean_A$ - $Mean_B$	t	df
25.2898	1.3934	25
P	one-tailed	0.08788
	two-tailed	0.17575

t-Test for Independent Samples

Gender Scores for Groups A & B in June 2002

Values entered

count	X_a	X_b
1	80	65
2	80	65
3	80	65
4	90	90
5	25	50
6	50	80
7	80	80
8	65	80
9	65	65
10	80	80
11	65	65
12		90
13		80
14		90
15		50
16		50

Summary Values

Values	X_a	X_b
n	11	16
sum	760	1145
mean	69 0909	71 5625
sumsq	55900	84925
SS	3390 91	2985 94
variance	339 091	199 063
st dev	18 4144	14 109

Variances and standard deviations are calculated with denominator = n 1

Test Analysis by Gender

$Mean_A$ - $Mean_B$	t	df
-2 4716	-0 3951	25
P	one-tailed	0 34806
	two-tailed	0 69611

t-Test for Independent Samples

Gender Scores for Group C in June 2002

Values entered

count	X_a	X_b
1	80	50
2	90	90
3	80	80
4	80	90
5	40	65
6	50	
7	50	
8	65	

Summary Values

Values	X_a	X_b
n	8	5
sum	535	375
mean	66 875	75
sumsq	38125	29325
SS	2346 88	1200
variance	335 268	300
st dev	18 3103	17 3205

Variances and standard deviations are calculated with denominator = n 1

Test Analysis by Gender

$Mean_A - Mean_B$	t	df
-8 125	-0 7937	11
P	one-tailed	0 22208
	two-tailed	0 44416

t-Test for Independent Samples

Gender Scores for Groups A & B in Booklet Tests

Values entered

count	X_a	X_b
1	145	118
2	100	144
3	159	33
4	132	132
5	150	108
6	163	115
7	93	131
8	106	122
9	150	80
10	100	89
11	122	102
12	106	114
13	89	89
14		224
15		124
16		127
17		179

Summary Values

Values	X_a	X_b
n	13	17
sum	1615	2031
mean	124 231	119 471
sumsq	209225	269471
SS	8592 31	26826 2
variance	716 026	1676 64
st dev	26 7587	40 9468

Variances and standard deviations are calculated with denominator = n-1

Test Analysis by Gender

$Mean_A$ - $Mean_B$	t	df
4 7602	0 3633	28
P	one-tailed	0 35957
	two-tailed	0 71914

t-Test for Independent Samples

Gender Scores for Group C in Booklet Tests

Values entered

count	X_a	X_b
1	167	152
2	157	179
3	171	189
4	158	179
5	184	112
6	131	169
7	160	
8	188	

Summary Values

Values	X_a	X_b
n	8	6
sum	1316	980
mean	164 5	163 333
sumsq	218704	164012
SS	2222	3945 33
variance	317 429	789 067
st dev	17 8165	28 0903

Variances and standard deviations are calculated with denominator = n-1

Test Analysis by Gender

$Mean_A$ - $Mean_B$	t	df
1 1667	0 0953	12
p	one-tailed	0 46283
	two-tailed	0 92566