Are Students Who Use Data Logging in Leaving Certificate Practical Work at any Disadvantage in Drawing Graphs Manually?

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ABSTRACT

The purpose of this research was to investigate if students who use data logging as a tool in Leaving Certificate Physics practical work would be at a disadvantage when drawing graphs manually. The ability of the students to manually draw graphs and to predict graph shapes was tested before and after the research period. The affect of using data logging equipment on the students' perception of Physics practical work was also investigated.

Two fifth year Leaving Certificate Physics classes, in an all girls secondary school, taught by the same teacher, were selected. These were two classes which had been pre-defined by school management and were therefore not chosen randomly. One of the classes – the experimental class – carried out Physics laboratory experiments using data logging equipment. Data logging equipment collects data and produces graphs electronically, using software tools. The other class – the control class – carried out similar experiments, but used 'traditional' laboratory apparatus. The research took place during nine laboratory Sessions, each of 80 minutes duration. Both classes were given identical questionnaires and tests before and after carrying out the laboratory experiments.

The results of this study found that before the research period there were no significant differences between the classes with regard to their perceptions of Physics practical work and their ability to predict graph shapes, but the control class was significantly better than the experimental class at drawing graphs manually. It was found after the research period, that both classes improved significantly at predicting graph shapes; that there was no longer any significant difference between the classes with regard to their ability to draw graphs manually – the mean scores of the experimental class improved significantly, while there was no significant change in the mean scores of the control class. It was also found that there were significant changes in the experimental class with regard to some of their perceptions of Physics practical work.

There is no evidence from this study to suggest that students who use data logging in Leaving Certificate Physics practical work are at a disadvantage in drawing graphs manually. The findings suggest that the use of data logging could actually improve this skill.

1. INTRODUCTION

Since 1995, the numbers of second level students choosing to study Physics at Leaving Certificate level has fallen by 20%, (Department of Education, 30 April 2001). The Irish Department of Education has provided the finance to schools for the purchase of data logging equipment. This equipment is to be used in carrying out of Leaving Certificate practical work specifically in Physics and Chemistry. One of the objectives of the Department is to encourage more students to choose these subjects at Leaving Certificate level. In spite of these innovations it seems that both terminal exams will still be exclusively paper based.

Computer data logging has been used in teaching science in a number of countries since the 1980s, particularly in the UK and the USA. Newton (1998), says that, recently “data logging technology has become sufficiently user-friendly and affordable for it to be more widely adopted”. However, its use in Ireland has been very limited in the teaching of science at second level.

1.1 What is DATA LOGGING?

Data logging is the collection and storage of information. Traditionally, data from science practical experiments was collected by hand and graphs and charts were produced manually. In the 1980’s software tools were developed to do these tasks electronically. The term data logging, as used in this study, refers to such computer/calculator software assisted practical work.

There are 4 components involved –

1. One or more **sensors,** which respond to physical quantities, e.g. light, sound, temperature, pressure, position, voltage, current, pH, etc. The variation in the physical quantity is then converted into a voltage signal that is recognised by a device called an interface box or data logger.
2. A **data logger,** which converts the voltage signal of the sensor to a digital signal, which can be read by the computer or calculator.
3. A **computer** and/or **graphical calculator**
4. **Software** which, processes the data, e.g. display data in a suitable form on the screen, plot graphs, fit curves, etc.

1.2 The aim of this study

The aim of this study is to investigate if students who use data logging as a tool in Leaving Certificate Physics practical work will be at a disadvantage when it comes to drawing graphs in the

Leaving Certificate examination. Therefore, the author set out to investigate how, if at all, using data logging in Physics practical work affects students' abilities to draw graphs on paper.

2. BACKGROUND

Most of the research carried out with all age group students shows that the use of data logging improves students' ability to understand and interpret graphs, to predict the shape of an emerging graph, to develop higher-level thinking and to work collaboratively. It has been found to have a positive effect on the development of scientific enquiry skills and promotes discussion among the pupils.

2.1 Practical laboratory work – with and without data logging

Barton (1998) describes the three most commonly stated areas in which problems have been identified with traditional practical work. The first is "time overhead" involved in collecting and processing data, leaving very little time to relate the practical to the theory. The second, is what he calls "information clutter"- the equipment, measurements to be recorded, calculations, graphs and the problems that may be associated with them can "obscure the purpose of the activity for many pupils". The third is "linking practical experience with abstract concepts" usually by drawing and interpreting a graph. A study by Barton (1997) found that student difficulties in plotting graphs manually often reinforced misunderstandings.

A number of researchers have cited certain advantages of using data logging over the traditional manual methods for collecting and recording results. Rogers and Wild (1996), Harrison (1997), Barton(1997), Newton (1998), Miller (1999), Kennedy (2001), Kwon(2002) include the following:

- the speed of capture and plotting of graphical data
- data capture over very short time spans
- opportunities to replicate the experiment frequently and quickly
- elimination of human error
- reduction of some of the tedium of data manipulation by pupils
- easy identification of shape of graph
- real-time graphing, resulting in immediate feedback
- pairing of real-time events with their symbolic representations
- elimination of the drudgery of graph production
- providing scientific experiences similar to those of scientists in actual practice
- encouraging collaboration and group interaction.

Barton (1998) summarised these advantages of the use of data logging over traditional methods as "time saving" and "focus effect".

2.2 Graphs in science

While much of the emphasis in schools has been on graph construction skills, much of the literature that addresses graph drawing in science concentrates on the abilities of students to interpret graphs or predict graph shapes. There are few studies on the ability of the students to manually draw graphs representing data collected. The importance of the representation of experimental data in graphical form is well recognised, as is the importance of the ability to extract information from the graph. According to Friedler and McFarlane (1997), the ability to draw, analyse and interpret graphs is crucial to the study of science. Kwon, (2002) states that: "Graphing represents a key symbol system of the world in the natural sciences".

2.3 Graphs and data logging

Friedler &McFarlane, (1997) found evidence that data logging improves the manual graph drawing ability of 14-year old students, but not 16-year old students. The results of an earlier study, (McFarlane, Friedler et al. (1995)), found that seven and eight year-olds exposed to data logging showed an increased ability to read, interpret and sketch line graphs compared to those using traditional apparatus. Barton (1997) carried out a comparative study, on 12 – 14 year-old students, to investigate if there are any advantages to pupils using computer generated graphs as opposed to plotting them manually. He found that manual plotting was a problem for all, particularly the weaker students; it not only caused a time penalty, but misunderstandings about the relationships between the variables being plotted were reinforced by the difficulties students had in drawing the best-fit lines. On the other hand, the computer-assisted graphing approach was particularly effective for the younger, weaker students; the production of real-time graphs stimulated the students to provide explanations, make predictions and spontaneously make links to previously acquired knowledge. He says that, "manual graph plotting should be avoided when the main aim is to interpret relationships via graphical analysis". Lapp and Cyrus, (2000), explored the extent to which graphing technology coupled with data-collection devices can benefit mathematics and science classrooms. They agreed with Barton (1997) that one advantage of data logging is its ability to give the student immediate feedback by displaying graphs of data in real time. This provides a very powerful link between real events and the graph as an abstract representation of these events. Therefore, data logging supports the development of physical intuition through direct inquiry. They also suggest that pairing events in real-time with symbolic representations, provides scientific experiences similar to those of scientists in actual practice and eliminates the drudgery of graph production. Kwon, (2002), examined the effects of using the CBR, (Computer Based Ranger– a 'probe' which logs distance, velocity and acceleration), on students' graphing ability. He compared graphing abilities of two groups of students – one of which was taught in traditional lecture style and the other of which was taught using CBR activities. The investigation also examined the extent to which prior knowledge of graphing skills affected graphing ability. The results of this study provide evidence that CBR activities significantly improved the students' abilities to interpret, model and transform graphs, and that prior knowledge of graphing skills on the Cartesian coordinate plain had no significant effect on students' understanding of graphs. He concluded that: "laboratory learning environments are more effective than the paper and pencil environment in developing an understanding of graphs in the context of real world situations". He also identified the real-time feature of CBR technology as an excellent medium for helping students connect a graph with real-word relationships.

2.4 Graphing Ability

The definition of graph drawing ability varies in the literature. It can generally be sub-divided into two areas: graph construction skills and graph interpretation skills.

Kwon (2002) defined 'graphing ability' as having three components, namely:

1. Interpreting – ability to translate from graphs to verbal expressions.
2. Modelling – ability to translate from real world situations to graphs.
3. Transforming – ability to see and draw a variety of graphs depicting the same event, for example having created a distance-time graph to predict the velocity-time or acceleration-time graphs for the same event.

Lapp and Cyrus (2000), identified areas of difficulty which students have with graphing and modelling and measured the graphing ability of the students in the context of these:

- Connecting graphs with physical concepts
- Connecting graphs with the real world
- Transitioning between graphs and physical events, e.g. graph-shape and path of motion confusion.

2.5 Data logging and learning theories

According to Rodrigues (1999), data logging provides a tool to enhance a science teacher's pedagogical practices, but its use will depend on the teacher's views of learning.

(a) The brain

Forrester and Jantzie, (1998), reviewed the literature concerning learning theories and the brain. The more often memory structures in the brain are activated, the more easily will memory be retrieved and used in decision making. Time to repeat experiments, because of the time saving factor when using data-logging equipment, means repeated stimulation of the same memory areas in the brain. Observation of the plotting of 'correct' graphs should provide activation of the 'correct' memory structures.

(b) Multiple Intelligences

Brualdi (1996), describes Howard Gardner's Theory of Multiple Intelligences:

1.Verbal/linguistic - involves having a mastery of language. Newton's (1998) research suggests that teachers, using data logging, should be encouraging their students to talk about what they are doing and finding. He found that explicitly telling the students to talk about what they see prompted discussion and description of data.

2. Logical-mathematical – consists of the ability to detect patterns, reason deductively and think logically, sometimes called scientific thinking. Newton (1998) argues that because data-logging software performs calculations quickly, and therefore gives the students the opportunity to quickly try out ideas with different data, its use can help pupils develop higher order data-handling skills.

3. Visual-spatial – the ability to manipulate and create mental images in order to solve problems. The creation of graphs is central to data logging. The predicting of the shapes of the graphs by students using data loggers has been documented by Barton (1997), among others.

4. Bodily-kinaesthetic - is the ability to use one's mental abilities to coordinate one's own bodily movements. Newton (1998) proposes that if the teacher defines tasks for the different group members e.g. one to make observations, one to monitor measurements taken, one to check the apparatus stays set up, then they will all have an active role in the experiment.

5. Interpersonal – has to do with person-to-person relationships and communication, seeing things from others' perspectives, co-operating within a group, communicating verbally and nonverbally. Newton (1998) says that the way that the teacher organises the pupils at the computer can encourage interaction between them. The students may be able to assume responsibility for decision-making, for example, in deciding if the experiment should be repeated.

6. Intrapersonal – relates to self-reflection, awareness of internal states of being, thinking and reasoning on higher levels and the ability to understand one's own feelings and motivations. Newton (1998) notes that because the computer produces the results students may attach more significance to them and will tend to feel they must be correct because the computer could not make mistakes. It is important for the teacher to encourage the student to account for these variations. The student will need to apply their own experience, knowledge and understanding of investigative work to interpret the graphs produced. These activities demand high-level cognitive skills.

7. Musical - encompasses the capability to recognize and compose musical pitches, tones, and rhythms.

While using data logging, there is an almost automatic inclusion of most of the intelligences in the learning experience, provided the teacher manages it appropriately.

Traditional practical work probably included most of the intelligences, but only within the limit of the time allowed. Data logging promotes the development of the different intelligences primarily because it allows more time to be available for analysis of results, repeating and predicting, therefore it frees the mind from the difficulties of the tedious tasks of graph drawing and data recording. Also, because graphs are produced as the data is recorded the students can relate the 'real' experiment with the graphical output.

(c) Constructivism

Crowther, (1997), gives an overview of constructivism. Constructivism is a learning theory, that focuses on the learner's ability to mentally construct the meaning of their environment and to create their own learning. The emphasis is placed on the student rather than on the teacher. Teachers are seen as facilitators who can assist students and students take control of their own learning. They construct knowledge in their own minds by taking in new information and using it to modify existing ideas. It also places a focus on group work. Constructivists define learning as the motivation of an individual to attach new meaning to past cognitive experiences. Constructivism is not just one theory, but a combination of a number of similar theories developed by Piaget, Vygotsky, Papert and others, since the 1920's.

Data-logging experiments involve collaborative activities. This is a key element of the constructivist view of learning. The members of the group will interact, will predict graph shapes, based on their past knowledge and learning. The group members will help construct each other's learning, and they will come to see their peers as resources rather than competitors. The teacher should also not be seen as a threat but as a necessary ally or tool in the process of learning. Newton (1998) commented that students' own understanding of their roles in lessons is determined by their past experiences and that teachers need to help students understand this role better to make the most of their practical experiences. Barton (1997) analysed tape scripts of pupil-teacher interactions during data logging experiments and concluded that the intervention of the teacher was crucial, particularly with prompt questions when they are interpreting graphs, and to encourage discussions between students and between students and teacher. The physical construction of graphs by the data loggers could be seen as promoting Papert's (1996) constructionist theory. The fact that the students do not get bogged down in the difficulties of drawing the graphs means that the learning experience is more positive. Success builds up self-image and motivation.

Many, (e.g. Lapp and Cyrus, 2000, Kwon, 2002), have commented on the importance of the effectiveness of real-time data collection as a means of connecting a graph with the real-world experiences of a student. Lapp and Cyrus (2000), found that the focus effect of data logging made students use their short-term memory to make predictions and construct explanations. They noted that applying concepts learned with data logging seems to give students a sense of confidence in their work. Harrison (1997) states that there is a strong belief that by using data logging in experimental investigations there can be more effective learning by pupils. Children can be encouraged to develop their own learning through questioning their own ideas and comparing them with those of their friends and colleagues. Hale (1996), pointed out that a drawback of using data logging in groups is that the group could converge on a misconception, but whole class discussions following investigations can promote further discussion and repair any misconceptions. Incomplete understanding is a part of constructing concepts, thus eliminating it from the learning process, is not necessarily desirable.

2.6 The teacher's role and teaching methodology

There is a common thread through most of the literature on the critical role the teacher has in a data logging class as the "scaffolding". To achieve the full learning potential of data logging Newton (1998) places great emphasis on the management decisions made by teachers and the teaching approaches employed. He sees the teacher's role in setting tasks as critical if the 'focus effect' benefits are to be exploited and states that if data logging classes are well planned they contribute to positive learning environments. He also suggests that teachers could encourage thinking by providing sentence starters to help students put their ideas into words. He further argues that because data logging software performs calculations quickly, and therefore gives the students the opportunity to quickly try out ideas with different data, its use can help pupils develop higher order data-handling skills. Nakhleh and Krajcik (1994) state that students need careful task analysis, directed teaching and class discussion to counteract the formulation of inappropriate concepts.

Barton (1997) found that pupils using data logging spent most of their time involved in question and answer sessions with the teacher, while those using manual methods spent most time processing data. As mentioned previously, he emphasised the importance of the teacher asking questions and encouraging discussion. In a later paper in 1998, Barton states that all studies identify the importance of the particular tasks set by the teacher and the interactions between pupils and teachers. Use of computer assisted practical work makes it possible to change the style and structure of practical work, especially with regard to what tasks should be set for pupils using computers and what role should teacher take during these activities.

Research suggests that we can be optimistic about the benefits of data logging but it may be too early to draw final conclusions; further study is needed to make any definitive statements on the pedagogical advantages of data collection devices. If data logging is to be successfully introduced into school laboratories then teachers must look carefully at their teaching methods and be prepared to change them.

2.7 Introducing data logging into the teaching of science

According to Lapp and Cyrus (2000), the increased availability and decreased cost of data-collection devices, coupled with probes for graphing calculators rather than computers, have made them more attractive for use in science and mathematics classrooms. Newton (2000) interviewed teachers, in the U.K., to find out about their experiences of using data logging in their science teaching. He found that "the implementation of data logging in classrooms is not straightforward".

2.8 Data logging in Ireland

In 1997, the *Department of Education and Science* in Ireland set up an initiative called *Schools IT 2000* to encourage the integration of Information and Communications Technology (ICT) into teaching and learning in schools. A *Schools Integration Project* (SIP) in data logging was part of this initiative. The findings of this project provide the only report on the use of data logging in Ireland.

3. RESEARCH DESCRIPTION

This research took place over the second and third terms of the school year 2001 – 2002. Two parallel Physics classes in the same girls' school were chosen, one of which was selected as the experimental class and the other was the control class. Both classes were in the first year of a two-year Leaving Certificate course. Nine practical sessions took place, each of 80 minutes duration.

During these sessions both the control and experimental classes carried out parallel practical investigations – the control class using traditional equipment and the experimental class using data logging equipment. All of the students completed pre- and post- tests and questionnaires.

3.1 The sample

The sample consisted of thirty-four 5th Year Leaving Certificate female Physics students from the same school. The students attending the school are highly motivated academically and from a wide range of socio-economic backgrounds. There is a strong tradition of uptake of the sciences in the school. The sample was divided into two classes - an experimental class and a control class. The students in each class could not be chosen randomly. On the basis of each student's preference for different choice subjects the sample had been divided into different classes by the school administration. One class had twelve students – this was chosen to be the experimental class. The other class had twenty-two students – this was the control class. Each class was composed of students of mixed ability. When this study was started all students had completed one term of Physics and had carried out experiments with traditional equipment.

3.2 The apparatus

The data logger chosen for this study was a *CBL 2 (Calculator Based Laboratory)* interface, connected to a *Texas Instruments graphics calculator* (*TI 83+ Silver Edition*). The following probes, attached to the CBL, were used:

- *CBR (Computer Based Ranger)* – an ultrasonic motion detector
- *Temperature probe*
- *Boyle's Law pressure probe*

Vernier software application *DataMate*, which displays and collects data simultaneously, was used.

3.3 Teaching

The same teacher taught both classes. This teacher was not an experienced user of data logging equipment but was very familiar with the traditional equipment.

Both the experimental and the control classes had five 40-minute class periods per week. The same theory was covered in a classroom with each class for three of these five class periods. For the remaining two class periods – a double period of 80 minutes - each class had a practical session in the laboratory. In any particular practical session, the experimental class used data logging equipment and the control class used traditional equipment, to carry out the same experiment. The teacher selected the activities for each practical with a view to synchronising practical investigations for the control and experimental classes.

3.4 Pre-Questionnaire and Post-Questionnaire

A pre-questionnaire was issued to all of the students before any experimental work with the data logging equipment started. The purpose of this questionnaire was threefold –

a) To determine the students' 'familiarity' with computers and attitudes to their possible use in the Physics laboratory.
b) To determine the students' opinions about practical work already carried out.
c) To examine some of the reasons why the students chose Physics for Leaving Certificate.

The students completed a post-questionnaire at the end of the research period. The purpose of this was to ascertain if the practical laboratory sessions had changed the students' perceptions of Physics and/or enhanced their learning experiences, and to see whether or not there were differences between the control and experimental classes in this regard.

3.5 Pre-Test and Post-Test

The experimental and control classes were given a pre-test during their second practical session. This was to determine their abilities to draw graphs manually before the use of the data logging equipment commenced. It was given to both classes to see if there were any initial differences between their graph drawing abilities. The post-test was essentially an alternative version of the pre-test. The students in both experimental and control classes completed it during their last practical session. The objectives of these tests were to assess students' ability:

a) To predict the shape of graphs.
b) To manually draw graphs.
c) To interpret and extract information from the graphs.

In both the pre-test and post-test, students were given two graphs to draw – graph A and graph B. Graph A was a straight line through the origin and graph B was a curve. A third question required the students to predict the shapes of various graphs. The grading scheme devised for the tests broke the tasks down into many steps. The correct answer to each step was worth one point, and each incorrect answer was worth zero points. The steps relating to the manually drawn graphs reflected the steps for which marks have been awarded previously in the marking of Leaving Certificate Physics graph questions.

4. RESULTS AND ANALYSIS

Quantitative analyses of the results of the pre- and post-questionnaires and pre- and post-tests for the experimental class and the control class were carried out using the statistical software package, Statistical Package for Social Sciences, (S.P.S.S.).

4.1 Pre-Questionnaire

(a) Computer Use

All of the students, except one in the control class, had a computer at home and approximately 50% of students in each class used computers in school. A Chi-Square test showed that there was no significant difference in the frequency of usage of computers between the two classes. The majority of students in each class used a computer once a week and rated their ability to use a computer as good or very good. The majority of the students in each class felt confident that they could use the computer to help with practical work in the Physics laboratory. Most of the students in both classes indicated that they did not expect to find computers used as a tool in Physics practical work.

(b) Reasons for choosing Physics

All, except one student in the experimental class, had studied mathematics and science at higher level for the Junior Certificate. A Chi-Square test shows that there is no significant difference in the grades obtained between the two classes. In each class an A or B was achieved by more than 75% of the students in higher level mathematics and by more than 84% of the students in higher level science.

There were twelve factors suggested that might have influenced the students' choice of Physics for Leaving Certificate. Chi-Square tests on the results showed that there was no significant difference between the classes with regard to the influence each factor had on their choice. The strongest influence in choosing Physics, selected by 65% of all the students, was that they liked Junior Certificate science. The next strongest influence was a liking for mathematics, selected by 43% of all the students. Parental advice and the student's 'feeling' that she could get a high grade in Physics had a moderate influence on 58% and 57%, respectively, of all of the students. 50% of the students selected enjoyment of practical work and just fewer than 50% selected the relevance and usefulness of Physics in everyday life as having a moderate influence on their choice. The advice of the Guidance Councillor had no influence on almost 84% of all the students, while 61% were not influenced by their knowledge of grades achieved by past pupils in Physics.

(c) Students' Perceptions of Practical Work Before the Research Period

Chi-Square tests showed that there was no significant difference between the two classes with regard to any of their perceptions of Physics practical work carried out before the experimental period started, and with regard to how they rated various practical activities.

In general, the results show that there were no discernable differences between the experimental class and the control class with regard to all of the questions asked. This meant that the two classes started off from a common base with regard to their knowledge and use of computers and their expectations of computers use in a Physics laboratory.

4.2 Post-Questionnaire

(a) Perceptions of Experimental Class Compared to Control Class after the Research Period

Chi-Square tests to compare the perceptions of the experimental class with the control class indicated no significant difference between the classes, except with regard to the question about the methods being 'old fashioned'. As might have been expected, significantly more of the experimental class than the control class, after using the data logging equipment, disagreed that the methods were 'old fashioned'.

(b) Changes in Perceptions Within Each Class after the Research Period

Paired Sample t-tests were carried out to see if the perceptions of the students within each class had changed after the research period.

- Only one result for the experimental class was significant at a 95% confidence level: significantly more agreed with the statement "I never know what graph to draw", after the research period than before. Three perceptions of the experimental class changed significantly at the 90% confidence level, after the research period: significantly less of the students in this class agreed that practical work "makes Physics more interesting", "makes theory easier to understand" and "methods are 'old fashioned'", after the research period than before.
- For the control class, there were no significant changes in their perceptions of practical work after the research period compared with before, except with regard to "the methods being old-fashioned" – significantly more agreed with this statement after the research period.

These results indicate almost no change in the perceptions of the control class of Physics practical work during the research period. However, the perceptions of the experimental class about Physics practical work seem to have become more negative during the research period, except with regard to the methods being ‘old fashioned’.

4.3 Pre- and Post-Tests

(a) Predicting graph shapes

Before the research period, the mean score obtained by the experimental class was 59.09% compared to 62.5% by the control class, but Independent Samples t-test indicated that this was not a statistically significant difference.

The mean scores of the two classes after the period of the research were 75.0% and 72.6% for the experimental class and the control classes respectively. This indicated that the experimental class were now scoring higher than the control class, but this again was still not a statistically significant difference between the classes.

Paired samples t-tests indicated that these increases in the mean scores for each of the classes after the research period were significant at the 10% level. When the marks for labelling the axes were excluded and only the marks for predicting shape were compared the increases in the mean scores of both classes - 22.50% for the experimental class and 27.78% for the control class- were significant at the 5% level.

Therefore, students in both classes improved in their ability to predict the shape of graphs during the research period.

The overall conclusion therefore is that both classes showed significant improvement in their ability in predicting graph shapes between the pre-test and the post-test. However, there is no evidence to suggest that one class showed a significantly greater improvement than the other.

(b) Drawing graphs

(i) Comparison of mean scores of the control and experimental classes for pre-test graphs

There was a significant difference between the mean scores achieved by each class for graph A before the research period – the control class was significantly better; the mean scores were 86.8% and 76.6% for the control and experimental classes, respectively.

The mean scores for graph B were 76.3% and 62.0% for the control and experimental classes, respectively. The calculated t-value of 2.184 was also significant at the 5% level indicating that the difference between the mean scores was significant.

Consistent with the findings for the graphs individually, when the mean scores for both graphs A and B together were compared, the mean score of the control class was significantly better than that of the experimental class – the control class mean was 81.6% compared with 68.5% for the experimental class.

When the mean scores for just drawing the graphs, (i.e. without the interpretation/analysis scores), were compared the control class was significantly better than the experimental class - the control class scored 92.9% and the experimental class 85 %. Therefore, before the research period the control class was significantly better than the experimental class at graph drawing and graph interpretation and analysis.

Table 4.3.4 Graph drawing ability (pre-test)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
total % for graph A	Equal variances assumed	3.629	.067	2.053	28	.050
	Equal variances not assumed			1.888	16.303	.077
total % for graph B	Equal variances assumed	3.299	.080	2.184	27	.038
	Equal variances not assumed			2.478	25.367	.020
total % for graphs A and B	Equal variances assumed	1.694	.204	2.656	27	.013
	Equal variances not assumed			2.942	24.131	.007
total for DRAWING graphs (before)	Equal variances assumed	2.157	.153	2.477	27	.020
	Equal variances not assumed			2.243	14.195	.041

(ii) Comparison of mean scores of the control and experimental classes for post-test graphs

For graph A, the mean scores obtained by the control and experimental classes were, 90.4% and 82.1%, respectively. The calculated t-value indicated that at a 5% significance level this difference was significant.

For graph B, the mean scores were 70.0% and 73.3%, for the control and experimental classes, respectively. The t-value calculated showed that this was not a significant difference between the mean scores of the two classes at the 5% level of significance. Thus, not only did the experimental class cancel out the difference that existed between their mean scores and the mean scores of the control class before the research period, but also they scored slightly higher than the control class.

For graphs A and B together, after the research period, the mean scores of 80.2% and 77.7% for the control and experimental classes were found not to be significantly different.

For graph A the mean of the control class was still slightly greater than the mean of the experimental class. For graph B the experimental class mean was slightly higher than the control class, (though not significantly so), representing a reversal of the pre-test situation. Combining

scores for graphs A and B shows that after the research period, the control class still score slightly higher than the experimental class, but not significantly so.
The mean scores for just drawing both graphs, (i.e. excluding the interpretation/analysis scores) for each class, after the research period, were compared. The control class scored 90.7% and the experimental class scored 94%. Thus, the experimental class reversed the pre-test results by scoring higher than the control class, but the difference was not significant. It was noted that while the experimental class scores improved, the control class results decreased slightly, although t-tests showed neither of these observations to be statistically significant.

(iii) Comparison of mean scores, for graph drawing, obtained by each class, before and after using data logging apparatus.

Experimental class

The experimental class showed significantly improved mean scores for graph B and in the combined score for both graphs, after the research period. They also showed an improvement, but not statistically significant, in the mean scores for graph A and for just drawing both graphs.

Control class

The control class, unlike the experimental class, showed no significant changes in the mean scores obtained for any of the graphs. In fact, their mean scores, except for graph A, decreased slightly, but not significantly. This would suggest that the ability of the control class to draw graphs and interpret/ analyse aspects of the graphs neither got better nor worse during the research period.

Table 4.3.5 Drawing graphs (pre and post test) paired comparison

Paired Samples Test

			Paired Differences					
Group			Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Control	Pair 1	total % for graph A - total % for graph A (post)	-3.9683	12.30422	2.90013	-1.368	17	.189
	Pair 2	total % for graph B - total % for graph B (post)	6.1111	15.00545	3.53682	1.728	17	.102
	Pair 3	total % for graphs A and B - total % for graphs A and B (post)	1.0714	12.29209	2.89727	.370	17	.716
	Pair 4	total for DRAWING graphs (before) - total for graph drawing (after)	1.9841	9.74019	2.29578	.864	17	.399
Experimental	Pair 1	total % for graph A - total % for graph A (post)	-5.0000	18.14842	5.73903	-.871	9	.406
	Pair 2	total % for graph B - total % for graph B (post)	-10.0000	11.18034	3.72678	-2.683	8	.028
	Pair 3	total % for graphs A and B - total % for graphs A and B (post)	-8.5714	9.41530	3.13843	-2.731	8	.026
	Pair 4	total for DRAWING graphs (before) - total for graph drawing (after)	-6.3492	11.54209	3.84736	-1.650	8	.137

5. CONCLUSIONS

The results of a questionnaire issued to the students in both classes before the research period revealed the following similarities between the classes:

- At the start both classes had similar perceptions of Physics practical work carried out before the research period. The students in both classes had very positive attitudes towards Physics practical work.
- The strongest influences on the students in both classes in choosing Physics for Leaving Certificate were a liking for Junior Certificate Science and Mathematics.
- There was no significant difference between the grades obtained by the students in both classes in Mathematics and Science in the Junior Certificate examination.

Comparison of the results of graph-drawing tests completed by the two classes before the research period, revealed significant differences between the two classes. The control class was significantly better than the experimental class at manual graph drawing and graph interpretation and analysis, before the research period. However, there was no significant difference between the classes, before the research period, with regard to their ability to predict the shape of graphs.

A questionnaire about the students' perceptions of Physics practical work, issued after the research period revealed, as might have been expected, that significantly more of the experimental class than the control class now disagreed that the methods were old-fashioned. Also, significantly more of the students in the experimental class agreed with the statement "I never know what to draw" after the research period than before. This possibly indicated the development of a lack of confidence in the students to decide what to graph because the data logging software had taken over that role when they carried out the experiments. Strangely, the perceptions of the experimental class about many of the aspects of Physics practical work became more negative after the sessions in which they used data logging equipment.

After the research period, examination of results obtained by both classes for manual graph drawing and graph interpretation and analysis showed that there was no significant difference between the classes after the research period. Also, while the overall results of the experimental class improved those of the control class decreased slightly, though not significantly. Therefore, the differences between the classes, with regard to drawing graphs, were reduced after the research period. This was confirmed when the mean scores obtained by the experimental class, before and after the research period, were compared showing a significant improvement in the mean scores of the students in this class for graph drawing and graph analysis and interpretation. A similar comparison for the control class showed no significant change in their mean scores.

While both classes improved significantly at predicting graph shapes after the research period, there was still no significant difference between the classes. This would suggest that while the use of data logging equipment may not have caused the improvement in predicting graph shape, it certainly did not hinder it.

There is no evidence from this study to suggest that students who use data logging in Leaving Certificate Physics practical work are at a disadvantage in drawing graphs manually. On the contrary, the findings suggest that the use of data logging could actually improve a student's ability to manually draw graphs and interpret and analyse graphs. The experimental class in this study were significantly worse than the control class at these skills before carrying out practical work with data logging equipment. At the end of the research period there were no significant differences between the classes in these skills suggesting that the experimental class had "caught up" with the control class. It was interesting to note that, while the graphing skills of the experimental class seemed to improve, the perceptions of the students' in this class about practical work seemed to become more negative. The reasons for this were not obvious from this study but could form the basis of another investigation.

In common with the findings of previous research, the author found that in the experimental class the graphs produced on the calculators, by the data logging software, gave rise to much discussion and suggestions about the meaning of each graph. Also, it was observed that the experimental class spent all of their laboratory class time focussed on the experiment - doing and re-doing the experiment to get better results, asking questions, obtaining graphs, writing-up the experiment, asking questions, and so on. The control class, in contrast, while waiting to take readings, spent their time talking about anything except the experiment. They had to be constantly reminded to write-up the experiment and to think about the meaning of the results they were obtaining. The author also found, as much of the literature suggested, that it was necessary to plan the data logging investigations very well before presenting them to the students.

6. LIMITATIONS OF THE STUDY

The research was carried out in just one all-girls school, with two fifth year Physics classes. Due to unavoidable circumstances, the control and experimental classes were not chosen randomly. The numbers in each class were different and relatively small. In this study it was shown that the two classes were significantly different in their graph drawing abilities before the research period. This meant that it was difficult to make any direct comparisons between the two classes after the research period. This would be possible with two randomly selected classes, which should have a common starting point.

The students who took part in this study, being fifth year students, already had some graph drawing experience and skills that they would have acquired in their previous school years.

Many mechanics experiments lend themselves better to data logging equipment than some of the other Leaving Certificate Physics experiments. Unfortunately, when this investigation started all of the students in the sample had completed most of these mechanics experiments using traditional equipment, during the previous term. All students also had some practice drawing Physics graphs manually during the first term.

The research period was very short – nine weeks, of which seven were spent doing experiments. Also, as the control class had their practical session timetabled for Friday afternoons – two of which fell on half-days - they had two laboratory sessions less than the experimental class, over the duration of this study.

Therefore, the findings of this study cannot be applied to the whole population of fifth year Physics students in Ireland. Randomly chosen classes of equal size and larger numbers would be more suitable. However, the results are encouraging and it would appear to be worthwhile that the use of data logging equipment in schools should be further investigated in a number of ways.

6. RECOMMENDATIONS

- This study could be repeated but carried out over a longer period.
- The research could start in September, before any practical work was carried out with traditional equipment.
- The study could be carried out with younger classes, for example Junior Certificate classes who have little or no graph drawing skills at the start.
- Larger sample class sizes, randomly selected would be more suitable. Alternatively, sample classes made up of an equal selection of mixed ability students could be used.

- The study could be repeated in boys only, girls only and co-educational schools in different regions in the country.
- A study could be carried out to investigate possible reasons for changes in the students' perceptions of practical work using data logging equipment.
- An examination of the methods of examining practical work at Leaving Certificate level might suggest better ways of rewarding students who use data logging equipment.
- A study of the changes necessary in teaching methods of teachers who wish to successfully introduce this technology into their practice would also be useful, as would a study of the supports needed by teachers to enable them to successfully implement this technology in their laboratories.

As very little research has been carried out to date on the effect of the use of data logging equipment on the ability of students to manually draw graphs, it would seem that further research is essential. Teachers need to be reassured that the introduction of this technology into their practice will have a positive impact on both their own educational experiences and those of their students. Students need to be confident that this new technology does not put them at any disadvantage in a terminal examination that involves manual drawing of graphs.

The results of this limited short study are very encouraging. It would suggest that there are very promising outcomes from the use of data logging equipment. Not only will school laboratory work be brought 'up to date' and more in line with real laboratories but the learning experiences of students and teachers will be enhanced by its use.

However, a word of caution is necessary. As with any new equipment, there must be recognition of the difficulties associated with its implementation and use. It is essential that to attain the full benefits of this technology teachers must have a support system that they can rely on for help and reassurance. The author found that there were more difficulties in interpreting error messages and knowing which 'leads' to use than there were in carrying out the experiments. Also, teachers will have to recognise a shift in their role in a practical class - the teacher must become the facilitator of learning rather than the provider of information.

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