PHD

Mobile Contextual Data for Hands-On Learning

Martin, Susanna

Award date:
2013

Awarding institution:
University of Bath

Mobile Contextual Data for Hands-On Learning

Volume 1 of 1

Susanna Marie Martin

A thesis submitted for the degree of Doctor of Philosophy

University of Bath

Department of Psychology

September 2012

Contents

List of Figures

List of Tables

Acknowledgements

I have been lucky during this research to be supported by four excellent supervisors who have provided insight, support, new perspectives and patience. So my first thanks go to you: Professor Danaë Stanton Fraser, Dr Dawn Woodgate, Professor Mike Fraser and Mr. David Crellin.

Perhaps the most important people to thank are the teachers and pupils who have allowed me to conduct research in their schools, disrupting their timetables and giving them endless questionnaires.

I would also like to thank Great Western Research and ScienceScope for funding this research, and the members of the CREATE Lab, in particular Dr Chris Bevan, for helping me run experiments in schools.

I would like to thank my family and friends who have been there through it all. To my Mum who gave me the stubborn gene that means I just wont quit, and to my Dad, who has provided technical and moral support throughout, both of you have inspired me to believe that I can achieve anything, and without you I would not have succeeded. Thanks to Daniel, Victoria and Fiona for having faith in me and only making the occasional perpetual student joke.

Thank you to 'The Girls' who have provided distractions when needed, but understood when I've been boring and stayed in to work. Here's to another 15 years of friendship!

Finally thanks to Jason for being the one to bring me cups of tea while I work, remind me that I have a life outside of academia, and give me the confidence to try new things.

You have all been there when I needed you the most.

Published Works

Sections of work reported in this thesis have previously appeared in peer-reviewed publications.

The study detailed in chapter four was presented at the 2010 international MLearn conference, Malta:

Martin, S., Stanton Fraser, D., Fraser, M., Woodgate, D., & Crellin, D. (2010). The impact of handheld mobile technologies upon children's motivation and learning. In M.Montebello, V.Camilleri, & A. Dingli (Eds.) *Proceedings of the MLearn 2010 conference* (pp 200 - 207). University of Malta.

A summary of the experiments was presented at the 2011 Computer Assisted Learning conference, UK:

Martin, S., Stanton Fraser, D., Fraser, M., Woodgate, D., & Crellin, D. (2011, April). *The future of hands-on learning technologies: Motivation and learning in context.* Paper presented at CAL 2011 Conference, Learning Futures: Education, Technology & Sustainability, Manchester, UK.

An overview of this work was presented along side a discussion of research methods 'in the wild' at the 2011 international MLearn conference, Beijing:

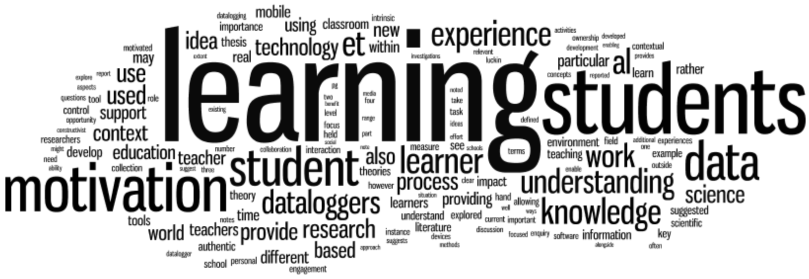
Martin, S., Stanton Fraser, D., Fraser, M., Woodgate, D., and Crellin, D. (2011). Mobile research in the wild: Practical experiences. *In Proceedings of the MLearn 2011 conference*. (pp 495-504) Beijing Normal University.

Abstract

This thesis investigates whether the use of hand-held technology affects motivation and learning in science. An innovative mixed methods approach was used to provide new insights into an emerging area of research. First, two pilot observational studies were conducted, which aimed to establish how a school currently uses hand held dataloggers, and gain further insight into how learners respond to this technology. This was followed by a primarily quantitative experiment that was concerned with the role of data ownership and the impact of 'seams' on the transformation process of the collected data. The results indicated that a hands-on experience increased confidence among students in explaining their own data, as opposed to data collected by someone else. A third study was designed to compare how student motivation and learning were affected when carrying out the same inquiry task either with or without the support of dataloggers. The results revealed no difference in accuracy or motivation for learning. The final, fourth, study was a longitudinal study designed in collaboration with a secondary science teacher, comparing three conditions: the inclusion of cameras to support student reflection, the inclusion of both cameras and the use of dataloggers to support teaching, and a control condition where the lessons were not changed. This study found that inclusion of dataloggers into modules led to increased assessment scores, while the use of cameras indicated that students are adept at taking relevant photos, and did not suffer from an extensive novelty effect. The results highlighted the importance of using a range of methods and tools for teaching students. The thesis concludes with recommendations and future research ideas, including exploring how data is visualised and the role of physical context. Of key importance is that future work is conducted in collaboration with educators in the wild.

Part I

Schools, Learning and Technology



1 Introduction

This thesis explores how hand held technology can impact upon a student's learning and their motivation to learn. The research considers how 'dataloggers' can provide students with increased contextual experience through a hands on approach, and the impact that this added contextual information may have.

Chapter one presents an overview of the literature and learning theories, this is followed by a methodology chapter. The four studies are described in chapters three, four, five and six. The thesis concludes with a discussion of the main findings, and the implications for future research.

In this next section a range of literature is examined and discussed, to provide an overview of learning theory and its application in this area of research. This literature review begins with a short summary of learning and the history of UK schools and education, followed by an overview of a range of learning theories. Motivation is then discussed, with particular reference to literature that relates to technology and learning. Details of the current UK education system and the role of technology within it are presented, alongside a discussion of mobile learning and relevant literature in this area. The concept of context is introduced and a number of key definitions are provided. Finally a description of the mobile dataloggers used during this research is presented.

The development of technology alongside a shift in ideas about how science should be taught to secondary age students[1] has led to a more holistically styled science curriculum in the United Kingdom (UK)[2]. Students are now encouraged to develop an understanding of science as part of their everyday world, whereas previously they were taught science facts by rote,

[1] 11-16 years old
[2] See Isaacs (2010) for an overview of the education system in the UK

often with little reasoning and information about how the knowledge was discovered and what impact it has on everyday life.

This change in focus has lead to students being taught more practical hands-on science, with the aim of exploring concepts for themselves. The British government's focus upon this methodology is demonstrated in the "How Science Works" agenda (2007) released as part of the National Strategies from the UK Department for Education. In the description they report:

> "How science works is more than just scientific enquiry. It provides a wonderful opportunity for pupils to develop as critical and creative thinkers and to become flexible problem-solvers...[...][3]... Effective enquiry work involves exploring questions and finding answers through the gathering and evaluation of evidence. Pupils need to understand how evidence comes from the collection and critical interpretation of both primary and secondary data and how evidence may be influenced by contexts such as culture, politics or ethics." (Department for Education (2007, Pg 1))

With reference to mobile and contextual learning this has led to increased interest and research in the use of hand held devices for discovering the world through collecting and gathering data. Much research (Resnick, Berg and Eisenberg, 2000; Rogers, 2004; Stanton, O'Malley, Fraser, Ng and Benford, 2003; Stanton Fraser, et al. 2005) has shown that this approach to learning renders data less abstract for learners, than when they are presented with pre collected data, and supports the understanding of the scientific process alongside that of the scientific concepts.

While the importance of learning has always been clear, the best methods for promoting learning have for a long time been a contentious issue. With educators working to combine and adapt academic and government recommendations to provide learners with the best skills, tools and environment for learning, people of different generations have been exposed to a variety of teaching styles and methodologies each based on alternative theories. While there has been a clear shift towards using technology, this does not mean that the learning theories of the past are defunct. Indeed a number are still highly applicable and influential to todays teachers and students as they can provide an insight into why hands-on learning can be so effective.

The idea of students preferring hands-on learning is not new. The following quote is a Chinese proverb often linked to Confucius (551 BC-479 BC), and while it is often phrased in different ways its meaning is clear: to learn

[3] Section from report removed

something successfully the learner must be given the opportunity to take part in the learning.

> "Tell me and I'll forget; show me and I may remember; involve me and I'll understand."

Learning is extending our current knowledge, building upon existing knowledge structures in collaboration with helpers. In the current English education system it is mandatory for students to be in formal education between the ages of 5 and 16, increasing to 18 by 2015. During this time learners will face a multitude of assessments from informal teacher evaluation, to rigorous government enforced examinations such as SATs and GCSEs[4], the results of which can have a profound impact on future education and job prospects. Clearly our learning and our educational experiences are fundamental to our development.

This chapter will highlight and review some of the existing literature that is pertinent to the research questions. This is split into seven sections: the first four discuss the science of teaching; experiential and authentic learning; motivation; and the relationship between schools and technology. These sections lead into the final three, which discuss research into mobile learning, theories of context and an introduction to dataloggers.

2 The Science of Teaching

Pedagogy is defined by the Oxford English Dictionary as 'science of teaching'. Scholars have long been trying to understand this, questioning not only what should be taught, but also how it should be taught. Prior to formal education, people learned by experience through observation, taking part in activities and discussions with more experienced individuals around them. As time passed this became formalised, with children encouraged to attend schools. Initially, these were run by churches, and access was limited to those from noble families, but ultimately education and school became open, and compulsory, for all. Later, the idea of intelligence and the ability to test academic ability became widely accepted amongst the general population, with people visiting science fairs and exhibitions to take part in experiments on head size, genetics and intelligence (Murdoch, 2007). In 1865 Francis Galton (1822-1911) developed the idea of testing intelligence based on the idea of hereditary genius. With a background in eugenics, Galton was interested in the idea of breeding intelligence. He wrote of the idea of creating public examinations based upon the idea of intelligence as an innate predetermined level, see Murdoch (2007)

[4]SATs and GCSEs are academic tests taken by students during their school career.

for an overview on the history of intelligence testing. Since Galton, various tests have been employed to measure our intelligence and skills. These have been adapted and redefined over the years, with teachers working increasingly hard to teach students the skills to pass assessments and to provide optimum learning conditions to best benefit their students. The methods employed by educators over the years have been shaped by both political ideology and academic advice based upon a variety of learning theories.

3 Learning Theories

Interactionalism, an early theory of learning, advocated by Johann Friedrich Herbart (1776-1841) was based on the idea that you can learn through making connections between your current and past knowledge. This was later supported by work by Pavlov (1849-1936) in his key experiments on conditioning and learning through reward and creating associations, emphasising that generating associations can lead to improved recall. According to Herbart there are five steps to the teaching process, (Bigge & Shermis, 1992, pg 39):

Preparation highlight the new topic and any issues relating to it,

Presentation use examples to explain the theory,

Association generate links to current knowledge,

Generalisation encourage students to see the larger picture and apply theories to other subjects,

Application take the new knowledge and employ it in practice.

These steps allow the student to connect the new information with other information that they already hold to be true and valid. This method of forming connections is paramount to this thesis, which is concerned with understanding the benefits of active experimentation and learning ‘in the wild’ through forming connections between the environment and the seemingly abstract learning material.

In particular this research is interested in how hands-on experiences, and the immediacy of modern hand held tools can allow students to improve the Association, Generalisation and Application aspects of the 5 steps, with the hypothesis that links to current knowledge and the larger picture are easier to make when the student is within the situation, and collecting their own relevant data. By providing the student with the tools to direct their own learning, they are enabled to take their existing knowledge and apply it to new ideas.

John Dewey (1859-1952) like Pavlov and Herbart proposed using existing interest and knowledge to stimulate the learner: Dewey believed that science is best understood through carrying out your own enquiry and personal exploration. Dewey was a keen advocate of having the student direct the learning, and held a similar view to the Russian psychologist Lev Vygotsky (1896-1934), who was working to understand the idea of learning and optimizing methods of teaching. He did this by developing the concept of the Zone of Proximal Development (ZPD). This was the idea that learners should be stretched, and encouraged to learn by being presented with tasks just above their current level of understanding. The teacher works as a facilitator to provide the tools and support for learning, to enable the learner to gain confidence in their ability. Vygotsky encouraged the use of peers to act as facilitators as well as teachers, encouraging reciprocal and collaborative learning. This idea is supported by the work of Piaget (1896-1980), well known for his research on the importance of play and interaction[5]. Piaget stressed that learners need to be involved and direct their learning to show the most benefit. In particular Piaget discussed the ideas of assimilation and accommodation. These concepts enable learners to construct knowledge from experience: assimilation allows information to be added to existing ideas whereas accommodation requires current beliefs to be adapted. It is important to note the differences between Vygotskian and Piagetian approaches, in particular Piaget was focused primarily on the individual, and the child's personal growth, whereas Vygotsky considered the child as a part of a wider social and cultural context. Vygotsky's work centres on the relationships the learner has with others, while Piaget liked to refer to children as 'little scientists' and was a key advocate for learning through personal exploration.

3.1 Constructivism

The idea that the learner is responsible for his or her own learning is key to the learning theory termed Constructivism. This is closely linked to Vygotsky's ZPD, which suggests that learners should be provided with learning tasks just above the level of their current ability, with a focus on encouraging them to motivate themselves through the learning. Von Glasersfeld (1989) discussed the idea of constructivism and stressed the importance of motivation for learning. He also notes the sense of pleasure a learner can obtain from constructing their own knowledge and directing their learning. Constructivism is based upon developing new knowledge through interaction with the world, and is based on

[5]See Smith (2009) for an introduction to Piaget and his work

two fundamental canons:

> "1) Learning is an active process of constructing rather than acquiring knowledge,
>
> 2) Instruction is a process of supporting that construction rather than communicating knowledge" (Duffy & Cunningham, 1996 cited in Heinze, 2008, p 20).

It is clear from these two canons that supporters of this theory believe that knowledge needs to be constructed rather than discovered, and that a teacher's role is to support the learner through this construction process, be it through providing the tools and resources, or through showcasing their knowledge and guiding the learner in developing their own interpretation of the world. The teacher can provide support and nudge the learner along the path, but they will not simply tell the student the answer. Applying this to hand held technology would suggest that dataloggers could support this interaction between students and teacher by enabling the teacher to ask the students to interpret their own data, and then being on hand to help form rational explanations alongside the student. Dataloggers would provide the teacher with an opportunity to support the learner without taking control of the learning process.

It is important to note that constructivist learning builds upon the students' existing understanding of the world, be that knowledge formed through formal teaching of other topics, or informal learning. A good teacher will be able to take an abstract experience from the student and relate it to the new topic, providing a series of stepping-stones to enable the learner to translate existing abstract knowledge into a fully formed theory of understanding. Indeed work by Mayer (2004) suggests that pure discovery as a teaching methodology is ineffective, and that an appropriate method is to use guided construction. For example he noted that students developed a better understanding of problem solving after reviewing a worked out example rather than producing the solution themselves. Despite this apparent conflict between constructing your own knowledge, and being given the answer, this kind of teaching still sits within constructivist thinking, and in particular alongside Vygotsky's zone of proximal development, with the worked example being a tool to move the student from their current understanding to a more complex understanding. This would be an excellent example of Bruner's scaffolding in action (see Wood, Bruner and Ross, 1976). [6]The student is able to learn how to complete the problem by

[6]Scaffolding was first described by Wood, Bruner and Ross (1976). It enables the teacher to provide the building blocks and the support for the learner to teach themselves. When the learner is successful they gain more control. If the learner has problems then the teacher can step in and

reviewing how someone else has done it: they still need to spend time to understand the logic of each problem solving stage, but by having a worked out example, they are able to understand the general process. They can then have a go themselves at solving a similar problem.

3.2 Objectivism

It can be interpreted that objectivism is the opposite of constructivism. Proponents of objectivism believe that knowledge exists outside of the person and learning is about discovering this information. They suggest that the learner is an empty vessel awaiting information from the teacher. There are six major assumptions of objectivist thinking, as defined by Vrasidas (2000, pg 2). In summary these are

1) the idea that the real world consists of entities which can be categorised based on their characteristics,

2) the real world has an existing structure which can be modelled by the learner,

3) reality can be represented by symbols,

4) symbols can be processed by the mind so that they mirror nature,

5) human thought is the manipulation of these symbols,

6) the meaning of the world is independent of the human mind.

This suggests that there are exact conclusions to be reached about the world. Therefore it is acceptable for the teacher to tell the learner these truths without the learners needing to discover the truth for themselves. With this understanding, the learner is seen as a blank slate waiting to be filled with knowledge from the teacher.

Objectivist learning theory may have its place with certain known 'truths', and the potential of saving time by providing this knowledge to students to prevent them spending excessive amounts of time developing their own understanding[7]. The research presented in this thesis explores the value of dataloggers for providing learners with opportunities to discover and form their own opinions rather than being presented with facts, and in particular allowing the student to understand how the real world is not always perfect and what happens in actuality can be more complex than the scientific models suggest,

provide support. This enables the learner to be in charge of their own learning and to learn at their own speed. Scaffolding is discussed in more detail later.

[7] For example when being taught simple, everyday maths we are told that 2+2=4, this is reported as a simple known fact, the students are not required to deduce this themselves or follow the mathematical proof. Of course some people would argue that once you start to understand more complex maths that 'facts' such as these are no longer reliable and we need to reconstruct our understanding of the world.

constructivist thinking is fundamental to this research.

3.3 Cognitive Apprenticeship

An interesting middle ground is the idea of cognitive apprenticeship. This is where the teacher provides an opportunity for the student to develop their own understanding, but it is based upon the teachers expert behaviour, encouraging the student to develop existing socially held ideas into their own constructed knowledge.

Vrasidas (2000) suggests that as a culture we have constructed underlying truths. Teachers then guide the learner to develop these basic ideas further by firstly showing and explaining the underlying assumption, and then encouraging and supporting the student to think about this based on their own knowledge and experiences. This allows the student to develop an understanding of the reasoning behind the assumption. This is different to objectivist thinking which would suggest that the student only needs to know the truth, and not the rationale or methodology for discovering that truth. In simplistic terms an objectivist teacher would tell the student that if a lit candle is placed in a sealed box the candle will go out when the oxygen falls below a certain threshold. In contrast a teacher using a cognitive apprenticeship teaching style might start the lesson by explaining that a candle needs oxygen to burn (underlying assumption) they would then provide the student with the tools and equipment to run the experiment themselves and ask the student to derive the level of oxygen at which the candle stops burning. By teaching in this manner the student is guided in the task and provided with the tools, but simultaneously provided with the chance to take control of their learning. It is possible in this more open style of teaching that the student's peers could also become facilitators, for instance if a student wonders what would happen if they put two candles into the box, they might then choose to share their learning with their peers and further develop their understanding of the candle burning theory.

It seems that dataloggers may support this window, by providing a tool which has a key aim of data collection, it restricts the manner with which students can explore and discover, but still supports them in taking control of their learning and allows for students to concentrate on what the data shows rather than the method of collection.

Vrasidas' (2000) evaluation of objectivist and constructivist theories concludes that they are on a continuum and while constructivist teaching might be optimal, there are instances where students benefit from objectivist methods, such as providing students with clear instructions to follow to ensure they can discover a result, this prevents the students from experiencing too much error during trial and error and becoming disengaged.

3.4 Experiential Learning

The idea of taking control of your learning is fundamental to experiential learning. This is based on the importance of learning through doing and education through experience, as advocated by Maslow (1908-1970). More recently Kolb has built upon this to develop the Experiential Learning Model see figure 3.1 which suggests a learning cycle of four specific stages:

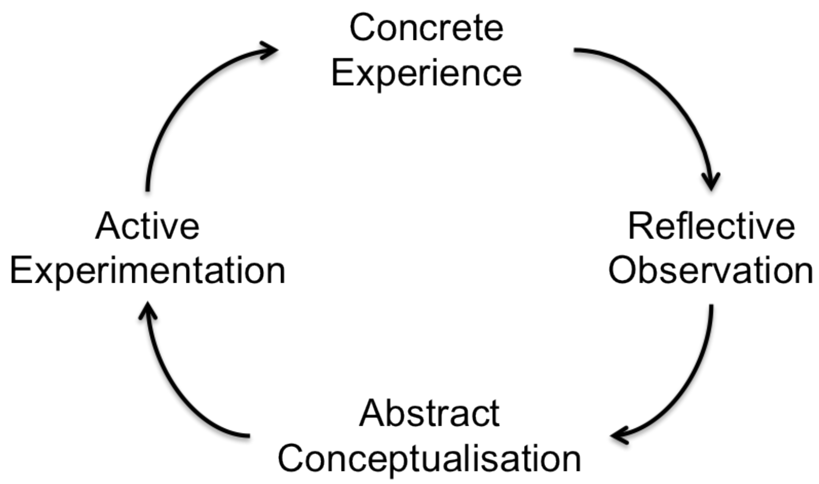


Figure 3.1: Kolb's Experiential Learning Model

These can be more easily summarised as seeing, thinking, learning and trying for yourself.

> "Learning is the process whereby knowledge is created through the transformation of experience"
>
> (Kolb, (1984) in Healey & Jenkins, 2000, p 185)

This is an active process enabling learners to structure their own understanding through experimentation and exploration. This approach to learning is often linked to problem based learning and experiential learning theories, whereby students are encouraged to direct their own learning and discover the truth for themselves. Healey & Jenkins (2000) used Kolb's model with reference to learning geography at degree level. They apply Kolb's theory by advocating field trips for gaining real life experience as well as applying the theory inside the classroom through using case studies (Seeing), discussion (Thinking), teacher led lecture (Learning) and poster generation (Trying for yourself).

Kolb's work is further supported by Dewey's idea of science being best understood through carrying out your own enquiry and personal exploration. More recent work by Zoldosova & Prokop (2006) has emphasised the importance of personal experience for natural learning. They explored how experience of field trips impacted on how students perceived their ideal school environment and the kinds of books that they would choose to read. They found that students who had experienced the field trips picked more educational books[8] and tended to include more education based tools and equipment into their designs of an ideal school. This links with work by Johnson, Franklin and Wardlow (1997) and Krajcik, et al. (1998) who both note that experience and authentic work are vital for learning as well as personal involvement enabling the students control, autonomy and experience of the experiment. Similarly Chen, Lai, Yang, Liang and Chan (2008) note how prior knowledge can be used as a framework to understand and generate new knowledge suggesting a link between scaffolding and experience to help the learner form new connections. They explored the role of PDA (Personal Digital Assistant) devices on students learning experiences. Chen et al. (2008) focused upon the idea that visualisation is important for the learning experience, and constructed software which would allow students to take photographs of plants, and annotate them in the wild, allowing immediate connections between the context and the data collected by the students. Interaction with the PDAs encouraged the students to perform further investigations, such as touch and smell the plants. They explored the impact the technology had on the learning process, and how in different instances it helped and hindered the students in their education. They concluded that the PDAs had a positive effect in terms of knowledge generation. However this was limited, due to the novelty of the devices, which led to students going off task. Chen et al. suggest that technology has potential to support experiential learning, but that it is reliant upon a supportive and focused teacher to guide the students through the process effectively, again highlighting the importance of the social environment as suggested by the work of Vygotsky.

Rosenbaum, Klopfer and Perry (2006) also explored the role of authentic experiences for learning, using technology as a tool for providing structure to real world interactions, exploring how students responded to an 'outbreak' game where the students needed to contain a disease, which was supported through augmented reality technology. They connected the idea of authentic experiences to Dewey's work on education through experience (Rosenbaum

[8] The students were presented with a list of 45 fictional book titles, of which 16 were designed to be directly related to the students field trip, the titles were reviewed by teachers to ensure validity.

et al., 2006, pg 32). It is apparent that a number of tools can be used to help students gain authentic experiences and develop an understanding of the real world. However, as suggested by the theories of Scaffolding and the ZPD it is also important that there is a teacher or peer present who can help the learner utilise the tool effectively, providing guidance and direction to the student as they construct their own interpretation of the world.

3.5 Distributed Cognition

The idea that knowledge is created through making connections between real world concepts and personal experiences is borne out in a framework of knowledge, which is also present in the theory of distributed cognition. This focuses on how multiple parts can work together on a central process or idea. See Rogers & Ellis (1994); Hollan, Hutchins and Kirsh (2000); Angeli (2007) or Saloman (1993) for introductions to distributed cognition. This can be linked to the idea of past knowledge informing new knowledge, as well as to that of students collaborating together to form a coherent understanding of their work. Work by Saloman highlights how the use of mobile technology can support distributed cognition, enabling knowledge to be shared and socially constructed. Saloman suggested that the information is processed between the individuals, while the tools for learning and the artefacts of learning are provided by culture. This implies that learning occurs as a collaborative process, and we define that learning through the identification of artefacts that are culturally bound. As a consequence, our interpretation of learning is limited to our own cultural experience and background. If this is accepted, this thesis, while broadly transferable, is limited to its applicability to comment beyond the learning culture within which it resides.

3.6 The role of teachers and peers

According to Cole & Engestrom (1993) the noted psychologist Hugo Münsterberg (1863 –1916) suggested that cognition occurs not only in the head, but also externally, during communication among individuals. Therefore our understanding and knowledge development can be shaped by conversation with our peers and thus the experiences which they have had, as well as our own. The relationship between teachers and students is also impacted by this idea, as it suggests that the teacher cannot teach the student a basic fact without it being positioned within the teachers own knowledge and experience: indeed the teacher will provide the student with the examples, and different examples may lead to different understandings for the student.

Historically the teacher has been in control of the learning experience by directing the student to learning resources and following a prescribed curriculum. While teachers are still obliged to teach to the national curriculum, there is now greater scope for teachers to allow students to lead the learning conversation and to respond to their interests. Education is currently focused upon the teacher teaching concepts and methods rather than facts, and the ability of a teacher to take a student's interest, and translate it into an educational lesson can be what sets a good teacher apart from a bad one.

Again this idea is not new; consider Vygotsky's ZPD which encouraged the learner to progress to the next level supported by other students and teachers, as well as learning artefacts such as books and technological devices (Brown, et al.1993). Gall & Breeze (2008) note in their literature review the importance of thought sharing for students. They explored musical interaction: however, the importance of collaboration and discussion is considered as fundamental for all students learning. They noted the ability to learn using hand held devices could potentially facilitate these kind of discussions, as the students need to work physically near each other to view the results on the screen, requires them to communicate and discuss their findings. Furthermore, Luckin (2010) notes that interactions between collaborators can have have an exponential effect upon learning rather than a summative one, due to the discussions acting as a catalyst for the learning process, improving the understanding for the group and consequently for the individuals.

3.7 Learner Centric Ecology of Resources

Earlier work by Luckin (2006; 2008) introduces the idea of the learner centric ecology of resources (LCER), building upon the ZPD model developed by Vygotsky. The LCER framework incorporates the fundamental ideas of the ZPD and transforms them to be relevant to modern teaching practices that involve the use of technology. Prior to developing the LCER, Luckin (2006) first introduced the idea of the ZAA, Zone of Available Assistance, and the ZPA, Zone of Proximal Adjustment; these are defined more fully in her doctoral thesis (Luckin, 1998). The ZAA focuses on the quantities and qualities of assistance that need to be available to the teacher to aid the learner, while the ZPA is defined as the area within the ZAA which is currently appropriate for a particular learner. Figure 3.2 on the following page shows Luckin's (2006) visualisation of the interaction between ZPD, ZAA and ZPA.

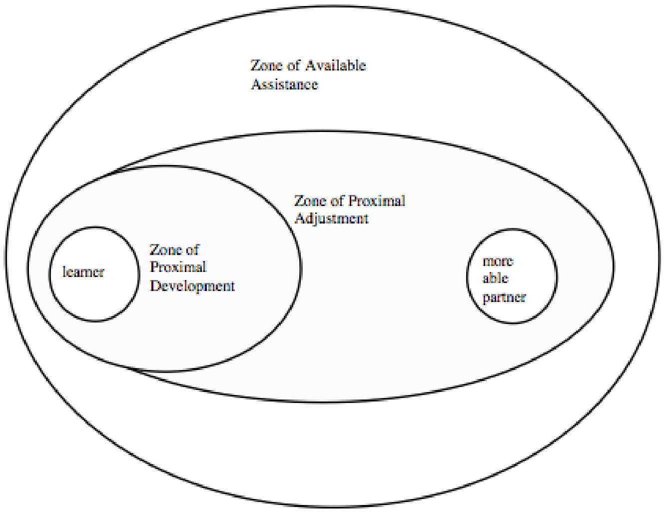


Figure 3.2: The Zones of Available Assistance (ZAA) and Proximal Adjustment (ZPA). Luckin (2006)

It may be possible to simplify this diagram further, to two overlapping circles. One circle represents the student and their zone of proximal development, that is a learning level, which they could reach with appropriate support. The second circle would represent a more able partner (MAP), which could be a teacher, peer, or tool. This circle would represent the zone of available assistance and illustrates the information that the MAP has at its disposal to support the learner. However dependent upon the learner's ZPD only some aspects of the ZAA would be relevant and useful for supporting the learner. This overlap between the two circles represents the ZPA, the information or resources that the MAP has, and the student can benefit from. By representing the model in this manner it is possible to see how a learner could benefit from multiple MAP sources, highlighting the social nature of learning, rather than it being a process limited to two people. It is also possible that different MAPs may have the capacity to provide a different level of support, this could be indicated by the extent that the two circles overlap. Figure 3.3 shows how this might be represented. It is not substantially different from Luckin's original, except that it includes the potential for showing multiple MAPs and also shows that the MAP will have other knowledge which is not currently relevant to the learner. It is still possible for the learner to be surrounded by the ZAA as in Luckin's diagram, but this suggested diagram would distinguish the different ZAAs, and in particular through identification of tools vs teachers, you might start to highlight where both are required. For example figure 3.4 shows how this could be used in relation to using dataloggers for supporting learning. In particular it can highlight how the teacher has knowledge about the subject that supports the student, but also has knowledge about dataloggers which allows the student to utilise the datalogger as a second resource for constructing their own knowledge.

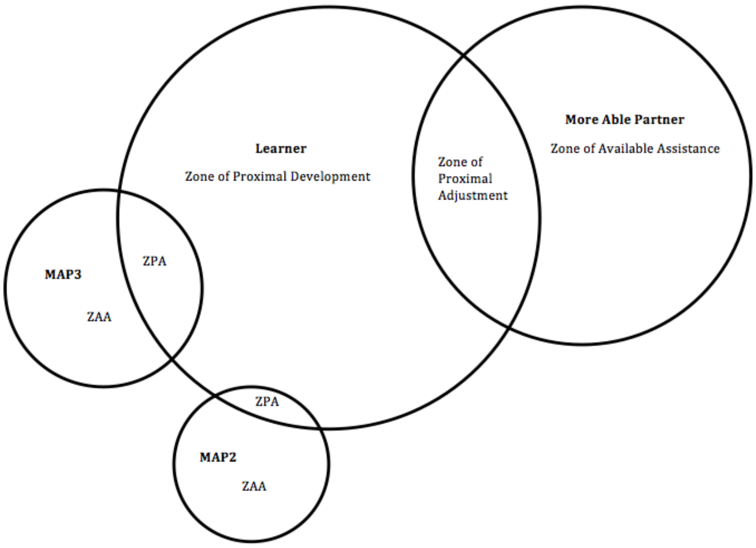


Figure 3.3: Alternative diagram of the ZAA, ZPA and ZPD relationship

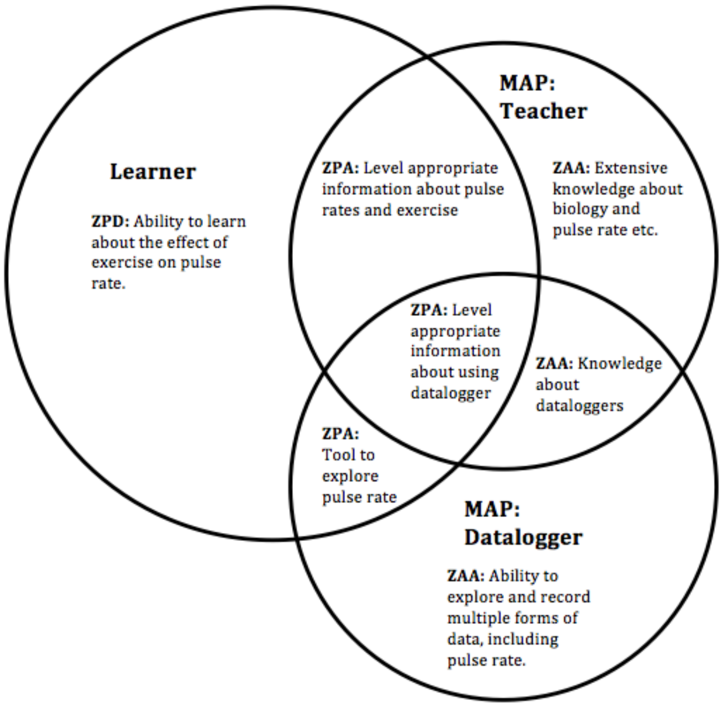


Figure 3.4: ZPA Diagram with multiple MAPs

The provision of resources, as well as knowledge, is often used in a technique used in teaching called scaffolding. According to Luckin (2008), while many forms of educational technology equipment have been designed with scaffolding in mind, the ubiquity of current technology and its development means that a new learning model is required to ensure that we consider how educational technology can open the classroom to a wider range of resources for supporting learning. Noting that previous literature has highlighted context as reflecting relationships and interactions over time, Luckin (2008) discusses the need for teachers to get context right, by engaging with the students past experiences and social interactions. An important question is how can we provide the right kind of technology to support the learner through scaffolding, when in such a connected world we cannot be sure where or what the next learning experience and resource will be?

3.8 Enquiry Learning

It is clear that knowledge is not static: it is situated in activity. What we know, learn and understand, are inherently connected to how we gained our information, and the situation within which it was created. Learning through enquiry is an important teaching method as it enables the students to discover concepts for themselves, taking ownership of their explanations and generate an authentic experience of the phenomena. Choo (2005) discusses the four essential traits of enquiry for learning: connecting, designing, investigating and constructing meaning [9]. These four traits enable the learner to develop a deep understanding of the subject, and hands-on experience can provide the learner with a real life understanding of the domain. Active learning is defined as learning where the student actively takes part in their learning using higher level functions than just passively listening (Sinha, Khreisat and Sharma, 2008) . Sinha et al. looked at the idea of 'active learning' noting that there are four types of interaction related to active learning: learner-content, learner-peer, learner-teacher and learner-interface[10]. They explored how interaction with a tablet computer could support the learning process. Their results indicated that having an interaction with the tablet (learner-interface) promoted active learning by encouraging further interaction with the tutor (learner-teacher), although they noted interactions between students did not reveal the same level of improvement (learner-peer). This study highlights that interaction with tools and with teachers are not standalone occurrences, instead all the interactions can have an impact upon each other, as indicated in the adapted LCER diagram 3.3.

[9] based on work by Hinrichsen & Jarrett (1999)

[10] the first three were identified by Moore (1989) while the fourth was discussed by Hillman, Willis, and Gunawardena (1994), both cited in Sinha et al. (2008)

3.9 Authentic Learning

Hartnell-Young (2007) draws attention to differences in approach to defining authentic learning, highlighting Wilson's (1993) view of authentic activities as those occurring in the real world and not in the artificial environment of the school, whereas Honebein, Duffy and Fishman (1992) consider a sense of ownership as key to making the learning experience authentic. Hartnell-Young concludes that there are a variety of learning theories, which can be applied dependent on situation and circumstance.

Vygotsky's interpretation of learning as a social activity, heavily influenced by our life experiences, clearly lends itself to this area of research, which is concerned with exploring how a student's past and contextual experiences of a situation can improve and extend their learning potential. In particular the current thesis explores the extent to which a personal experience of a datalogging experiment supports the students in developing their scientific understanding and motivates them to learn. It has been shown that the use of technology such as dataloggers can support this by reducing the task load on the students through recording the data, freeing them to ask more questions, and to interact more with the teacher and peers (Barton, 1998; Fearn, 2006). Furthermore, socially mediated learning requires the learner to be motivated to learn (Jarvela, Volet and Jarvenoja., 2010) and to share their understanding. Dataloggers may support this by providing an engaging scientific tool, which can stimulate and promote discussion (Silburn, 2008).

It would seem therefore that a tool such as a datalogger, which reduces the need for performing arguably the more mundane tasks such as recording data and drawing graphs, will provide a motivating experience for the learner, and ultimately support the learner two fold. Firstly by providing control, and secondly by providing a motivating and potentially enjoyable method. If constructivist theory holds true then students should benefit from having tools that simultaneously provide opportunity for learning through reducing the amount of mundane work, but also enable the student to become directly involved in the learning process, providing the student with an opportunity to take control of their learning.

The research presented in this thesis explores this concept of ownership both in the real world, conducting experiments within the classroom and , while conducting experiments outside of the typical classroom: exploring the impact of learning "in the wild".

Building on work by Gipps (2002), who notes that using dataloggers in an enquiry based approach is an appropriate and effective way to acquire scientific content in a natural environment, the experiments were designed to fit in with the current educational methods as reported in Bencze & Bowen (2007) who discuss how the national curriculum encourages science teachers to develop a comprehensive literacy during their lessons. By this, they mean a well rounded teaching approach focusing upon three key domains within science teaching:

Teaching Science - the laws, theories and products of 'science'

About Science – the characteristics of experimentation and methodology

Do Science – confidence and expertise in doing science and applying it to new situations.

They comment on the importance of allowing students to produce knowledge for themselves, thus enabling them to experience science first hand rather than learning simply from rote and accounts of others' experimentation. The development of dataloggers allows this to occur more easily than before, enabling students to understand the connection between their environment, the measurement, and the number associated with that measurement Silburn (2008). Consequently they may be able to generate more meaning from their data than if they were just presented with the numerical information alone. By providing students with the opportunity to gather their own data, they are provided with an opportunity to develop their inductive reasoning skills, and to actively generate their own 'science' rather than just learning science.

The ideas of authentic learning and situated learning have been a key foci for a number of researchers in the education field, Herrington, Mantei, Herrington, Olney and Ferry (2008) defined situated learning as:

> "activities that promote learning within an authentic context and culture" (Herrington et al., 2008, pg 420)

Lombardi & Oblinger (2007) define authentic learning as learning that focusses on real world situations, often using role play, problem based activities and case studies. Lombardi & Oblinger note that students often prefer to learn by doing rather than by listening, and that many teachers believe that students learn better using this method. However, they note that teachers have only recently been able to apply this teaching method to a range of subjects effectively due to the emergence of authentic learning supportive technology.

A wide range of research has been conducted on the impact of school trips and the benefits of real world experience. For instance, Orion & Hofstein (1991) detail the factors that can influence learning during a scientific field trip. In particular they note the importance of reducing the novelty factor of the field trip location prior to the event, while Knapp & Barrie (2001) highlight the benefits of a field trip on science learning. Their investigation showed that, regardless of whether a student attended an issue based field trip or a subject specific field trip[11], all students improved in their post test scores when tested on both issue based and subject specific questions. This suggests that the field trip improved the students' performance on the two vertices regardless of the original aim of the trip. While field trips are clearly of benefit to students, Kravcik, Kaibel, Specht and Terrenghi (2004) noted the difficulties teachers face in generating meaningful field trips. This can be helped by the use of technology to support the teacher and the student. For instance, datalogging enables teachers to easily save and store datalogging records from previous field trips for comparison. Of key importance to Kravcik et al. (2004) is that learning is a social activity, and the tool they developed to aid their Remote Accessible Field Trips (RAFT) enabled students inside and outside of the classroom to communicate and collaborate, providing those in the classroom the chance to gain experience of the field trip without physically being there. For Kravcik et al. (2004) the key to learning is social interaction, their research argues that personal experience is also vital as it may lead to a sense of ownership and control, which according to the literature (Lepper, 1988; Anastopoulou et al., 2012; O'Neill, 2010), can improve student motivation.

Evans & Gibbons (2007) investigated the effect of using an interactive simulation, to teach undergraduate Business & Management students about a bicycle pump, compared to a non-interactive software program. They measured their post test scores as well as their timings, to conclude that students who used the interactive simulation had an increased depth of learning. Time scores showed that students used the interactive software for longer. It is possible that they found it more engaging, and consequently had more motivation and willingness to learn. This study highlights the importance of motivation to encourage effective learning. Spicer & Stratford (2001) also explored virtual field trips (VFT) in comparison to real field trips (RFT). Their investigation found that, while the VFT were engaging and exciting, the students would not want it as a substitute for RFT. The authors suggested that VFT should be used in conjunction with RFT, rather than as a replacement, suggesting that the actual experience of an RFT is personal and cannot be replicated by a VFT.

Johnson et al. (1997) conducted research into the differences between hands-on activity and worksheets for learning. He used a counter balanced replication to obtain results on immediate and delayed cognitive achievement,

[11] On an issue based trip students learnt about global problems such as the impact of humans upon dunes, during a subject specific trip the students learnt about the specific habitat in the area.

as well as establishing students' attitudes towards the subject. He used two physics topics as his course material. The classes were randomly split into two groups, and were then taught one topic either using a worksheet or with a hands-on approach. The method and topic was then switched so all students experienced both conditions and learned both topics, albeit in different ways. The regular teacher led all other aspects of the lesson. The results of the post test indicated that there was no significant difference between learning approaches. However, analysis of the student responses to the attitude questions was significantly different with students having a more positive attitude to the topic studied using hands-on activities. Johnson et al. considered this important due to positive attitudes towards learning being a fundamental aspect of the education process. This links back to the idea that in order for a student to construct their own knowledge they need to be inspired to do so. The work of Johnson et al. suggests that if there is no difference in the learning, but there is an attitudinal difference it makes sense to use the method that the students find inspiring. In other words, the learning is more likely to occur if the student is motivated.

Rosenbaum, Klopfer and Perry (2006) questioned the definition of "authentic learning" and how technology can mediate the learning, with a particular focus upon the potential benefits of simulations within the classroom. They used hand held computers to explore real life experiences as an opportunity for students to learn. In this project they created a realistic role playing game, which they termed as authentic, whereby the learner had to take on the role of medical staff and deal with a fictional disease outbreak. Their work showed that the students found the role play game to be highly authentic, and in their discussion they postulate that this could be used for learning by incorporating experts into the virtual reality, providing more learning opportunities for the students. The opportunity for authentic learning is a key aspect within science curricula as it enables the learner to develop their own understanding of how science was developed, and how the evidence links together to form a theory.

The idea of taking part in the learning, as authentic or situated, is key to the idea of students "learning in the wild". The term "in the wild" can refer to the students learning outside of the classroom and in an authentic, real world environment, allowing the students to understand real world, real time inquiry. By providing students with the opportunity to have direct hands-on experience, they are able to not only gain experimental experience but also improve their knowledge of the experimentation process as an event that will not always provide the ideal outcomes. Researchers also use the term "in the wild" to refer to studies which are embedded within the real world context, rather than a lab based environment. While "in the wild" studies are arguably harder to control and conduct they allow the researcher to collect information and insights into a real world situation: consequently the findings are directly applicable to the situation.

It is clear from this review of the literature that many of the current theories around learning with technology: hand held learning, authentic learning, activity learning, and enquiry learning to name a few, are extensions of the broader learning theory of constructivism. In particular in the manner that each has the learner directing and leading the learning, while the teacher and tools provide support for the learner to construct their understanding. Each of these theories have looked to exploit opportunities for the learner to take control of their learning and provide them with the tools and guidance to form their own understanding of the world. This thesis aims to add to this literature, using the ideas of constructivism to develop investigations, which allow exploration of how students can be supported by dataloggers as a tool for collecting data and for supporting science investigations outside of the classroom, enabling them to have a more authentic, and enquiry based experience of science. This thesis explores how dataloggers can impact student learning and motivation through: providing a contextual experience; automating the collection and presentation process; and giving students an opportunity to collect their own personal data.

4 Collaborative Learning

It is clear from the review of constructivist and allied approaches that peers and teachers can influence students, they do not learn in isolation. The computer supported collaborative learning (CSCL) literature focusses upon how technology can be used alongside collaborative learning to support the student. While collaboration is not the focus of this thesis, this next section details research that has explored the role of collaboration on learning, and learning with technology.

There is a wide range of literature, which focuses on enquiry learning and the role of collaboration within the learning process (Pea, 2002;O'Malley et al., 2003;Dillenbourg, 1999). In particular Fails (2007) notes the importance of collaboration for the social and cognitive development of the child, and that the use of mobile devices to support constructivist and enquiry learning can provide enhanced learning opportunities for the child. Work by Scanlon et al. (2011) explored group interactions during a datalogging task, with a particular focus on the transition between individual activities and group work. This was reported as initial work with anticipation that their project would extend the analysis and explore whether 'ground rules' are formed between groups for data collection. Similarly Adams et al. (2011) explored how co-located and distributed groups connected via live interactions could have an impact upon the reflection process. In particular Adams et al. explored how the use of the Internet could provide students with experience of the events without being physically located in the environment. The results indicated differences in approach towards the data with students in the field focusing on obtaining accurate and valid data, while students inside the classroom were occupied with analysing the data and having reflective discussions. This suggests that experience may support different skills.

Work by Jarvela, Volet and Jarvenoja (2010) explores the link between motivation and collaboration for learning, in particular highlighting that collaboration can have a profound impact upon motivation dependent upon how successful the collaboration is. For groups that struggle to interact, collaborative working can reduce their motivation. In contrast, in instances where the collaboration is positive, the process can be highly motivating and encourage knowledge sharing amongst learners. Tao & Gunstone (1999) explored the benefits of collaborative work on computers for fostering conceptual change. Their qualitative observations suggested that students benefited from collaborating in pairs, which leads to a shared construction of knowledge. However they also noted that later, some students reverted to their original understanding. They concluded that collaborative work was beneficial for the formation of a shared knowledge, but that both students needed to invest further in this knowledge and to be aware of their own understanding.

Research by Laurillard (2008) notes that while collaborative technologies can support learners in the exchange and development of knowledge, there is the risk in collaborative learning that people in positions of power will limit an individual's involvement in a learning process. Bunderson & Reagans (2011) reported that perceived hierarchy could hinder the knowledge sharing process, risk taking and development of shared goals. In schools it is typical to encourage group work for the sharing of ideas, but requiring the students to each produce their own work, thus allowing them to produce a piece of work which reflects their own understanding rather than the group understanding.

These studies highlight the importance of collaboration and social negotiation for learning, and suggest that the roles students are given within a group may also affect their level of involvement in the work. While the research reported in this thesis is similar in that it explores group data collection and collaboration, the focus of the analysis is not upon the group interaction and collaboration per se, but on the experiences of the individual within the group. The investigations are designed to mimic the school experience, allowing for collaboration during the activity but with the students being individually assessed, an approach commonly found in the classroom.

The previous section has focused upon students and learning, in this next section the focus is placed upon the role of motivation.

5 Motivation

Palmer (2005, pg 1875) states that “motivation is a prerequisite and a co-requisite for learning” yet there is a clear dissonance between theories of learning and our understanding of the role that motivation plays in supporting the learning process. While a number of researchers (Anastopoulou et al., 2012; Johnson et al., 1997; Lombardi & Oblinger, 2007) have suggested the importance of connecting learning to the student using personal examples and motivating them by linking the subject to their interests, this is not always explicitly included in the learning theory. For example in constructivism it is suggested that the learner will build upon existing knowledge with new knowledge to form an understanding of the world: however as Palmer (2005) notes, the learner will need to apply effort to make this change, so would need to be motivated to go through this process. Although constructivist theory tends to imply that motivation is necessary, research appears to focus on learners’ conceptions and misunderstanding, rather than the requirement for motivation (Palmer, 2005). Similarly in Piaget’s theory of development the child is referred to as a little scientist and the assumption is that the child will explore the world and develop an understanding through either assimilating or accommodating the new information. In both of these the child would need to be motivated to consider the new information and contemplate its relationship to existing understanding. Again, there is the assumption of the learner being engaged and propelling themselves through the learning process, but less emphasis is placed on how the learner becomes motivated or interested to explore their world in the first place.

There are a large number of theories that can be applied to learning. Many build upon the Piagetian view of cognitive construction, that is, the personal construction of knowledge, or the Vygotskian interpretation that focuses on social construction. Different theories also vary in the emphases they place on ‘creating knowledge’ or ‘discovering knowledge’. A discussion of how constructivism has multiple faces is presented in a paper by Phillips (1995) who describes three axes that constructivists may differ on, Phillips defines the key axis as whether knowledge is created or imposed by nature. He uses the work of John Locke to provide an extreme example of knowledge being imposed, "if the knower has not had experience of a particular colour, he or she – no matter how clever-cannot invent the simple idea of that colour" (Phillips, 1995, pg 7). It appears that this view is closer to an objectivist's view point, rather than a constructivist one (see Vrasidas, 2000 for an overview). However, Phillips goes on to suggest that the mind can take these pieces of knowledge and, crucially, construct new understandings. Phillips acknowledges that Locke's work is at the edge of constructivist theory, but he notes that, if you look at the other end of the scale, with humans as creators of the knowledge, then there is also significant confusion, with some constructivists, such as Piaget, focusing on the individual construction, whereas others (e.g. Vygotsky) focus on the social construction of knowledge. Despite these differences, both theories place emphasis upon the teacher as providing support, either through providing experiences to facilitate learning (Piagetian) or through providing guidance and opportunities to develop understanding through interaction with peers and teachers (Vygotskian). It is also clear that learning is understood to be an active process with the learner needing to put effort in to respond to the teacher and the stimuli, whether this is to discover or to create knowledge. Thus it can be concluded that in order to learn, the learner must apply some kind of effort, and to apply effort the learner must be motivated to do so (Palmer, 2005).

The work discussed in this thesis draws on constructivist theory and the Zone of Proximal Development, in particular exploring how technology can act as a tool for supporting the learner's self-directed learning and understanding of new concepts. In particular the learner needs to be motivated to learn, to benefit from the tools and support available in their zone of proximal development. If the learner is not interested then they will be unlikely to utilise the support offered, and unlikely to develop their understanding to a higher level.

In order to explore the relevance of motivation to learning, a definition of motivation is needed. Throughout the literature the term motivation is appropriated to refer to a range of characteristics, for instance interest, engagement and attitude. Krapp (1999) notes that interest was once a key area of research into learning and development but there has been a decline in research in this area. According to Palmer (2005, pg 1875) "the term motivation can [..] apply to any process that activates and maintains learning behaviour". Motivation can be influenced by external factors such as rewards, or through internal factors such as the individuals self beliefs. Some researchers such as Johnson et al. (1997) have looked at student attitudes and values as measures of motivation, while Huizenga, Admiraal, Akkerman and Dam (2009) used measures of interaction (based on observation of the students) as indicators of engagement, but measured motivation through the use of a self report questionnaire. Clearly researchers are interested in a number of factors that have been used to indicate motivation and engagement in the learning process.

In the motivation literature there is often a division between intrinsic and extrinsic motivation. Intrinsic motivation refers to the idea that people will be engaged in an activity for no other reward than the interest and enjoyment it generates, while extrinsic motivation has an obvious external reward for taking part in the work.

It was suggested by White (1959) that learners will feel an instinctive pleasure when they learn something new, and this positive experience will be self reinforcing and encourage the learner to search out new learning opportunities. Research into intrinsic and extrinsic motivation has suggested that it is intrinsic motivation that can have a positive impact upon a learner's learning and conceptual understanding in science, and that extrinsic motivation can in fact have a detrimental effect. Work by Deci, Koestner and Ryan (2001) has indicated that, unless the activity is dull (and therefore unlikely to instigate intrinsic motivation in the student), if an extrinsic reward is offered it will have a hindering impact on the students intrinsic motivation, in particular if the reward is offered for success rather than just engagement. However, other researchers such as Cameron, Banko and Pierce (2001) have suggested the reverse is true. The present research is focused on intrinsic motivation as this research is concerned with the students conceptual understanding, furthermore this is the principal form of motivation explored in similar experiment methodologies (See for example: Tuan, Chin and Shieh, 2005 and Huizenga et al. 2009).

It has been suggested by Pintrich (2003) that there are four outcomes of motivation that the literature uses to understand and define motivation theory. These four outcomes are:

1) why the student took part,
2) the level of involvement provided,
3) the persistence by the student, and
4) the achievement or performance of the student.

Each of these outcomes has been used to quantify and suggest motivation. It is particularly interesting that academic achievement has been used to imply motivation. This is potentially a risky methodology, as sometimes researchers use motivation as evidence of learning, and therefore we should not rely on assessment results to suppose motivation. Indeed it is possible that a highly motivated child could still perform badly, while a demotivated student may still be able to achieve a high score and thus appear engaged and motivated based upon their assessment. Furthermore as reported previously in this thesis, assessments of learning often measure different aspects of student understanding, for instance a key difference is whether knowledge was acquired through surface learning (e.g. memorisation of facts) or through a deeper learning process whereby the student has fully comprehended the information and can apply it to new topics.

Pintrich (2003) suggested that while there are four outcomes of motivation, there are three components within motivation:

1) belief in ability to perform the task,

2) belief about its value, and

3) the affective reaction to the task.

It would therefore be more valuable to understand the relationship between the student and the components as a measure of motivation rather than the student and the outcomes. Ergo, to understand the extent to which a student is motivated you need to know firstly whether they believe they can achieve the task. This can be influenced by the amount of control they feel they have over the situation, or ownership, and their self efficacy. Secondly, you need to know the extent to which the student places value on the task, and the extent to which they want to succeed. If the student wants to gain 85% they may use more effort than if they only want to pass at 40%. Of course that is not to say a student who gets 85%, in all cases, has expended more effort than another who achieves 40%! Furthermore, if the assessment is more important to the student, for example the end of year examination in comparison to a weekly pop quiz, they are likely to place a higher value upon it, and therefore show a greater desire to achieve. Finally the student's affective or emotional response to the task, and their performance can indicate motivation. For instance the fear of failure may lead to motivation, as might the desire to outperform a peer. Similarly, research has shown that a student's mood may impact upon their attainment (Villavicencio & Bernardo, 2012)

In AIED[12], researchers are interested in methods to measure a learner's motivation during an interaction with a technology, to enable the tool to be made to respond in an appropriate manner. For instance Rebolledo-Mendez et al. (2006) developed a tool known as the m-Ecolab. This software was designed to provide a motivational framework for the user, adapting to challenges and providing personalised feedback in response to a user's motivation level. They found that this tool was particularly useful for students who began a task in a demotivated state.

The key difference between much of the literature in this area, and the focus

[12] Artificial Intelligence in Education

for investigation in this thesis is that often in the AIED literature, the aim is to develop systems which respond to the learner's motivation, and use this as a way to respond to the learner and provide an experience which supports the learner. In contrast, the aim here is to discover how technology might influence levels of motivation, and how this can be reviewed alongside measures of attainment to provide a broader understanding of the student's learning. Thus in terms of this research, the term 'motivation' refers to the idea of intrinsic motivation, and is focused purely on measuring the students' perceived enjoyment of the task, and understanding of their motivation, rather than providing a framework for monitoring learner motivation and generating appropriate feedback. The key difference is that in this research, it is acceptable to use a student's self report as it as much about their motivation, as their perceived motivation.

Motivation has also been a key area of research in gaming, and in particular in developing interactive tools which can adapt in response to the user's motivation (see the work by du Boulay et al., 2010 around creating an intelligent tutoring system). Habgood & Ainsworth (2011) pointed to the greater importance of intrinsic, as opposed to extrinsic motivation when designing gaming tools for learning. They looked to understand firstly whether there were differences in the learning gains when comparing intrinsic, extrinsic and control variants of a zombie maths game. They then compared time on task when students were given the opportunity to choose either the intrinsic or extrinsic variants. Their findings indicated a better academic performance when the task involves intrinsic motivation, and that students spent seven times longer playing in a free-time situation. This was not to say that extrinsic rewards hindered the learning, as all students showed improvement', rather that the results suggested a larger change in attainment following the intrinsic intervention.

It has been suggested that intrinsic motivation can be self-reinforcing: if the student enjoys the activity then they will be more inclined to do it again and engage in future learning experiences. The use of dataloggers can allow students to enjoy collecting mundane data and provide an opportunity for the students to push their own learning forward (Choo, 2005).

For constructivist theoreticians, learning is an active process: it follows therefore, that in order to provide the necessary effort, the student must be motivated. Furthermore, the research suggests that this motivation is increased if it is intrinsic. Ergo, a tool that motivates the student to take part in a lesson will be providing the 'activation energy' for the student to engage with and learn about the scientific topic.

Palmer (2005, pg 1874) notes that a teacher needs to provide a lesson, which is motivationally, and academically stimulating to ensure that the students can become involved in the lesson, and learn important scientific concepts. Palmer indicates that a number of existing learning models lack this clear definition and proposes a model based on three components:

- Selection of concepts that represent appropriate challenge
  - Students should not be pushed to extend their capabilities too soon and forced to constantly accommodate new information, it is better to provide small stepping stones to a new concept. Students need to be given time to practice the concepts they have learned, so allowing a transition to concrete understanding.
- The use of ‘dual purpose teaching technique’
  - Topics and techniques should both teach and motivate, for example the use of class discussions, and computer simulations. Motivation can also be created by variety, and ensuring that students experience a range of techniques and activities.
- A classroom climate that promotes positive motivational beliefs.
  - Motivation cannot be solely achieved by teaching techniques; the classrooms also need to provide the student with a chance to have control by choosing lab partners and tasks. Teachers need to provide praise and reinforce the connections between the subject area and real life.

Palmer’s first theme fits within Piagetian learning theory which is concerned with the ideas of assimilation and accommodation: Assimilation is the idea that the child or learner will reshape an understanding of the outside world so it fits with their internal understanding. In accommodation, the reverse is true, and the child is required to adapt and stretch their own internal theory to incorporate the new understanding. The second theme provides support for the use of dataloggers to provide a tool for learning, but also a method for engaging and motivating the learner. The use of dataloggers also sits alongside the third theme, giving students control over their learning, and highlighting connections between abstract data and the real world context.

Yen, Tuan and Liao (2010) note that, in the past, studies into students’ conceptual understanding have focused on the ideas of assimilation and accommodation. Yen et al. were interested in exploring how a student’s motivational factors correlated with their conceptual learning, and if this varied according to web based versus classroom teaching. They found that motivation was correlated with the student's attainment, and in particular they found web based instruction to be better than classroom teaching in terms of their learning outcome. This may be due to the affordances which web based instruction offers, such as the ability to manipulate experiments, which would not be possible in real life. Web based instruction also allows students to repeat investigations at their own pace, something which again, may not be practical in a real world classroom.

These factors link to work by Lepper (1988) who proposed four ways of building intrinsic motivation in the classroom: via challenge, curiosity, contextualisation and control. Data logging can relate to all four of these areas. Firstly, data logging presents challenge by providing a new tool to master and relies on the student using experimental skills. Secondly, they allow students to capture data, which might be difficult to obtain otherwise and promote curiosity by showing connections between abstract data and the real world. Thirdly, the loggers provide context, and finally, they give control back to the learner by allowing them to direct their own learning and make decisions around sampling and methodology. This would suggest that dataloggers might help support the learning process through generating intrinsic motivation, and encouraging the students to become involved in the learning process. This thesis explores how the use of dataloggers affects the students' self reported motivation in specific terms such as their task enjoyment, but also in more general terms such as their thoughts about the benefits of technology.

Work by Bandura (2006) into self-efficacy suggests that a person's belief about their own ability can impact upon the amount of effort and persistence that they apply to a task. In terms of motivation and learning this would suggest that, if a student is feeling demotivated, and then they may reduce the amount of effort, thus having a negative effect upon their ability to learn. Mistler-Jackson & Butler Songer (2000) reviewed the literature and found self-efficacy to be one of five main attitude categories relating to motivation. The other four are control, interest, value and goal orientation. Mistler-Jackson & Butler Songer focused on the idea of self-efficacy when exploring Internet technology and student motivation. They generated an 8-week science network program, designed to explore the impact of technology on students with different motivational levels. The students took part in an inquiry based weather project using a range of techniques including hands on investigations, data collection, discussions with other students and experts, and the sharing of personal stories. The authors developed their own motivation questionnaire and used this to categorise the students as having high, medium, or low motivation. They found that their inquiry led program resulted in increased motivation in terms of self efficacy and empowerment, with students in the low and medium motivation categories reporting, at post test, a greater desire to spend time on the projects. This work can be extrapolated to inquiry based learning of the kind which can occur with dataloggers, suggesting that students who are provided with the opportunity to take part in their own hands on investigation will feel more empowered and engaged in the investigation, and consequently more motivated to spend time and effort on it.

Weiner (1990) notes that motivation and learning are intrinsically linked, and researchers will find it hard to separate the two. Work by Jarvela et al. (2010) notes that motivation can be socially mediated and influenced: for instance, working with motivated others will encourage one's own motivation. It is also suggested that motivation can have a mediating effect on engagement. For instance, Lee & Reeve (2012) considered the differences between motivation and engagement, concluding that these two are also closely related, and it can be hard to know which aspect is being measured. They consider motivation to be an internal process whereas engagement can be seen as the external representation, e.g. amount of attention the student is paying in class. They showed motivation and engagement to be correlated both in terms of student reports and in teacher reports. However, teachers find it easier to pick up on engagement. Taking their point that the two are intrinsically related, the questionnaires used in this research were designed to incorporate aspects of both motivation and engagement. It is clear from the literature that motivation is an important factor in supporting students' learning, in particular around inspiring and supporting their engagement in the learning process. While considering measures of motivation, it is important to recognise that "motivation is a private, subjective and difficult-to-directly-observe experience" (Lee & Reeve, 2012, pg 1). This leads to a number of important questions. How can we support motivation? What tools can we use to help stimulate the learner to engage in learning behaviour? And how can we stimulate interest and positive attitudes towards science learning?

The next section considers methods that have been used by researchers to try and measure students' motivation levels, and discusses the issues inherent in trying to quantify a human characteristic, which is clearly multifaceted.

Aldridge, Fraser and Velayutham (2010) discuss work by Bandura (2006) who notes that you cannot have an all purpose measure of motivation. It is therefore justified to develop a measure of motivation that is appropriate for the learning domain in which you are interested. Researchers have used a number of measures for quantifying motivation, and furthermore, they have used motivation as an overarching term that may represent different student characteristics. For instance, researchers have explored students' self reported enjoyment (Cordova & Lepper, 1996), their desire to pursue a subject further (Zoldosova & Prokop, 2006), the time spent reviewing material (Woodgate et al., 2008a), and the extent to which the student believes they can achieve (Tuan et al., 2005).

By far the most common form of measuring motivation has been to use self-report questionnaires. While there has been some effort to standardise these, for example Tuan et al. (2005) and Vallerand et al. (1992) have both developed questionnaires to measure student motivation[13], researchers have chosen to focus on different aspects of motivation, and the aspects measured in these questionnaires are not necessarily those considered relevant by others. It is apparent that motivation is often typified in a variety of ways (Aldridge et al., 2010), including but not limited to:

- Self-Efficacy - the student's confidence in his or her own ability.
- Learning Goal Orientation - the extent to which the students perceive themselves to be engaged in the class,
- Science Task Value - the extent to which the student finds the topic relevant and interesting
- Self-Regulation - the extent to which the student is aware of the effort they need to place in the task to develop an understanding.

When monitoring learner motivation, researchers have explored these factors as indicators. However, the extent to which they have included each factor varies, providing little consistency in the literature for a measure of motivation. For instance, Johnson et al. (1997) explored attitude, using a likert scale. This involved asking the students to respond to 20 questions based upon the 'Attitude toward any school subject' scale. Unfortunately they do not provide any example questions. Lai et al. (2007), Rau, Gao and Wu (2008) and Zurita, Baloian and Baytelman (2008) have all developed their own questionnaires with items which they note as representing motivation. Lai et al. report using 30 questions in a survey which focused on: Learner Performance; User Interface; Motivation and Attitude towards the activity. As with Johnson et al. (1997) they

[13] Tuan et al. (2005) developed a questionnaire which explored student motivation in science education and its correlation with other factors such as achievement and student attitude, while Vallerand et al. (1992) looked to validate an existing motivation measure, which explored why a learner exhibited a particular behaviour.

do not report a full list of questions, however some of the example questions include:

- "Guided by the learning prompts, I feel better directed in outdoor activities".
- "Guided by the learning prompts, I feel very interested in outdoor activities".

It is unclear from their paper whether these are the motivation questions or if they related to the "attitude towards the learner prompts" activity. Similarly Rau et al. (2008) report using a motivation questionnaire, but again fail to provide a full list of questions. An example question is provided in the results section: "lecture notes received through SMS can increase my motivation." In their second study they suggest that motivation should be split into intrinsic, extrinsic and overall. To do this they report using the Learning Trait Scale (Rau et al., 2008, pg 7) unfortunately they do not provide details of the questions involved in this assessment measure.

Zurita et al. (2008) conducted a survey and reported that "All students agreed that they felt more motivated to participate in learning activities supported by mobile computing since mobility enabled the face-to-face interactions with other students and with the teacher" (Zurita et al., 2008, pg 121). It is unclear from this how the question was exactly worded but it appears that the researchers have asked the students directly how motivated they are.

Qualitative work by Facer et al. (2004) used student language and the suggestion that students were deeply situated within the learning game fantasy to indicate engagement, while Woodgate et al. (2008b) observed students interacting with mobile tools and suggested that increased discussion and time spent on the task indicated a deeper level of motivation. As mentioned earlier, Zoldosova & Prokop (2006) used student drawings and book choices as indicators of motivation. They asked students to select books from a list, concluding that students who selected subject relevant books were indicating an interest to further develop their own understanding. They also asked students to draw a classroom, and used the presence in the drawings of science relevant equipment to indicate their engagement in the subjects. This methodology is very different to the more widely used questionnaire, and is valuable because it does not rely on the student providing a self report which may be more prone to bias. However, it, like observation, is based upon the researcher's interpretation of meaning and consequently it could be argued that it is limited in its ability to reliably measure student motivation and engagement.

In the gaming literature, researchers have attempted to develop methods for measuring motivation that do not rely on observer interpretation. For instance, Rebolledo-Mendez, Du Boulay, and Luckin (2006) aimed to develop tools for supporting the learning process. Motivation was assessed in this instance by monitoring the effort made by the student, through looking at their persistence when faced with errors. The independence of the learner was evaluated by considering the amount of help that the software provided, and finally, confidence was considered as an indicator by monitoring the challenge seeking displayed by the students.

Some computer games have attempted to measure motivation through the use of facial recognition (see Graesser et al., 2008 and the Autotutor), looking to understand when users appear to be struggling. Methods such as those employed in gaming research are not always usable in the real world exploration of student motivation, as often, students will be using a tool that cannot be easily adapted to measure motivation.

There is no single, universally agreed measure of motivation, but in order for other researchers to replicate the studies and understand how conclusions have been reached, the development of questionnaires needs to be explained thoroughly to justify the inclusion of questions and their relationship to the understanding of student engagement and motivation.

This section has explored how researchers have defined and measured motivation. It has highlighted that these terms have been used in a broad way, and that a clear explanation of the methods employed is important for allowing future researchers to extrapolate understanding from the findings. Finally it should be noted that "motivation research is also still at early stages in terms of our understanding of how motivation impacts the learning process" (du Boulay et al., 2010, pg 6).

One of the aims of this thesis is to provide an insight into the impact of dataloggers on student motivation, and develop ideas around motivation as a fundamental aspect of learning. Motivation is used here broadly to suggest a student's enthusiasm for the topic, and their self reported engagement in the topic. It is used as a supplement to the learning measures and intends to provide an insight into how use of mobile dataloggers might impact upon the students in ways that are not always evident in short term learning activities and assessments. Based on the work by Cordova & Lepper (1996) and Johnson et al. (1997), motivation is explored as an internal construct that is measured through self-reports from the student, and provides an indicator of the student's interest and engagement in the subject and resources. Relying on the student to provide a measure of their motivation is common in the literature, and while it is not without risks, it is deemed an acceptable starting point for understanding motivation. Based upon Bandura's (2006) work that suggests it is appropriate to develop a bespoke measure of motivation, the students in this research were provided with questionnaires with the aim of exploring particular aspects of engagement relevant to the tasks in hand, rather than a broad measure of motivation, in a similar vein to Lai et al. (2007); Rau et al. (2008); Zurita & Nussbaum (2007) who all used their own bespoke questionnaires. It is anticipated that this will result in a greater understanding of motivation in relation to the use of dataloggers for data collection in school science investigations. All of the motivation questionnaires are fully reported in the appendix.

6 Schools and Technology

6.1 The Government and the Curriculum

In a report exploring mobile learning, science and collaboration by Vavoula, Sharples, Scanlon, Lonsdale and Jones (2005) they noted that:

> "An important tool in making science learning more like science doing is the use of modern computer technologies to offer learners ways of interacting with artefacts, materials, experts and their peers that were previously unfeasible in educational settings."
>
> (Vavoula et al., 2005, p.5)

Furthermore, according to a report from the Department for Education (2011)[14], in a survey of teachers in 25 EU states, 86% felt that students are attentive and motivated when using ICT in class. This suggests that technology motivates students and teachers through providing new methods for interacting and learning.

Crook, Harrison, Farrington-Flint, Tomas and Underwood (2010) argue that ICT can make new classroom and learning practices possible in three key ways: the reconfiguration of space, new ways to orchestrate class activities and new experiences from visualisation. Dataloggers can be linked to all three. They enable students to learn outside of the classroom, allowing them to lead the learning, and provide instantaneous visualisations of numerical data that can otherwise sometimes appear abstract and unrelated to the natural world.

[14]What is the evidence on technology supported learning? Published December 2011

It is suggested in the National Curriculum Guidelines 2004[15] that during key stage 3 students should collect their own data and could use technology to support this

> "make observations and measurements, including the use of ICT for datalogging (for example, variables changing over time) to an appropriate degree of precision." (National Curriculum Guidelines, 2004).

It is apparent from these varied sources that technology used appropriately can support students' learning and motivation. Indeed the British Government has acknowledged this, and suggested the use of technology for supporting the students' data collection and understanding during science education.

6.2 What is Learning and Who are the Educators?

What is learning and how can it be assessed? According to the Oxford English Dictionary (OED) the verb 'to learn' is defined as 'get knowledge of or skill in by study, experience or being taught', furthermore to be the provider of this knowledge you will be an 'educator' whether this is formal as part of the education system, or informally outside of structured education systems.

In 2010 a small, largely undocumented, revolution occurred on Twitter[16] whereby educators, educationalists and others banded together to discuss the point of education. This discussion was held in an effort to bring education back to the basics of providing learners with knowledge and skill. Instigated by Doug Belshaw and Andy Stewart and titled Purpos/ed[17] the result of this initial discussion was a book with 500 word answers to the question 'What's the purpose of education?' (Belshaw, 2011). Some of the responses were obvious, 'To prepare people for life' to 'foster growth and independence', others were more focused on the current education system and responded 'it's all about control and power', 'I think somewhere down the line we forgot what the purpose of education is'. These responses have hints of ideologies and theories behind them, but are more based in experience than literature.

While learning and education are not the same, they are undeniably linked and in terms of this project, learning is considered within the formal environment of the school education system.

[15] https://www.education.gov.uk/publications/eOrderingDownload/QCA-04-1374.pdf

[16] a microblogging website, used by the public for a number of different reasons, in this instance the users primarily use it as an extended Personal Learning Network, collaborating with other users to further their understanding and to share skills and resources. www.twitter.com

[17] http://purposed.org.uk/about/

Some of the more interesting responses to the Purpose/ed discussion wrote outside of the box. One in particular defined the meaning of purpose as something with an end point, and then declared that education should not have an end point at all, so the wrong question was therefore being asked. Finally one of the most poignant answers focused on the living bridges of Cherrapunji, North East India. These bridges are grown over centuries; cared for and shaped by many family generations, as the bridge grows it becomes stronger. Kevin McLaughlin used this as his metaphor for the purpose of education, he sees current day education as built upon foundations laid by the Romans, noting how aspects have been knocked down and rebuilt, while other aspects are protected and developed. The idea of education as a living entity is transferable to learning, with the student as the metaphorical bridge, students are taught a certain depth of knowledge, and as they move through the education system, we tend to build on top of their existing knowledge, applying it in new ways to different topics. This in itself is similar to the idea of the ZPD and scaffolding, whereby teachers support the students in learning through utilising existing knowledge to explain and introduce new concepts. However, some concepts are completely reshaped along the way, especially in science education where students may have been taught a simplistic representation of a concept, yet later they are told that the original concept was incomplete. This is not because teachers have a desire to misinform, but because the student is not ready to learn the complex explanation yet. The introduction of new technology into the curriculum provides teachers with support to explain concepts, which may have in the past been thought to be too complex, such as technology which can demonstrate dangerous chemical reactions, or present phenomena that the eye cannot see. In terms of this project, the dataloggers can measure phenomena which are difficult to measure using traditional, manual tools[18], allowing the students to focus on their data rather than the collection process.

The projects reported in this thesis have been developed in line with the theories of situated learning, and work to establish how learning can be taken outside of the classroom with hand held devices, and how these devices and the idea of mobile learning can be introduced into the classroom as a supportive and exploratory tool.

[18]for instance the accuracy of a number of tools such as stopwatches are limited by the users reaction speed.

7 What is Mobile Learning?

> "Some advocates of mobile learning attempt to define and conceptualise it in terms of devices and technologies: other advocates define and conceptualise it in terms of the mobility of learners and the mobility of learning, and in terms of the learners' experience of learning with mobile devices" (Traxler, 2007, p.1)

There is no single definition of mobile learning: this next section details a variety of discussions into mobile learning and the associated theories and positions the current research within this area. Ayala & Castillo (2008) describe mobile learning objects (MLOs) as

> "small educational components that can be reused in different learning contexts" (Ayala & Castillo, p.1)

Ayala & Castillo (2008) highlighted three characteristics of Mobile Learning Objects (MLO):

Reusability: adaptability to context and user.

Portability: learning anytime anywhere and across the physical and digital realm.

Social Interactivity: connections between multiple users of the MLO.

They go on to describe how these three characteristics can sit alongside the three different learning approaches described by Sharples, Taylor and Vavoula (2005) shown in Table 7.2

Mobile Learning Object Characteristic	Learning Approach
Portability, merging digital and physical realms	Situated Learning
Social Interactivity and Connectivity	Collaborative Learning
Reusability, individuality and context sensitivity	Personalised Learning

Table 7.2: Characteristics of mobile learning objects and corresponding learning approaches

They used this categorisation to inform their suggestions for how and when MLOs should be used to support each type of learning approach. This research focuses primarily on situated learning and the use of the datalogger to provide students with just-in-time knowledge, enabling the student to work in a real world environment and transfer their classroom taught skills to an authentic situation. Currently students in the UK are familiar with using computers and the Internet while at school and often at home. They are also often experienced using smaller devices such as mobile phones and cameras outside of school (Traxler & Wishart, 2011). In addition to this there has recently been an emergence of research into promoting mobile learning. However, few schools have yet used the full functionality of these devices to benefit students and the learning process.

Hand held dataloggers fit directly into this category, as they are designed to be small, user friendly and with an educational focus. The base box of the model used in these studies has three inbuilt sensors (to measure sound, temperature and light level). Additional sensors can be plugged in to allow extensive adaptability and reusability within different scientific topics and subjects, for example allowing students to check their pulse rate in biology, use light gates in physics and measure pH in chemistry, amongst other functions. In addition to this functionality, the dataloggers used in this research also work alongside GPS units to enable students to georeference where their data has been collected from, and use this location data to generate a graph upon Google Earth. See figure 7.1 for an example of a graph displayed on a Google Earth landscape.

Figure 7.1: Graph layer on Google Earth produced using ScienceScope JData3D software

Chen et al. (2008) investigated the effects of mobile learning, using PDA devices, upon outdoor experiential learning. Their results indicated that using a PDA led to more effective knowledge creation. However they also noted that use of inappropriate tools could limit the benefits and change the dynamics between learner and technology, in particular the novelty of the camera overshadowed the students in their exploration of other functions and activities. Further research into mobile learning in schools by Heym & Hartnell-Young (2008) shows that students already know of beneficial ways in which they can use their phones in school, such as the calculator function, datalogging features for audio and visual material and the use of the stopwatch function. These current features can be used across the curriculum from science and maths, to PE and geography, and even to art and drama. Liu (2008) discussed the benefits of hand held devices for active learning and noted that the portability and context sensitivity of hand held devices can change the learning process from one of knowledge acquisition to a new style of learning whereby it is social, collaborative and creative. This statement is later extended to note that ubiquitous learning is not only learning with technology and hand held devices: it is the learners attitude and willingness to learn any time anywhere.

In a recent report for BECTA (British Educational Communications and

Technology Agency)[19] McFarlane, Roche and Triggs (2007) use the term mobile learning to refer to

> "portable, mobile technologies which can be held in the hand and used in any location or context"
>
> (McFarlane et al. (2007) pg 3)

While Sharples, Milrad, Arnedillo-Sánchez and Vavoula, (2009) define mobile learning as having four dimensions:

1. Portable Technology
2. Spatial Mobility
3. Learning across tools and topics
4. Timeless Learning[20]

They suggested that these four dimensions are all important areas to be explored when considering mobile learning and its impact. This research primarily focuses on the first two dimensions, considering the benefits of taking technology outside of the classroom and giving students the freedom to gather data in the environment.

It is clear that mobile learning has been defined in countless ways, such as: learning while mobile, learning with a mobile phone, to learning with a device which is mobile (see Caudill, 2007 for example). In this thesis the focus is based upon the former and is heavily based upon definitions by O'Malley et al. (2003) and Sharples et al. (2005).

> "Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies." (O'Malley et al., 2003, p 6)
>
> "Learning that happens across locations, or that takes advantage of learning opportunities offered by portable technologies." (Sharples, 2009, p 19)

Based on the earlier review of learning theories, this thesis focuses upon the notion that learning is about creativity and collaboration, drawing on work

[19] A quango funded by the then Department for Schools and Education, this was liquidated in March 2011 following a change in government.

[20] this is the idea that learning is never concluded, our understanding can always be deepened through additional experience

based on constructivist theory and highlighting the role of motivation in education, and seeking to facilitate and explore this further by considering the impact of context upon students' learning and motivation when using hand held dataloggers. The hands-on experience of collecting one's own data and sharing it with others may lead to a greater feeling of ownership and motivation towards the topic. By conducting their own experiments, learners will not only gain scientific conceptual knowledge, but also scientific process knowledge, learning transferable experimental skills and understanding that scientific concepts can be based on perfect environments and in the real world there may not always be a perfect "fit".

Woodgate et al. (2008a) found that sometimes the presentation of too much information, automatic processes and a lack of visual contextual media can result in hindering the discussion and reduce the student's reflection. They posited that this might result in learning being reduced, or potentially being less likely to be retained. The aim of this research is to build upon this body of work and understand how technology can influence and interact with student learning, and in particular their motivation and engagement with the particular topic.

8 Context

> "Context is a widely used, and ill-defined term" (Turney, 1996, pg 1)

The term 'Context' has been defined in numerous ways. A key interpretation of context is that posed by Cole (1998), who suggests that the combination of people, roles, objects and so on can serve as "guides to action" (Luckin, 2010, p 9). Cole discusses the origin of context as coming from the word contextere meaning to weave together and forming a shell, which surrounds the person. He suggested that combined experience and context enable understanding of each of the individual parts with the combination allowing interpretation of future parts, so ultimately all new experiences must be viewed through the shell of history and experience. Consequently it can be hard to tease apart the task and its context. Furthermore, Cole notes the importance of context when the brain is interpreting which schema to use.

> "A large, orange, striped, furry leg with a cat-like paw dangling from the shelf in our child's closet is likely to evoke a different schema, different emotions, and different actions from those evoked by a similar object glimpsed under our hammock in a lean-to in the middle of a Brazilian rain forest." (Cole, 1998, p.130)

In this example Cole (1998) was showing how the environment and the situation are vital when developing an understanding of empirical facts. The same is true during scientific investigations. If you are collecting data, details about location, time and environment are important for producing an accurate provenance. Knowing that a sample's temperature is 23 degrees is of little relevance if you do not know when that sample was taken in order to ascertain reasons for its 23 degree temperature, and whether that temperature would have been anticipated or not. Cole places emphasis on Dewey's teachings, suggesting that there can never be a single object or event, as it is always inevitably connected to another object or event, forcing the interpretation of the object or event to be based upon preexisting interpretations of past events and objects. What this means is that we cannot reduce a collection of factors down to a single event without knowing where something has come from, nor can we begin to understand its relevance or meaning. This researchexplores how using hand held dataloggers can generate and record additional artefacts of context which can be used to support and enrich a student's learning experience.

A shift in how teaching is approached has resulted in an awareness of the value of context to learning. Luckin (2010) wrote:

> "Context matters to learning; it is complex and local to a learner. It defines a person's subjective and objective experience of the world in a spatially and historically contingent manner." (Luckin, 2010, p.18)

The idea of mobile learning generating a forum for creating new contexts and interactions has been evident in much of recent research. In particular, work by Sharples, Taylor and Vavoula (2007) has involved understanding learning in an increasingly mobile society, and how this can provide opportunity for generating new contexts and relationships between people and technology. In a recent report by Brown et al. (2010) the concept of context was extended to encompass any setting in which a situation occurs. This was deliberately defined broadly and included aspects such as time, location, goals, resources and activities. The distinguishing aspect of mobile learning is the assumption that learners are continually mobile. Rather than seeing learners as physically present in a certain place, such as a classroom or a museum, learners are active in different contexts and frequently change their learning contexts. Brown et al. discuss the idea that learners benefit from constructing their own knowledge from within a realistic context. This is based on work by Lave & Wenger (1991). They comment that authentic learning provides opportunities to experience a variety of stimuli and generate alternative perspectives on each theory. Work by Luckin (2010) shows how context can be defined in a variety of ways dependent upon a person's personal experience, their background and indeed, somewhat ironically, their personal context. It is clear that context builds upon itself constantly shaping new experiences. Luckin provides a clear insight into context in the quote:

> "Clearly context matters and its significance needs recognition, it is complex and for some it is not a singular entity, but rather a multiplicity to which we are serially exposed" (Luckin, 2010, p.8)

Throughout Luckin's book she emphasises the importance of understanding context to inform our understanding of learning.

> "Individuals might build something coherent around their learning needs through the possibilities within their environment" (Luckin, 2010, p.8)

She also recognises and focuses on the role technology can have in mediating this interaction between context and learning, highlighting the importance of how the physical and digital can interact, and drawing attention to the importance of context to the relationship between the physical and digital experience.

In this thesis, this overlap is developed further through considering how experience and context can map onto physical and digital artefacts, and how these in turn can impact on how a student learns, and is motivated to learn. Context is defined here as two separate but interlinked concepts, with the anticipationthat by defining it in this manner, it will be easier to explain how the research projects are separate yet intertwined by the underlying focus of understanding context. Context is firstly defined in terms of experience, and then secondly through describing how aspects of context can be visualised and understood through media.

8.1 Contextual Experience

Contextual experience cannot be recorded in a traditional manner such as photos, video or other artefacts shared between people. Instead this is a personalised experience, only understood by the individual. While it can be retrospectively reported, such as in written diaries, it is based on the idea that, by performing an act yourself, you gain intrinsic knowledge about the occurrence and the event, which cannot be realistically mimicked by media.

> “Photography is a discrete medium. It suspends the world for one instant rendering it silently within the two-dimensional boundaries of an image frame” (Teodosio & Bender, 1993, p.1)

Teodosio & Bender (1993) highlight how instantaneous a photograph can be. It is the same for any data collected with a datalogger, it is a recording of that single moment. While, photos and video can to an extent provide additional cues to a new viewer of the data, it is clear that actual experience of the data collection will provide a greater insight into the context of the data. Based in situated and authentic learning theories, this concept of context highlights the importance of learners exploring the world for themselves, forming their own ideas and understanding where their data comes from.

8.2 Contextual Media

Contextual media provides additional, environment relevant, data to a set of readings or measurements. This idea of context builds upon the ideas of the Participate Project (Woodgate & Stanton Fraser, 2005), which investigated the qualitative relationships between contextual media and learning.

Work by Naaman, Harada, Wang and Garcia-Molina (2004) on the role of context when forming photo collections discuss how additional context cues such as time, location and weather conditions can act as memory cues and filters when searching for a photo within an extensive collection. In the same manner, additional contextual media can support a student when they are recalling their investigations. The photos can act as triggers for recalling such things as the experiment conditions, and potentially discussions held during the investigation. Contextual media also includes any form of information that records the process of the event, for instance, photographs of the students taking a measurement. This contextual data can act as an aide memoire and provide the student with a stimulus to recall the event. It can also supplement the collected data, by providing further details of the contextual environment for the data collection (Stanton Fraser et al., 2005).

The Ambient Wood project, (Randell, Price, Rogers, Harris and Fitzpatrick, 2004; Rogers et al., 2002; Rogers, 2004; Rogers et al., 2005; Weal, Michaelides, Thompson and DeRoure, 2003) explored the use of sounds to stimulate discussion and reflection by learners while they were exploring a woodland habitat. They combined this with images and video to show in detail some of the activities, which were occurring in the woods. By providing video and photo media, the learners were able to visualise aspects of the woods, which they otherwise may not have appreciated, such as pollination. An ambient horn played abstract sounds to generate attention to a particular process: this was due to initial investigations having shown that location relevant sounds were often ignored by the learners as they were congruent to the environment. By presenting them with a new way to view and explore their environment the students were stimulated and motivated to explore further. This enabled them to gain a more in depth understanding of their surroundings. In terms of this research, this ambient wood project highlights how multifaceted an environment can be, and how interrelated each aspect: for example if learners are asked to record oxygen levels in water, it is also important for them to know the light levels and the plants which are around and in the water to enable them to hypothesise about the causes of different oxygen levels. The use of hand held dataloggers provides students with an easy way to collect a variety of data types as well as actively experiencing the environment. When combined with photos and GPS data, the abstract data are more easily understood, enabling the students to tell the story of their data rather than just repeat the numerical values. In summary, Contextual Media refers to physical objects used to record and document specific data, for instance photos, video, written description, as well as GPS coordinates. These media can provide additional information to the learners by aiding in the illustration of an event or data set. Ownership

In this thesis, ownership refers to the idea that the learner can take control of their learning, and lead the inquiry at any or all stages. It is about providing the learner with the tools to direct their own learning and for the learner to feel that they make decisions about their learning, and the results which they have found are due to their direct involvement with the design and implementation of the investigation. A review of the literature has shown that ownership is considered to be an important part of personal inquiry learning, with students needing to understand the process and their role within scientific inquiry (Anastopoulou et al., 2012). Furthermore O'Neill (2010) notes the when students have a sense of ownership in their science lessons, they develop an 'agency in science'. This then empowers the student, and encourages the desire to learn more science (O'Neill (2010, pg 1). It is noted that ownership can mean different things dependent upon the field; for instance in literacy it might be about developing the ability to choose what is read, while in a broader sense it might refer to the student's ability to influence the lesson by asking questions of the teacher and shaping the wider learning experience. The idea of ownership and control is heavily present in the motivation and learning literature (see Mistler-Jackson & Butler Songer (2000); Johnson et al. (1997); Krajcik et al. (1998); Palmer (2005); Lepper (1988)), with researchers noting that it is important for students to feel in control of their learning, as this can lead to increased participation, engagement and ultimately more meaningful learning (O'Neill, 2010).

8.3 Centricity

Hartley (2007) comments on the importance of the student being at the centre of the learning experience. The idea of centricity is closely linked to experience; the key difference is that experience also encapsulates the idea of ownership through experience. It is anticipated that by subdividing experience into centricity and ownership then we can start to understand how different levels of centricity can impact upon the student's motivation and attainment. While centricity can also be linked to the idea of personalisation, again there is a difference. With a personalised learning experience the technology is customised or tailored for the user (Barkhaus, 2003). In contrast centricity is defined as a method for measuring hands-on learning by looking at the degree of involvement with which an individual has had with the data. For example if there is a high degree of centricity then the individual has collected the data and experienced the situation themselves, making the data heavily egocentric. In comparison if the learner did not collect the data and did not make decisions about its collection, then the data is termed allocentric. If a student collects data about carbon monoxide levels outside their school gate, this data is, for this student, egocentric. However, if the same student also receives a graph providing details of carbon monoxide outside of a school in America, then this second set of data is allocentric as the student did not have any direct interaction with this data. If students benefit from collecting and manipulating their own data, then the implication is that the use of dataloggers would provide an opportunity for this to occur. Barton (1998) noted that when comparing manually drawn graphs to computer generated graphs, the students would focus on different aspects of the data, suggesting that the different levels of centricity may impact upon the student's learning experience. The idea of centricity is similar to the idea of experience and relates heavily to the theories of situated and experiential learning. Centricity was chosen to define the concept rather than experience to highlight that it is purely about interaction with the data, rather than the broader view of experiencing the situation. Centricity differs from ownership as centricity is focused upon the level of interaction a student has with the data. This can be represented along a continuum from allocentric to egocentric. In contrast, ownership emphasises how the student identifies with the data and the extent to which they feel they have control over their learning.

8.4 Seams

Seams are disruptions between learning stages or between media. Research varies with regard to the impact of seams upon the learning experience. Work by Boticki & So (2010) explores the concept of seams with regard to learning environments and suggest that learners benefit from having fewer seams during the learning process. In contrast Chalmers, Dieberger, Hook and Rudtrom (2008) query the concept of seams and suggest that a seamful design, rather than seamless, can aid the user by encouraging reflection. In this thesis the impact of seams upon learning are considered with respect to the impact of automation upon the students' reported motivation and conceptual understanding.

In the Participate project (Woodgate, Fraser, Paxton et al. 2008a; Woodgate, Stanton Fraser, Crellin and Gower, 2008a; Paxton, Chamberlain and Benford, 2007) the use of software, which could facilitate combining scientific data measurements with additional contextual cues such as photos and GPS was explored. This software enabled the students to review their data in a graphical visualisation superimposed upon Google Earth, with clickable nodes to display linked photos. It was shown that, while the students were highly engaged with this level of interaction, the researchers observed that they also engaged with some of the perhaps more mundane aspects of data, as well as the Google Earth visualisations. They developed this project further to enable schools to share their data on a website, allowing students access to data recorded from across the globe. This additional context of GPS and Photos made the original datasets more interesting and inviting to the students. In later work by Woodgate et al. (2009) they note that the automation of combining GPS, photos and data reduced the amount of discussion from the students. They noted that, when the system failed, the students spent more time reflecting on their individual resources, comparing and combining them in different ways. This work suggests that a seamless transition from real world to digital representation may affect the extent to which the students understand their data.

Work by Chalmers et al. (2008) into seamful design defines seams as

> "as gaps and breaks in functionality, imprecise positioning, and errors in recording and representation". (Chalmers et al., 2008, p.1)

With this definition in mind, a seamless transition can be one that has no breaks between data translation: the subject is recorded and translated into a graphical representation without user interaction. Conversely a 'seamful design' is an approach which utilises seams and discord between devices, which according to work by Chalmers et al. (2008) can encourage discussion and reflection.

Woodgate, Fraser, Paxton et al. (2008a) found that sometimes, too much information, automatic processes and a lack of visual contextual media can result in hindering the discussion and reduce the student's reflection.They posited that this may result in learning being reduced or potentially being less likely to be retained. Throughout the research for this thesis, seams have been considered as an underlying area to explore, and as such are included as minor investigative points within some of the projects. In particular, interest was focused on how automation, a seamless experience, might impact upon the students' learning and motivation.

9 Dataloggers

In recent years there has been a considerable push to incorporate ICT into more and more of the life, environment and infrastructure of schools. According to a report written by Baggot le Velle et al. (2005), £1.7 billion was invested in training, hardware and software for schools in 2005. Consequently much research has focused on how science education can incorporate new digital technology and media effectively into the syllabus, to teach new techniques to the students without compromising the active, hands-on approach which science has traditionally taken. The datalogger allows teachers to incorporate ICT into science education, enabling students to collect their own data, and providing contextual information to supplement their data analyses.

In his article on datalogging and scientific enquiry, Frank Fearn (2006) notes that he first heard of dataloggers 15 years ago (1991). Philip Harris, the precursor to the Data Harvest and Logit brands, all started datalogging business activities in the early 1980s. As dataloggers are still used in schools now it is fair to say that datalogging technology has been available and in use for at least twenty five years in the United Kingdom. However during this time dataloggers have been used by teachers to a varying extent. The publication of Fearn in the School Science Review suggests that not only are dataloggers still relevant to schools, but that teachers still require support and ideas for methods of using the tools inside and outside of their classrooms. According to Fearn (2006), when dataloggers were first introduced teachers praised them for removing the boring tasks of data collection and automating the graphing experience. The automation of the graph drawing process was advocated by Barton (1998) who had noted that students understanding of graphs can be limited by their ability to accurately draw graphs. The introduction of datalogging tools removes this requirement, allowing students to focus upon the analysis of the data. In this article, Barton notes three key issues with practical work: time overhead, information clutter and linking practical experience with abstract concepts. Dataloggers can help on all three issues. More recently Mee (2002) has explored the impact datalogging can have on a student's graphical skills and concluded that use of dataloggers can actually improve a students manual graphical skills, while Davies & Connor (2005) advocate the use of real data to teach students, and the importance of ownership for motivation.

A datalogger is a device that records data using inbuilt or external sensors. In the context of this thesis, a datalogger refers to small portable hand held device often used in the school environment. In particular, the datalogger most commonly used in this research is manufactured by the company ScienceScope see figure 9.1 for examples of ML (9.1a) and GL (9.1b) dataloggers.

(a) ML datalogger (b) GL datalogger

Figure 9.1: ML and GL dataloggers

ScienceScope are a company based in Somerset, who produced their first datalogger, Datastore, in 1982. Designed to work on BBC Computers, it helped to introduce the concept of datalogging in schools. Following their success they worked to develop their accompanying software into a professional tool which could be adapted to all stages of science education. In 2001 the LogBooks were launched to work alongside datadisc software and the Phillip Harris datalogger range. ScienceScope continue to improve and diversify their products, working closely with a range of academic partners to research and develop their products. ScienceScope have worked on a range of research projects[21].

[21] Including but not limited to:

- HP Catalyst Project (http://catalyst.navigator.nmc.org/gallery/poster.php?nid=13095&vid=22012 accessed 10/04/2012)
- Participate Schools (http://www.participateschools.co.uk/ accessed 10/04/2012),
- Personal Inquiry with Nottingham & Open Universities (http://www.pi-project.ac.uk/resources/ accessed 10/4/2012)
- Plug Back into Science (http://www.bath.ac.uk/psychology/plugbackintoscience/ access

ScienceScope has collaborated with academics, students and school teachers to develop tools and investigations, which are relevant and appropriate to the school curriculum. Relocation in 2011 has led to ScienceScope basing themselves within a school in Radstock, UK, as part of the UK's first STEM (Science, Technology, Engineering and Mathematics) Enterprise Centre. This allows them to support the school with state of the art datalogging equipment and to also gain direct feedback and suggestions from the users of the dataloggers.

ScienceScope dataloggers are approximately 12 x13 cm in size, and can easily fit in the hands. They collect, display and store data: these data can then be uploaded into bespoke software. One of the key benefits of dataloggers is their flexibility. A standard ScienceScope datalogger used on its own measures sound, light and temperature. However additional sensors can be easily added to enable them to be used in multiple situations and widely varying investigations. ScienceScope provide instructions for uses and suggested experiments for each sensor, see table 9.1 for example sensors and their uses:

Sound	Light	pH Level	Pulse Rate
Speed of sound	Rate of reaction	Water quality	Heart rate
Sound levels	Light intensities	Buffer chemistry	Effect of caffeine
Insulation	Material Properties	Acid titration	Effect of exercise

Table 9.1: Examples of Science Scope sensors and suggested experiments

ScienceScope have developed a range of bespoke software to work alongside their dataloggers, all designed to allow the students to explore the data visually. Table 9.2 details the different functions provided by each piece of software.

Software	Target Audience
Datadisc GraphPad	Key stages 1 &2 (5-11)
Datadisc Explore	Key stages 3 &4 (11-16)
Datadisc PT	Key Stage 5 (16-18)
JData3D	All ages but requires teacher support for younger students

Table 9.2: Examples of ScienceScope Software and its target Audience

In the three Datadisc programs it is possible to view live data as numerical values, view visualised live data, or review previously collected data. Whatever

10/04/2012)

the methods of displaying the information, GraphPad uses simple visualisations such as day and night for light levels (see figure 9.2).

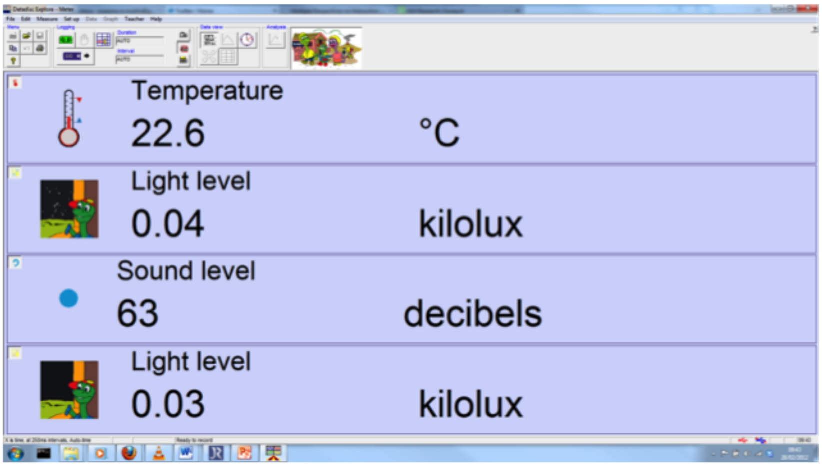
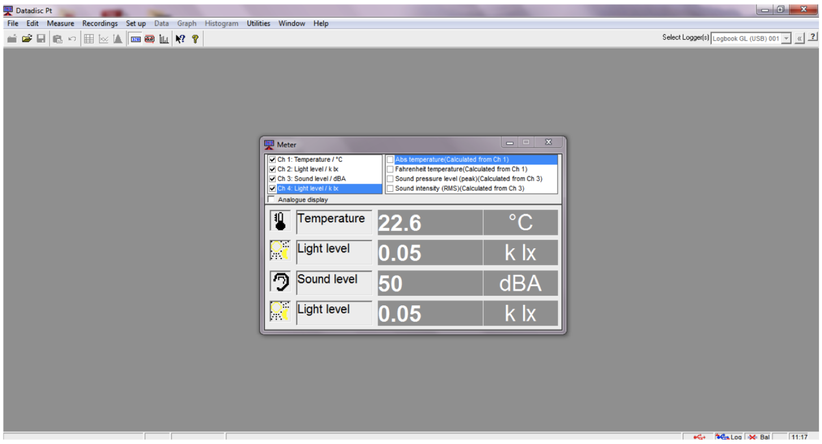
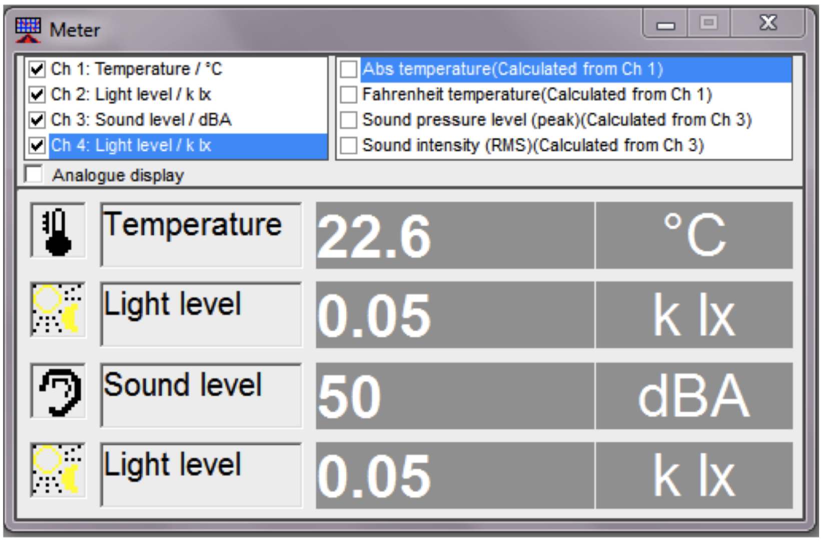


Figure 9.2: Datadisc GraphPad Interface

The PT, on the other hand, offers the option to see the live data (without visualisation) but only after choosing from a menu, with its primary focus being the manipulation of saved datasets (see figure 9.3a).



(a) Main DataDisc PT Window



(b) DataDisc PT detailed view

Figure 9.3: DataDisc PT Interface

Datadisc Explore provides a middle option, allowing the user to have immediate feedback, but with additional functions built into the software. See figure 9.4.

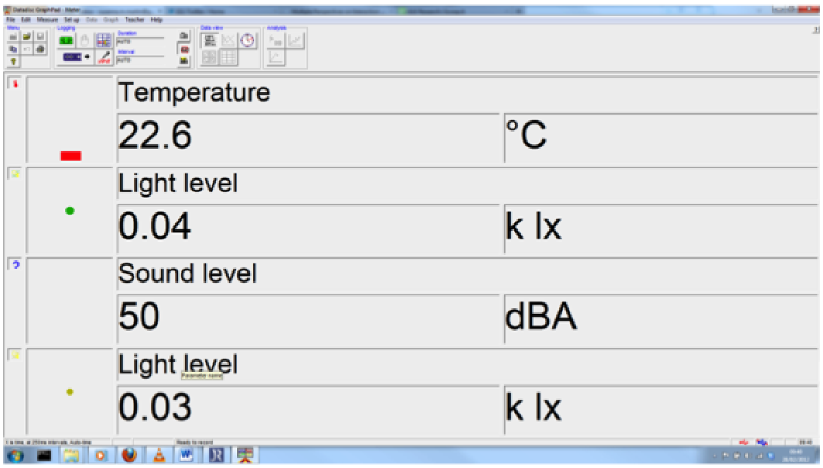


Figure 9.4: DataDisc Explore Interface

JData3d is a tool for producing interactive graphs for superimposing on Google Earth. Its primary function is to combine Datalogger data with GPS information and photographs[22]: consequently it does not have data manipulation functions inbuilt. GPS data can be recorded using a number of tools. In this research we used a Garmin recorder (see figure 9.6). During the course of the project, ScienceScope redesigned the dataloggers to include an inbuilt GPS.

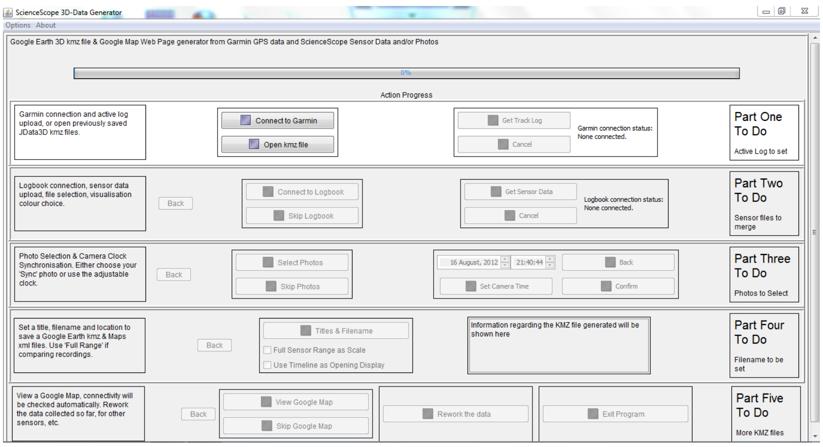


Figure 9.5: JData3D

[22]Both of these systems work by combining and using the time stamped information recorded alongside the required data.

Figure 9.6: GPS Unit

Sensor data can be exported into a number of formats including Excel, giving the user the flexibility to use a range of software. When using the software with live data it is possible to repeat an experiment and show the results on the same graph, allowing the user to see differences immediately. See figure 9.7.

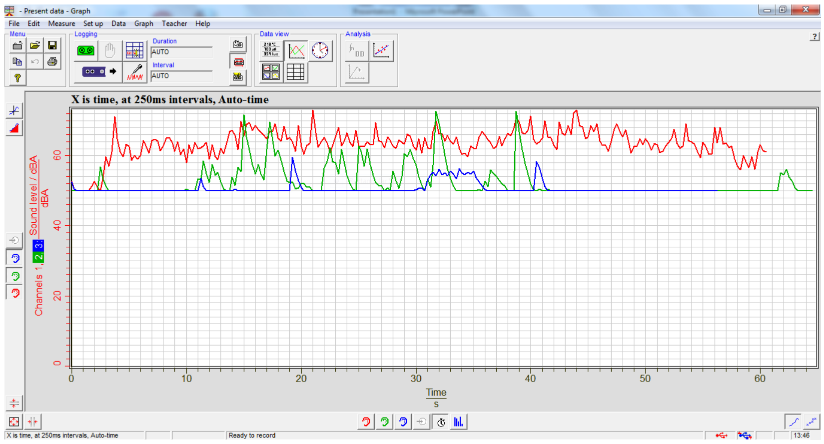


Figure 9.7: Graph showing multiple sound recordings

Datalogging can automate the recording process of data collection, providing immediate feedback, and reducing the time taken for students to input data. Some dataloggers can also provide instantaneous representations of the data, allowing immediate feedback and facilitating reflection (Hennessy et al., 2007). Dataloggers are useful to the science classroom due to their versatility and affordance for enquiry based learning. They also enable students to benefit from the immediacy of the graph production to generate understanding of the relationship between the environment, the datum and the graphical visualisation. Fearn (2006) advocates the use of dataloggers for scientific enquiry and provides four case studies into using dataloggers outside of the classroom, providing suggestions for how the dataloggers can trigger further questions from the students, and how the teaching can reflect the student's own curiosity to learn. For an overview of some of the key research into dataloggers see Silburn (2008) who provides an excellent introduction into dataloggers and their role within Australian education. Newton (1999, 2000) provides further information on datalogging and the role of dataloggers within the UK curriculum, while Deng, Chen and Chai (2011) and Ng & Yeung (2000) give an insight into the use of dataloggers in Asia. Ng & Yeung discuss how datalogging can facilitate a student's scientific sense making and act as a mediator between abstract scientific concepts and the real world environment.

Deaney, Hennessy and Ruthven (2006) worked with a number of teachers to understand how dataloggers can be used in the classroom. They report a range of case studies, in particular the teachers' and students' responses to the introduction of the dataloggers. They detail a number of positive factors regarding the use of dataloggers within the classroom, such as dataloggers allowing the collection of more accurate data, students becoming more focused and enabling the enlivening of "dry" areas of the curriculum. The students reported that they liked the live action and the immediacy provided by the dataloggers.

Use of dataloggers can enable students to concentrate on the design and the outcome of their enquiry. Both Choo (2005) and Rogers & Wild (1996) comment on students spending an excessive amount of time and energy on the mundane aspects of data collection such as recording, tabulation and plotting: dataloggers can reduce this time consuming task. Scaife (1996) terms this Computational Offloading, whereby external representations can reduce the cognitive effort required to solve a problem: in this instance an immediate graphical representation of the data can enable the student to understand their dataset without having to spend the time plotting each data point. By speeding up this process, the student is able to spend additional time reflecting, and thereby understanding the graph and the data. Gipps (2002) reports that datalogging is well suited for enquiry learning with the real time graphical visualisation enabling the students to "see" their science.

Woodgate, Stanton Fraser, Crellin and Gower (2008b) take this a stage further and argue that, not only do dataloggers allow the students the chance to collect, visualise and collaborate on their data, but, by spending more time on the data collection process in comparison to the data representation process, they become more engaged with the idea of scientific practice, and develop an understanding of experimentation in the real world. They also note that, when the students had collected the data themselves, they appeared motivated to continue, enjoying the personal relationship they had with their data (Woodgate, Stanton Fraser, Crellin and Gower, 2008b). Mistler-Jackson & Butler Songer (2000) discussed the importance of authentic experience for increasing student's motivation. Dataloggers can provide this by enabling students to use tools similar to those used by professional scientists. A further advantage of the datalogger is its mobility. By being able to take the datalogger outside of the classroom, the lesson immediately feels as though it is a field trip. This connection to the outside world can encourage scientific interest, and allow students to see the connection between their classroom studies and the real world context (Knapp & Barrie, 2001; Rudmann, 1994). Furthermore, any data collected by the students can be collated by the teacher for use with future students allowing comparison of experiments over time and situation. By using dataloggers you reduce the chance of data being manipulated or distorted by the students as they record their results.

Work by Kanjo et al. (2007) investigated combining data collected by dataloggers with GPS recorders to enable the graphical visualisations of the data to be placed geographically upon maps such as Google Earth. This enabled the students to view the connections between the location of the data collection and other external factors within the environment, which may be useful to explain the data that they had recorded. The responses to Kanjo et al's investigation suggested that additional contextual information encouraged the students to reflect on their methods. It also presented students with additional cues to remind them of their investigations, allowing new students to be introduced to the investigation at a later date. This can be very useful as it can be time consuming for teachers to repeat investigations with students who were absent from school during the initial phase. During the Kanjo et al. investigation, the researchers introduced a new reflection technique for the students to showcase their learning. They termed this "60 second scientist" where the students are required to storyboard, film, edit and present a 60 second movie clip of their work. This worked to encourage discussion and reflection within the group.

10 Concluding Remarks

This introduction provides an overview of the main body of research relevant to this thesis, while as ever there is more research available, the material that has been reviewed is highly relevant and provides an introduction to the breadth of this thesis. Clearly each approach, theory, and explanation are heavily entwined and reliant upon each other: indeed a learning theory approach may work for one teacher one day, but that same teacher may use an alternate strategy on a different day or with a different learner. This highlights the importance of adaptability of the teacher to support the learner rather than using a particular school of thought. In the next section the aims of this thesis and the methodology used are discussed.

Part II

Aims and Methods

11 Aims of this thesis

This thesis explores some of the questions which have arisen during this literature review, in particular it considers whether ‘doing it for yourself’ can help in the learning process? the benefits of generating your own contextual media, and the role of automation and seams upon the learner’s contextual experience.In order to explore these questions, two pilot studies and three experiment investigations were designed and run, a mixed method approach was adopted. Each investigation was designed as a single entity: however they all work to form a coherent understanding of mobile context data in hands-on learning. In the next section methodologies used during this research will be discussed and described, providing justification for why certain methods were chosen.

This research programme was designed to explore and evaluate the effect of dataloggers for education, both when used alone, and also alongside additional contextual media. At the beginning of this thesis, three key questions to consider were identified. During the development of this programme of work a fourth question emerged, based around the methodology and practice of the research. This question is important not only as a tool for evaluating learning interventions, but also as a key question for policy makers, and exam boards who strive to quantify learning. Through out this research, different methods have been employed to attempt to capture learning in a quantitative manner. This has highlighted how multifaceted learning is, and the importance of not reducing understanding of learning to a single measure. As a result this thesis explicitly explores four key questions, which underlie our understanding of mobile contextual data for hands-on learning.

1. To what extent does automation affect the student's learning and motivation?
2. How does the addition of personal experience with a datalogger affect learning and motivation?
3. Is it beneficial to generate your own contextual media?
4. How can we quantify learning?

Table 11.1 below shows how the five investigations target the research questions:

Hypothesis	Longitudinal Observation	Single Event Observation	Ownership and Automation	Technology Vs. Traditional	Ownership and Technology
To what extent does automation affect the student's learning and motivation?	✓	✓	✓	✓	
How does contextual experience with a datalogger affect learning and motivation?	✓	✓	✓		✓
Is it beneficial to generate your own contextual media?					✓
How can we quantify learning?			✓	✓	✓

Table 11.1: Hypothesis and Investigations matrix

12 Methodology

During the initial review of the literature it became apparent that a large proportion of the research conducted within this area uses a qualitative approach. For instance: Bamberger & Tal (2008) who investigated class visits to museums through interviewing the students; Rogers et al. (2002, 2004) who explored the ambient wood project and used video to record and observe the students and Facer et al. (2004) who used mobile learning to structure and support childrens' imaginative play, while work by Woodgate, Stanton Fraser, Crellin and Gower (2008b) take this a step further and use interviews and pre and post tests during their exploration of mobile learning. The research in this thesis builds upon this body of work and extends it by using a mixed methods approach to incorporate more quantitative results into the field. A mixed method approach was deliberately used, rather than a completely quantitative approach, to allow a rich and in depth analysis to occur.

12.1 Mixed Methods:

The layman's opinion is often that quantitative methods reduce real life to simplistic numbers that are lacking in context, while qualitative descriptions can be fluffy and hard to generalise. In a paper by Niaz (2006) the generalizability of qualitative research is discussed. It is noted that a lot of learning theory has been developed and accepted, even though it was based on researchers such as Piaget and Vygotsky who used very small sample sizes. Despite this, their explanations are accepted as appropriate. Consequently Niaz suggests that generalizability is not based strictly upon evidence but as a facet of the research communities' consensus. Niaz concludes by noting that it is currently common practice to utilise both qualitative and quantitative research methods. This mixed method approach is encouraged, for example by Ercikan & Roth (2006), who suggested that polarising qualitative and quantitative research methods can have a negative impact upon research in education, proposing instead a more integrated approach. Ercikan & Roth define data as

> "representations of phenomena in nature, society, education and culture" (Ercikan & Roth (2006, p.15))

and suggest that how these representations manifest are then described as either qualitative or quantitative. This research endeavours to use research methods that are appropriate to the investigative environment and the data collected.

Alibali & Nathan (2010) state that, as children spend a large portion of their time in the school environment, it is arguable that school can have a deep effect upon their development. This reason is considered one of many for why education research should be conducted within the school environment. A key reason that is highlighted in their paper is the impact a teacher can have upon how a topic is taught. Therefore, in order to evaluate education tools, it is vital that they are seen within the context of their everyday use, rather than within an artificial environment.

An issue with conducting research within a school environment is the limited ability to control an experiment. For instance, investigations need to be scheduled within the schools' chosen timetable rather than the experimenter's. It can also be hard to design effective comparison investigations, as there are multiple confounding factors such as class size, teacher, and attainment level of the class. While these issues make it hard for the researcher, they highlight again the importance of using a real population for research, as a result from the lab is unlikely to be repeatable or even applicable in reality due to external factors. A benefit of researching within a school environment is the opportunity presented to discuss investigation plans with teachers and develop realistic class room activities to evaluate the tools. Consequently a range of methods were used and adapted for this research, taking inspiration from ethnography, action research, grounded theory and observation methods.

According to Punch & Punch (1998)[23] ethnography can be used to provide an initial insight into the field of interest: this makes it useful as a first stage of research. In particular ethnography can be good for obtaining an understanding of the current environment. With reference to this area of inquiry, ethnography can be used for informing our understanding of the current ways with which technology is used in educational contexts. This information can then be used to develop appropriate methods for smoothly introducing new technologies into school without raising issues for parents, students or teachers. Denzin & Lincoln (2005) noted that Denscombe (2002) identified several important aspects of the ethnographic approach. Perhaps key to this area of inquiry is that:

> "A specific social group will be studied in its natural setting, not the lab; a full ethnographic study would involve the research becoming part of this natural setting."
>
> (Denscombe, 2002 in Denzin & Lincoln, 2005 p.16)

In terms of the current area of inquiry this would involve the researcher immersing themselves in the school environment to observe how students and teachers currently interact with technology. One of the fundamental problems of this kind of research is remaining clear on how the researcher defines themselves and the priority of the project: is it to gain documented evidence of a particular phenomena or is it to embed themselves within the research area of interest? If it is the latter, then very often the documented evidence is neglected. For instance in Dicks (2006), work by Emmison & Smith (2000) is discussed,

[23] cited in Denzin & Lincoln (2005).

in particular their idea that photographs are limited representations of real world phenomena and as such should be viewed as incomplete sources of information. So while documented evidence is excellent for explaining phenomena to others, when conducting an ethnography the important factor is to have a clear and deep personal understanding of the phenomena. Not only is this point paramount to the methodologies undertaken during this research, but it is fundamental to the research itself. By highlighting that photographs are limited representations, it can also draw attention to the idea that any single piece of media is not enough by itself to explain a phenomenon. For instance, the output from a datalogger is not enough to allow interpretation: it needs to be connected to other forms of contextual media, and ideally with a contextual experience.

In an article by Crabtree, Benford, Tennent, Chalmers and Brown (2006) the idea of ethnomethodology is discussed as a form of ethnography whereby the researcher is reporting upon aspects of the real world which are seen but often unseen. They discuss methods of reporting this as either through formal analysis or through thick descriptions. The idea of thick description was developed by Geertz (1926-2006) based upon the work of Gilbert Ryle (1900-1976), It is this idea of thick description which has been used in this thesis. Using the skills of ethnography to discuss and report upon qualitative data as supporting documentation for the quantitative responses. During the two observational studies reported in this thesis the researcher role was shifted to become 'more than' a researcher, becoming part of the student teacher unit and joining in with a lot of the academic activities. Consequently the video data collected for formal analysis was often neglected as a priority. As a result it is more appropriate to present thick descriptions of these events than to formally analyse the video recordings of the event, which do not give a full account of the observations.

It is not only qualitative data which can be hard to collect and seen as insufficient for explaining phenomena. Quantitative data has also had its criticism, with suggestions that it is limited in its ecological validity and that it is too reductionist for the understanding of real world data. It can also be hard to design tests that measure only a single phenomena, with quantitative data being open to interference from confounding factors and unanticipated variables. While both qualitative and quantitative researchers are concerned with understanding cause and effect, qualitative researchers often do so with a specific case study in mind, whereas quantitative researchers will focus on the global scale, looking to provide results which can be replicated (Mahoney & Goertz, 2006).

Everyday education utilises quantitative methodologies to assess students on their learning, employing assessment tests to score the students and situate them on a scale of expertise. This consistent use of quantitative measures within education suggests that this is an acceptable starting point to measure learning effects. This thesis uses these quantitative assessment tools in combination with traditional qualitative research methods to provide an in depth and novel understanding of the impact of technology upon student learning and motivation.

As all the investigations were carried out in collaboration with schools, and four of them occurred in schools, attention was paid to guidance from Woodgate & Stanton Fraser (2006) who report on some of the practical issues of working in schools. They list 7 key constraints and issues, which they have faced in their research:

National Curriculum: Research initiatives will more likely be taken up by teachers if they can be used to teach the curriculum as it means the teachers do not need to find extra time to cover the entire syllabus.

Time: Activities designed need to be easy to run and require little additional preparation work by the teacher.

Technology: It is vital to discuss new technology with teachers and support staff, if new software is required then it is important to give advance notice. It is also important to bring spare equipment in case of fault.

Usability: The research needs to be valid, and the technology must be usable and of benefit to the students, and not just shiny and novel.

Timetable: Consider your research, is it possible to conduct your work within a lesson or would it be more appropriate to work with an after school club?

School Terms: Be aware that schools have many events that cannot be moved, such as OFSTED inspections, exams and holidays. It is important that the researcher is flexible, sensitive to the needs of the school, and works with the staff to time the investigation appropriately.

Consent: Full consent will be needed from the parents, as well as from the school before research can take place. In some cases schools may ask the researchers to obtain Criminal Records Bureau clearance, if this is the case it is important that this is done well in advance of the research.

Each of the investigations was designed with teachers in mind and was considered in regard to the seven suggestions.

13 Investigations and Experimentations

In this section a brief overview of the five investigations conducted for this body of work is provided. In the third chapter the two pilot observation studies are discussed, this is followed by chapters four, five and six which detail the three mixed method investigations. Finally in the seventh chapter the implications of the research are considered and suggestions for future research are reported.

13.1 Pilot Studies

Longitudinal Field Trip Observation

The first study was an ethnographic, experienced based, observation investigation. The primary aim was to understand how dataloggers are currently used within a science module, and explore how the students approach using them. This study was initiated by the invitation of a teacher, Ms X[24], to take part in an extended GCSE field trip and its associated lessons. Over a period of 4 weeks, I was able to attend both the lessons in the field and the lessons in the classroom. During the field work lessons the students were shown how to collect data on the properties of a local river using dataloggers and GPS coordinates. Back in the classroom they collated their data and started work on their coursework projects. The students had not used dataloggers before, so this provided an excellent insight into how they would respond to new tools. Using observation techniques and video recording a focus was placed on understanding how the students interacted with the loggers, and their spontaneous comments about the data, which they collected.

Single Event Observation

The second study also used an ethnographic and observation approach. Working with Ms X again to observe a group of AS Level[25] students in the datalogging part of their Environmental Science Coursework. Initially this observation was going to focus upon comparing a group of students using ScienceScope dataloggers with another group using the school's own resources which involved manual datalogging and record keeping. However due to conditions on the day, the students were working in groups in different sections of the river, making it impractical to observe all of them, a decision was made to solely focus upon the students using the ScienceScope dataloggers and develop

[24] names are anonymised

[25] AS Levels are examinations taken in the penultimate year of school when students are aged 16/17 see Isaacs (2010) for an over view of the education system in the United Kingdom

further the understanding of their initial use of dataloggers. A particular focus was to observe how the students used the dataloggers with minimal support from their teacher, and their spontaneous use of the datalogging functions.

13.2 Ownership and Automation

Ownership and Automation was the first quantitatively designed study. It was developed to explore the concepts of Ownership and Automation. This investigation occurred on the university campus and was run three times, each time with pupils from a different school. Using a mixed methods approach, this investigation explored student learning using pre and post test questionnaires, workbook responses were also qualitatively analysed, while video was used to document the event. Students were split into counterbalanced groups and experienced different methods of data collection and data presentation.

The focus of this investigation was primarily to understand the impact of contextual experience: this was subdivided into "Ownership" and "Centricity". Understanding the impact of changing the centricity and sense of ownership upon the students learning was explored. The pre and post assessments were based upon typical national curriculum questions used during the SAT[26] examinations sat by students of this age range.

13.3 Technology Vs. Traditional

The second study was designed to explore whether there was a difference between using a datalogger, and a traditional non technological piece of equipment for the same task. The aim was to understand whether students performed better with automatic tools. Of particular interest in this study was the student's response to motivation and confidence questions. This study was designed to compare two groups of students. Half the students completed a pulse rate project using a datalogger and half completed the project using a stop watch and the traditional fingers on the wrist technique. The pulse rate project asked the students to consider the effect of exercise on pulse rate and asked them to develop an investigation to test their hypothesis. Conducted within school, this project was designed in response to a teacher inviting the researcher to work with a group of students. As such the experiment was based around a curriculum topic and designed to fit into the school day, increasing its

[26]Standard Assessment Tests (SATs) are tests. students undertake twice during primary school and once during secondary. The results are often used to prepare students for later exams such as GCSE's and A Levels as well as providing the school with data to check the student is in the appropriate class.

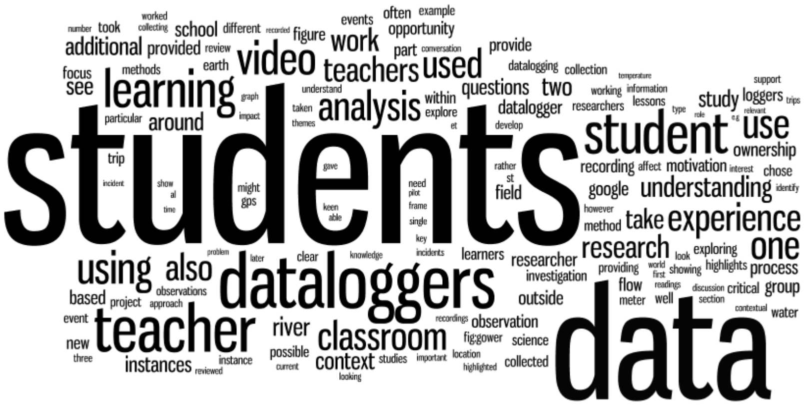
ecological validity.

13.4 Ownership and Technology

The third study was a longitudinal study spanning four months and thirty-four lessons. This project enabled the observation and investigation of a single class as they covered 6 science modules. The teacher worked alongside the researcher to generate new course content that could be used with dataloggers. During this study the students experienced two typical modules, where the students were taught as normal with no intervention from the researchers: two modules where they could use cameras to help them reflect on their learning: and two modules with both dataloggers and cameras. The aim was to understand whether there was a difference in student motivation and assessment performance between providing the students with a tool for reflection, compared to having a tool that would provide a potentially more hands-on experience of science. When the students were provided with cameras they were encouraged to document their learning and were provided with their photos during the next lesson in the series. At the end of each module the students' performances were assessed by the teacher and given a mark. This was consistent with traditional teaching and the assessments used a variety of methods ranging from an end of unit test to homework assessment. The students also completed motivation questionnaires to monitor their enjoyment levels of each module.

Part III

Observations of students on field trips



In order to develop appropriate experimental designs to explore context with regard to learning and motivation, it is important to have experience of the classroom and teaching environment. The main focus of these pilot investigations was to inform later experimental design, with a particular emphasis upon exploring how the dataloggers are used and the student experience of ownership and engagement. The approach used for this was primarily ethnographic, whereby the researcher was embedded within the class. While the lessons and experiences were recorded where possible, the main focus of this part of the process was to gain an understanding of current teaching and secondary education. By using this approach it was possible to take part in the lessons and develop an understanding of how a science lesson is conducted with dataloggers. Through becoming a member of the learning and teaching group it was possible to explore factors that affected the datalogging experience without searching for answers to specific hypotheses, providing an opportunity to gain an understanding not based on predictions and hypotheses but on experience. According to Law (2004) by attempting to organise a messy world, we introduce more mess into our understanding. This highlights the idea that we cannot reduce an event down to a single concept, datum or even description. In the following two studies it was important to stay open minded during the analysis, rewatching the videos to provide new insights and combining this new knowledge with memories and written notes. Despite this the descriptions will be personalised from the experiences and context and therefore are not the equivalent to experiencing the original events.

14 Rationale

Dicks (2006) notes that data collected to measure a phenomenon are merely a representation of the world based upon how we know and experience it. Consequently the data alone cannot provide all the insight and additional information that you would gain from experiencing the context first hand. This idea underlies the ethos of this entire project, and as such it was appropriate to begin this exploration into the use of hand held dataloggers through immersion within a local comprehensive school and gaining first hand experience of how this school currently used dataloggers, and how they responded when provided with additional datalogging tools. This initial exploratory investigation was developed as an exercise in experiencing and documenting current school life, school activities outside the classroom, current use of dataloggers as a tool for learning, and providing an opportunity to talk to students and teachers about their thoughts and experiences, while also providing a chance to see dataloggers used in a real world environment.

Research has shown that field trips can act as a link between classroom science and the more applicable science of the real world allowing students to gain real world experimental skills with the support of the teacher (see Knapp & Barrie, 2001; Rudmann, 1994 for examples). By providing opportunities for the students to use their classroom taught skills it can be demonstrated how these skills are applicable to the real world and can encourage interaction and interest with the subject.

> "Trips can create relevancy to science classroom learning when connected to the outside world" (Rudmann, 1994, p.139)

Building on Rudmann (1994) and work by Deaney et al. (2006) who observed methods of teaching using dataloggers within the classroom, an observational investigation was developed in collaboration with a school teacher who currently uses the dataloggers, aiming to understand the role of handheld technology within the current curriculum. The focus was on how dataloggers can be used outside and inside of the classroom, exploring how data collected during the field trip is transferred for analysis and displayed as graphs and visualisations by the students.

15 Analysis

Video recordings allow researchers to review a phenomenon. The data can be repeatedly analysed and scrutinised using a variety of techniques (Heath &

Hindmarsh, 2002). Early investigations using video focused on documenting aspects such as human movement and facial expressions with video allowing the researcher to review frame by frame (Heath et al., 2010). Later, work based studies became prevalent with researchers interested in understanding how communication and organisational activities occur in the work place. These investigations used video to investigate communication and collaboration, exploring how people used objects, gaze and body language in addition to verbal communication. The method used to analyse the video is dependent upon the questions being asked, and the interests of the research will impact upon which parts of the video are selected for analysis. For instance questions that focus on exploring how medical personnel interact with tools during an operation may require a frame by frame analysis to pinpoint instances of gaze towards displays and minor adjustments of dials. In this type of research conducting a critical incident or conversation analysis would not extract the relevant data to answer the question. If however the researcher was interested in differences between formal and informal talk in the operating theatre then the inclusion of conversation analysis would be vital, and it could be combined with a frame by frame analysis to pinpoint the context around changes in language.

There are two key ways of extracting data for analysis: inductive or deductive. Inductive approaches occur when the data is viewed with broad questions in mind. In contrast a deductive approach is used when there are clearly articulated research questions. In this instance, samples are systematically extracted to answer specific questions. According to Derry et al. (2010, pg 16)

"it makes sense to go into a project with theoretically motivated questions that originate from the research literature or observations".

However, they also note the importance of being open to the possibility of discovering new phenomena. Furthermore Callanan (2007) discusses how video analysis allowed the extension of their research into learning in museums to include a focus on gender differences, something which they had not anticipated, but became apparent through a review of their video data. This highlights the importance of keeping an open mind when reviewing the video data.

Work by Leech & Onwuegbuzie (2008) documents a variety of qualitative analysis methods that could be applied to video analysis. These include methods such as Key Words-in-Context (KWIC) whereby researchers review the data to explore how particular words are used and the context around their use. Similarly, they note that it is possible to quantify aspects of the video data by documenting the number of times a certain phrase, word or event occurs.

Leech & Onwuegbuzie note that different approaches are appropriate for different research questions and that it may be beneficial to use a selection of methods to triangulate the results. For instance a word count could be supported by also undertaking a KWIC analysis to establish how the word is used in each instance and whether there is consistency in its use.

A review of the learning and technology literature shows that researchers have used a variety of methods for analysing qualitative data. For example, in the SENSE project critical incidents were reported based on instances that showed

"delayed readings, effect of the wind on the readings, and recall on incidences of particular import" (Stanton Fraser et al., 2005, pg 3).

This is similar to a method discussed by FitzGerald (2012) who notes that a common analysis method in the HCI[27] literature is to utilise the critical incident technique, [28] Abergbengtsson (2006) used a similar technique which looked to understand how students constructed graphs:

> "The video-recordings were carefully scrutinised several times and the most interesting sections were transcribed verbatim," Abergbengtsson (2006, pg 121).

In education research this technique has been used to highlight breakthroughs and breakdowns, often as a tool for reflection. The researcher will in this instance show footage of the events to the teacher or student, and ask them to further reflect and provide more depth and detail around the incident. Conducting research in this manner allows researchers to respond to the video and develop their understanding further by asking questions of the participants. This kind of follow up interview was not possible for the data collected during the pilot studies.

Ash (2007) describes an approach that uses three levels of analysis. Firstly, the researcher will flow chart the whole event and provide an overview of the events including any additional interview details. This is followed by an intermediate analysis to identify significant events. This analysis looks at events in greater detail and considers the tools used and the interactions between participants. The third level is termed microgenetic and focuses on the dialogue. By using these three stages it is possible to gain an impression of the overall event but also to focus in on specific incidents that reflect and respond to the research questions.

Another method used by researchers is to select timed excerpts of the

[27] Human Computer Interaction

[28] introduced by Flanagan (1954)

footage for analysis. For instance, in their work on Kidstory, Abnett, Stanton, Neale and O'Malley (2001) were interested in understanding how pairs of students collaborated in computer based storytelling, using either one mouse or two. They chose to analyse a ten minute section within their video, focusing on instances when students were occupied with the task of drawing a car. They coded the conversation between the pairs and analysed the types of conversation. Choosing a ten minute section allowed the researchers to concentrate their attention on an event which all the pairs experienced, focusing upon details and enabling them to answer specific questions relating to mouse use across the different student pairs. This type of analysis is not appropriate for the data recorded in the pilot studies as the video was not of a single event such as working for a period of time at a computer, but captured students working in rivers, moving along the rivers and often the video cuts out and moves to a new location. Therefore, to just select the middle segment of each clip, or to review every 2 minutes would not provide an accurate overview of the entire event, and there would be potential to miss details that could inform future investigations. Furthermore this style of analysis is useful when you are comparing an intervention, e.g. the use of two mice or a single mouse for interacting with a computer. In this research the video was intended to provide a situated understanding of current datalogging practice, as opposed to exploring a comparison.

A third approach is to focus purely on the talk which occurs during the video footage. This form of conversational analysis might provide an insight into questions around the language used by students to indicate their ownership of the data or their level of engagement in the field trip. This type of analysis would also be an insightful way of exploring when students are on topic, by observing the content of their conversation. However an in-depth analysis of the conversation had by the students would be limited here, as the sound quality in the open air, with participants quite widely distributed, renders the majority of the utterance unintelligible. Therefore an analysis of the audible parts of the conversation would be limited in its usefulness.

An alternative method would be to generate codes based on the data. For example in their study looking into play and navigation, Bell et al. (2009) conducted interviews and then performed a thematic analysis looking for instances of student motivation, game styles and relationships between player. These themes were derived from the interviews and connected photographs. In these cases the researcher is often guided by previous research for ideas of what to identify and how to generate appropriate themes. Similarly Cole & Stanton (2003) reviewed their video tapes looking for particular instances of sharing behaviour, while Crook et al. (2010) reviewed their video and interview transcript for topics which were relevant to developing their understanding around scientific reasoning, personal inquiry and personal ownership. While this kind of analysis would be possible with the data collected, the present study is interested in discovering as much as possible about current practice, while avoiding predefining our expectations. Thus, what is required here is an open ethnographic approach, as using a predetermined coding frame would limit the extent to which new and unexpected behaviours could be identified. The data collected during these pilot studies is most appropriately reviewed using the Critical Incident Technique, in a manner similar to FitzGerald (2012) and Stanton Fraser et al. (2005). Critical incidents are identified by considering factors which relate to context such as ownership and seams, a focus is also placed upon understanding how dataloggers are used by the students and teachers.

It is apparent that often researchers will explore their observation and interview data with themes in mind, looking to extract instances of interest for further review. Ideally a method such as this will result in what Geertz (1973) termed 'Thick Descriptions'. Segall (1989) describes thick descriptions as layered descriptions that are rich in context and allow the reader to draw their own conclusions about the event. Obtaining a thick description is easier if, as in critical incident theory, the researcher can return to the observed subjects and ask them to provide further details about their motivations and experience of the event. It is possible to combine these approaches and utilise aspects of both to provide an in-depth review of the data.

Erikson (2006) discusses three distinct approaches to video analysis. Type one uses a bottom up approach, forming themes and codes from reviewing the video. Type two offers an alternative approach whereby the researcher identifies specific events driven by research questions. Type three involves selecting a particular topic within the subject of interest, for instance equations within a maths lesson, the researcher then looks for all instances where equations are mentioned or involved. In summary, a researcher can be guided by the video, by the research or by an object or concept.

The current research uses a methodology which fits within the second type, a method which is based around the idea of critical events, allowing for identification of key events which can inform the design of later studies. Thus the video shot during this research has been transcribed to document all intelligible verbal instances (available in the appendix on page 311), which are then analysed to identify key instances of the students using the dataloggers. This includes where there are problems with the dataloggers, instances where additional learning has occurred as a result of the students conducting their research in the wild, and instances where the students appear particularly motivated. These events are then described in more detail, situating the transcript and providing the reader with the ability to make their own interpretation based upon the extracts. Focus is placed upon exploring the video with relation to contextual experience and contextual media, in particular understanding the role of dataloggers in terms of impacting the student's sense of ownership and centricity with the data, as well as instances where seams and disruptions in the process impact upon the learning experience.

16 Longitudinal Field Trip Observation

The first investigation targeted two of the four research questions:

To what extent does automation affect the student's learning and motivation?

This investigation provided an opportunity to see first hand how students respond to the opportunity to use dataloggers to record data which previously would have required them to take written notes.

How does contextual experience with a data logger affect learning and motivation?

The intention was to explore if the students felt a greater affinity to their own data, if they felt ownership over their own data, and how this might affect their motivation.

16.1 Participants

Seven male Environmental Science GCSE[29] students consented to take part in the investigation[30]. They were supported by a variety of teachers including one student teacher. Ms X, who was supported by two other teachers within the department, led the investigation. On a couple of occasions Ms X was unavailable to attend the investigation so a different teacher would step in. As the students were leading their own learning the teachers were there to support the process rather than lead. It was common within the school for teachers to step in and cover lessons so this was not an unusual experience for the students.

[29]The General Certificate of Secondary Education, more commonly known as a GCSE, is a compulsory course and test taken by British students over a period of two years between the ages of 14 and 16. A number of subjects such as Maths, Science and English are compulsory, additional subjects such as Environmental Science are taken as an option course. Students commonly take 10 GCSEs

[30]Consent and information forms for all experiments can be found in the appendix, see A.1 on page 258

16.2 Procedure

The first study was an ethnographic, experienced based, observation investigation to understand how dataloggers are currently used within a science module and explore how the students experience their use. This study was conducted based on an invitation from a teacher, Ms X, to take part in an extended GCSE field trip and its associated lessons. Lasting for a period of 4 weeks, including three lessons in the field and three lessons in the classroom. During the fieldwork lessons the students were shown how to collect data on the properties of a local river, using dataloggers and GPS. In the classroom the students collated their data and started their coursework. The students were unfamiliar with dataloggers so this provided an excellent insight into how they would respond to new tools. This research used observation techniques and video recording to understand how the students handled the loggers, and their spontaneous comments about the data that they collected.

The students were required to undertake the project as part of their environmental science GCSE. The project had been designed by Ms X to take place on a local river, exploring how the river characteristics changed as it flowed downstream. As the river was located in the same town as the school, a number of the students had an initial familiarity with its characteristics based on its geographic positioning. This investigation was part of the schools standard curriculum. However, although the teacher had run the project before she had not done it with the support of the automated dataloggers. The school had a limited number of loggers of their own, so while the teacher was experienced, there had not been enough pieces of equipment previously to use with a sizeable group, due to a lack of this resource she had previously used other apparatus. We provided additional dataloggers, of the same model that the school already used, and GPS devices to enable the students to work in groups sharing the dataloggers.

The learners were introduced to GPS recorders and dataloggers that could take measurements of dissolved oxygen, river flow and pH and link these measurements to specific locations along the river's course. The group went on a number of field trips to the river where they used the technology to take snap shot recordings, combined with a standard kick sampling technique to survey invertebrate species at the locations where the snapshot recordings were taken. This enabled them to develop an understanding of both how the physical characteristics of the river change along its course, and also how these changes impact on the animals which inhabit it. Finally the learners uploaded their sensor data into the JData 3D (see figure 9.5 on page 63) software to produce a graph overlaid onto Google Earth, enabling them to see a geographic representation of their data.

16.3 Methodology

Ethnographically informed observation work was undertaken and the field trips and classroom lessons were video recorded. The project ran for approximately 4 weeks with the students having at least one lesson a week. The classroom based lessons were of normal length, one hour, while the lessons outside of the classroom were longer, approximately three hours. Ethical approval was gained for the study and each student and their parents/guardians gave their consent to participate. The researcher often took an active role in the class, which meant that it was easy to listen and observe the learners as they developed their knowledge of the dataloggers. An initial interpretation based on the experience with the learners suggested that they found it highly motivating to be outside of the classroom. They were also keen to use the dataloggers – often arguing over who got to use which one. One student chose to bring a personal camera on the trips to supplement his river data with photographs.

The video was transcribed and separated into instances inside or outside of the classroom. It was then reviewed with key themes in mind to identify critical incidents:

Outside How do students and teachers use the dataloggers? - e.g levels of confidence, questions asked.

Outside How do dataloggers facilitate extra learning? - e.g. discussions around data quality, data collection and context relevant learning.

Outside & Classroom Evidence of student engagement - e.g instances of students displaying interest and ownership over data.

Classroom Evidence of data handling - e.g discussions around how to display their data, understanding of the representations.

Outside & Classroom Seams in the learning - e.g. how do disruptions in the logging and data analysis affect the class.

As the focus is on the learning experience for the students, analysis focused upon interaction between the students with teachers, peers and researchers, rather than interactions between teachers and colleagues, or teachers and researchers. The following section presents critical incidents identified from the video footage that reflect the key themes. Often the themes show overlap, in particular understanding how the dataloggers are used provides insight into additional learning, and sometimes highlights student engagement.

16.4 Observations

In this thesis the research is focused upon understanding how automating the data collection and providing personal experience of the data collection process can affect students' learning and motivation. In the following section, events from the observation that relate to these two questions are highlighted and discussed. The observations are split into two sections: learning 'outside' and learning 'inside'. Instances are highlighted which affect the students learning experience as well as instances which showcase how the teachers have to adapt their teaching and work in an environment different to a classroom.

During the descriptions the teachers will be identified by the letter T, student teachers by ST, the researcher by SM and the pupils by the letter P.

Outside of the Classroom

It was clear from the beginning that the students were keen to be outside of the school and to be using a new technology. They all wanted to be involved and each gave themselves a designated role (see figures 16.1a and 16.1b). The teachers were familiar with the students already and were happy to work with them on more informal terms than you would find in the classroom. For instance, one teacher shared his sweets with everyone. The atmosphere was relaxed and teachers and students were openly discussing science and learning with each other. The teachers admitted that they had limited experience with the dataloggers and were keen to see them in use by the students.

(a) Boys taking readings (b) Students working independently

Figure 16.1: The students worked independently, but took readings in the same place and communicated to let each other know which reading was required

Early on the student teacher (ST) realised that two of the groups were recording and using the dataloggers differently:

(ST) "Can I just check, with your logbooking, do you do a new snapshot? one of 200, two of 200 etc?"

(P) "Yup"

(ST) "Because those guys went out and made a new file, don't do that, do what you're doing"

Here one group of students had been exploring with the dataloggers but had consequently generated new files rather than storing the snapshots sequentially, the ST realised that this would mean the multiple files could not be compared with the single GPS file. This is clear evidence of the teacher learning on the job and sharing new knowledge with the students.

The ST also learnt how to use the GPS equipment and taught the students how to use it

(ST) "and if you press page on the right there"

The students were also clearly aware of what they needed to record. One student who was using the flow meter noticed that his datalogger was not taking the correct recording:

(P) "Does it have speed on this one? Like on [Student's Name]'s one, when we had the other one, this has temperature in degrees, and then DB, decibels."

(SM) "Is it plugged in?"

(P) "Yes"

(ST) "It's not actually spinning though"

At this point the students and the ST realised that the flowmeter had become tangled in pond weed which was preventing it from recording.

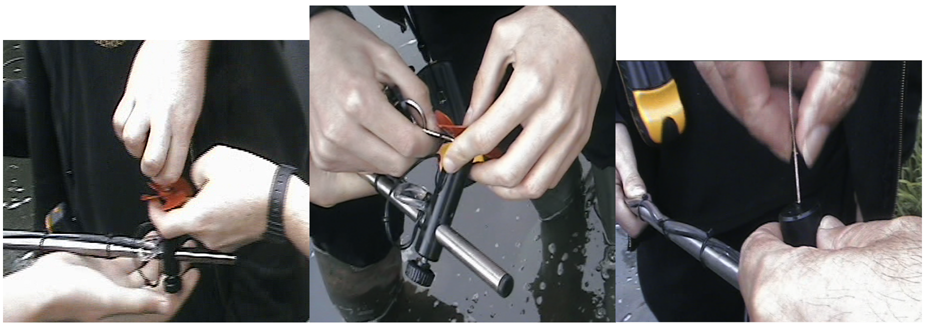
(P) " Is there anything tangled in there?"

While they were removing the weeds (see figure 16.2) they discussed the need to switch the datalogger off:

(ST) "Save the data and switch it off and on"

(P - sat on the bank, not involved in removing the weeds) "the thing about these dataloggers is you switch them off and then on again and they are still connected"

(ST) - "They have a memory to save it, that's brilliant isn't it?"



(a) Unscrewing the flow meter (b) Using a key to help unscrew (c) Teacher using a stick to remove river weed

Figure 16.2: Fixing the flow meter

During the process of fixing the flow meter the students and teachers collaborated on the same level, each offering suggestions. The students were taught informally when the ST informed them "Lefty loosey" when they were trying to work out how to unscrew the flow meter. This informal learning, while not directly relevant to the curriculum topics is something which may be less likely to happen within the classroom environment.

The previous example highlights how the students and the teacher had to learn new topics and develop solutions while out in the field.The students were motivated to fix the dataloggers and determined to find solutions for their problems.

In addition to having to fix their equipment, the students also had to be aware of factors which might affect their results:

(P1) "There's a dead bird here",

(P2) "Oh! I'll have to take another sample".

This contextual information is important for the students, so they can develop an understanding of how hard it is to get optimum results in the field. They also had to adapt their data sampling techniques. At one point the students had to lay down on a bridge (see figure 16.3) in order to get their measurements. However, they were unable to obtain a water sample to measure the temperature: this meant that at this location, they would be missing a datapoint for temperature. As the students were in charge of collecting the data they were able to understand why there was a missing datapoint, whereas had they just been provided with a dataset with a missing point then they would have had no information to explain why there was no temperature data at this point.

Figure 16.3: Students laying down on the bridge to obtain readings

Throughout the trip, the teachers kept the students informed about their location and their route (see figure 16.4), highlighting that they wanted to take measurements at the same places as in previous years so that they can build up a larger dataset. This provided the students with a reason for their datalogging and explained the logic behind some of the locations chosen for the recording. The teacher also used the students' local knowledge, by choosing to take an additional reading from a bridge which a student knew was nearby. This pre-existing understanding of the area also provides additional context for the students, as they were already familiar with the location and how it might impact their river readings.

Figure 16.4: Teacher showing the students on a map where they will take their data readings

The teachers were often required to teach new topics in response to what the students were doing. For instance, one group of students chose to take a recording in a section of the river where it was flowing quickly past some rocks:

(T) "What's happening to the dissolved Oxygen here?"

(P) "It's going lower and lower"

(T) "That's because the turbulence is pulling the O2 into the water"

Again, it is clear that, had the student just been presented with the dataset, it would have been difficult for the student to deduce the reason for the drop in the Oxygen levels. This highlights the benefit of understanding the context and personal experience. It was also clear that the students chose to record in that location because they thought it was interesting and exciting, showing how they were motivated to do their work. The skills of the teacher turned this opportunity into a learning experience.

A second example was with a different teacher who started discussing the symbiotic relationship between some of the animals and plants along the river course. The students were keen to find examples of this; figure 16.5 shows a student lifting a crab from the water to show the teacher. The teacher then responded with a discussion around the crab, which again highlights an opportunity taken to provide additional information to the students' which was not directly relevant but would help provide context and additional information.

Figure 16.5: Student showing the teacher a creature that he found in the water

The students also questioned the teachers and each other throughout the experience, negotiating the data collection methods, and taking control of the collection process.

(P1) "Do we need to leave the flow meter in for a minute like with the other samples?"

(P2) "no have it in for about 10 or 20 seconds"

(P) "remember I've got the GPS so you need to measure near me."

(P) "don't do that, you're disturbing the flow walking past us"

(P) "oo that's fast isn't it, does that make sense?"

(P) "I have to work on the assumption that it has taken a snap shot, because if it has it hasn't given me any indication"

From these extracts it is clear that the students relied on each other for answers, and were concerned about external factors and their implications on the data as well as the accuracy of the loggers. The students acknowledged that they did not know what a normal result should look like, and queried their teacher for what to expect. Initially they found it hard to know whether they had recorded data or not - they were wary of going out of one part of the datalogger interface and into another to view their recordings, in case it messed up the save file. However through repeated use of the datalogger, there was an increase in their confidence around their ability to use the loggers, and what was happening behind the scenes.

In the Classroom

In the classroom the students were encouraged to explore the data and find methods for displaying the information. The teacher was keen for them to develop their own ideas, and acted as a facilitator and a sounding board, rather than an instructor.

(P) " If we try and condense all of that data into one graph it's not going to work"

(T) "What we are trying to do is come up with a way of making this data, a combination of Google Earth and the actual written numbers make sense so this tells a story and so you can interpret the data. [...] all we want is a way of doing it, we can do it later on, but we want the way of doing it."

(P) "the first thing would be to put it into a graph, into several graphs for each different thing I suggest on these excel files we might as well condense date, time latitude and longitude into one column and then it will use them for an x axis, and we can use all of these reading for the y- axis on about 5 different graphs"

(T) - "okay can you make it happen, who says make it so? Picard?"

The teacher passed on knowledge that she had gained from her use of the software

(T) "let me just show you, unclick the, take the calibration data away, I think it is easier to understand the data."

(T) "that's a good idea,"

(P) "what?"

(T) "What [Student's name] is doing, let's see that document again , you've actually got the data next to it."

The student had taken a screen shot of google earth to show the relevant location and then created a table next to it to report on the data values, see figure 16.6. While this does not include a graph, it highlights how the students were generating their own ideas for visualising the data, and exploring different methods.

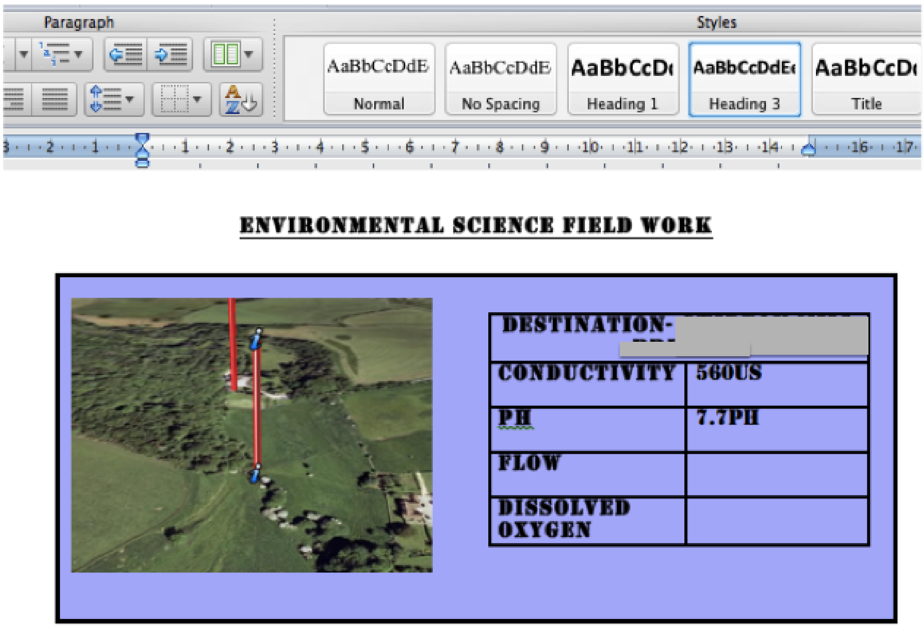


Figure 16.6: Example idea from a student on how to lay out the data

The teacher went on to suggest improvements, showing enthusiasm for all the methods and encouraging the students to develop more ways to display the data, including suggesting they explore a way to place their data values on top of the Google Earth map.

(T) "do we need to graph the data or would this be sufficient?, is there too much, I'm just wondering if we should summarise it? You could put a small bar chart there next to it? .... You're working on a different way of doing it, so we've got two good ideas, we sort of need a third really,"

The suggestion of using Google Earth as a method for situating the data led to a discussion around the value of Google Earth and its accuracy due to the photos being updated infrequently. The students could tell that the photographs of the area were old as the school had recently been going through a new build process.

(P) "I think these pictures were taken ages ago, because even though the school is there, the TVR building, which has now been knocked down is still there."

The teacher and student went on to discuss certain attributes of the school and the photo to conclude that the photo must have been taken around 2006/7 (two to three years earlier). This discussion highlights the informal learning which takes place in the classroom environment. The teacher took advantage of a seam in the learning. By discussing the age of the photo, the teacher was encouraging the student to think about sources of data and their validity Another example of a seam during the process was the requirement to spend time uploading the data, the teacher exploited this disruption by encouraging students to upload the data themselves, providing them with an opportunity to make decisions around data presentation.

(P) "Have you uploaded the data from this week?"

(T) "I have't yet I was going to show you the process"

(SM) "Did you pick discrete or continuous?"

(T) "I put discrete because they're only, they're not really connected"

During the evaluation stage of the project one of the students queried the reliability of the data that they had taken.

(P) "I think there may be something erroneous with the conductivity data"

(SM) "why do you say that?"

(P) "Because, all of these are at 560."

Upon further investigation it was concluded that the datalogger had been connected to both a conductivity meter and an additional meter, and while the second meter had recorded correctly the conductivity data had been incorrectly uploaded. This example highlights that the student was able to identify a problem with the data as it was showing unanticipated responses. He was also able to establish the cause of the problem and provide a solution, uploading the data again.

Ownership of data was displayed by the students, often by them identifying when they thought the data belonged to them:

(P) "Is that the datalogger I was on? look that's following everywhere that I went, Is that the one that I was on?"

One student was particularly engaged with the task and was very excited to identify data points on the graph which he knew he had been responsible for collecting. See figure 16.7 showing the student pointing to the screen.

(P) "look, look, I took that, well me and [xx] took that, good"

Figure 16.7: Student pointing at the screen when he sees his own data "Look, look, I took that"

The students were able to identify when the data was unexpected and draw conclusions for possible explanations:

(P)"There's two readings, there's one on the road"

(P2)"Where abouts was it?"

(P1)"the bridge last friday, right at the end before we left"

(P2)"Unless (TN) walked back to get the mini bus or something"

The way students talked about the data suggested that as a group they shared ownership of the data and would collaborate on the best methods to display it.

(P) "Has everyone else been working on some of those aswell? Because we want to present all of our data"

(SM) "You were doing longitude an latitude points last time weren't you?"

(T) "it really didn't work, we'll have to come up with.... (SN)'s is probably the best way."

16.5 Discussion

The aim of this observation was to explore how the students responded to the use of dataloggers, and what impact it had upon their motivation. From the extracts it is clear to see that the students enjoyed using the dataloggers and were heavily motivated to use them. Even when they experienced problems, the students were keen to find solutions and continue logging data, indicating that seams caused by problems did not disrupt the students interest. The students were not afraid of the loggers, and as time passed they become more adept and confident with using them. Furthermore, the students were inventive in their use of the loggers and their exploration of the river: for example when they chose to take a recording in a faster flowing section. This supports the literature on motivation, which suggests that when students are enjoying themselves they will apply more effort (Palmer, 2005). Furthermore the use of dataloggers seems to fit alongside the work by Lepper (1988), which discusses how intrinsic motivation can be encouraged through: challenge, curiosity, contextualisation and control. The experiences of the students have shown that they are interested in the loggers and value the additional context of a school trip, they also appeared to appreciate being given a level of control over their data collection.

It was very clear from this experience that the teachers worked as learning facilitators rather than instructors, and that the dataloggers were a tool used for shaping the learning discussion, giving control to the students. The students worked collaboratively inside and outside of the classroom, sharing resources and ideas, acting as a cohesive unit rather than individuals.

One student chose to bring his own camera on the trip highlighting his understanding that recording information and context were important for his report, and his motivation to support his own learning. The teachers were responsive to the students and took opportunities to pass on additional knowledge and to encourage the students to question their own understanding. Unfortunately it was not possible to obtain the final coursework to understand if the photographs were incorporated into the work, and what support they gave the student in providing context for the datalogging.

When the students were in the classroom they were keen to be involved in uploading the data and exploring how it could be displayed cartographically. There was particular enthusiasm when a student could relate the numerical data to a location, or to a memory of having collected the data, the students were also able to explain issues with the data. The teacher was able to use disruptions in the lesson to her benefit, for example using the student's digression on Google Earth as an opportunity to discuss its reliability as a resource.

In conclusion, it was apparent that the dataloggers provided were a useful learning tool for the students. They were easy to use and the students responded well. The experience of doing field work was well received and led to discussions which may not have occurred had the activities been confined to the classroom, using this method has provided an insight into how students and teachers are currently using dataloggers.

17 Single Event Observation

Following the observation described above, a similar research opportunity was offered by the same school to observe a group of AS Level students[31] as they took part in another environmental science field trip. This differed from the first observational study, as this was a standalone, one day trip to a more distant location, compared to the locally based weekly trips of the year 10 students who

[31] AS Levels are qualifications studied after GCSEs they are the equivalent of half an ALevel

were working on the river project. This study provided the opportunity to closely follow learners using dataloggers, and others using more 'traditional' scientific measuring methodologies in line with the AS Level syllabus. Again, ethical approval was gained in advance for the study and each student and their parents/guardians gave their consent to participate and for video recording. An interesting incident occurred during this study when a 'traditional' flow meter broke, leaving some learners unable to complete their task. The learners who were using the ScienceScope dataloggers stopped their own recordings, and spontaneously interacted with the dataloggers to change the settings so they could help out their peers. This was very insightful, as the learners had not been shown that aspect of the dataloggers.

This investigation targeted two of the four research aims:

To what extent does automation affect the student's learning and motivation?

This investigation allowed the exploration of how students responded to being provided with dataloggers as a method of automating the datalogging process.

How does contextual experience with a data logger affect learning and motivation?

As before the focus was to understand the impact of the contextual experience upon the students.

As in the previous observation study the video was reviewed with general questions in mind around, how the students used the dataloggers, how the loggers facilitated the learning, and evidence of student engagement.

17.1 Participants

Initially all the students on the trip, around 25, were to take part in the study. However, during the course of the study a decision was made to focus upon a single group of five male students, ranging in age from 16 to 18 in order to capture more in-depth data. Consent was gained from the five students and their parents/guardians. The remaining students still took part in the educational trip but were not directly subject to filming and observation. Where additional students appear on screen their identities have been hidden.

17.2 Methodology

As in the previous observation study the students were video taped during their field work, again the researcher took an active role in the class. As in the earlier study the video data was limited in its quality. The video was transcribed and critical incidents are reported in a chronological order. The critical incidents were identified by focusing on events that highlighted how the dataloggers were being used and handled, and examples of the loggers supporting learning and engagement.

17.3 Observations

Initial observations while in the field indicated that the teacher was very confident with handling the dataloggers and had designed a device to enable the students to recover water samples from the centre of a fast flowing river. The device was basically a measuring beaker fixed to a long pole. She gave roles to each of the students and presented them with the appropriate sensors. She also chose to become part of the group and be in charge of GPS recording. By assigning herself a role the teacher gave herself the opportunity to stay involved with the datalogging group and to give them additional support. Figure 17.1 is a clip of the teacher showing the students the datalogger. She holds it on the corner, indicating that she is familiar with the datalogger and does not feel the need to use two hands.

Figure 17.1: Teacher holding a datalogger

This shows her confidence to the students, and in turn gives them additional confidence in the design and durability. The teacher informed the students that

(T)*"you do not have to write anything down"* which led a student to respond

(P) *"That's quite fortunate"*

indicating their pleasure that the process would be automated. This was followed by a second comment from a student:

(P) *"and all of that's recorded on there?"*

These comments indicate that the students were unfamiliar with dataloggers, but were quite happy to accept what the teacher described about the loggers. The teacher went on to talk them through the functions, and to give out the sensors. She chose to keep the GPS unit for herself so she could stay involved with the group. Figures 17.2 and 17.3 show the teacher explaining to the students about the dataloggers.

Figure 17.2: Students looking at the sensors

Figure 17.3: Students Collecting Data

Initially the teacher talks them through the process:

(T)*"Pots in, down, fill, up, sensor in"*

Soon the teacher is called away and the students continue to work alone. A few minutes later one of the students reports a problem with the temperature probe.

(P) *"temperature probe is not liking this?!"*

(SM) *"What's it saying,"*

(P) *"146ºC, I wonder if it's not connected properly?"* ....

The student spontaneously solves the problem

(P) *"There we go that's correct"*

(SM) *"I don't know why it goes up when it's not connected properly"*

(P) *"hah, maybe it's just British optimism"*

This extract highlights how the student found it very easy to fix a problem themselves, and showed little concern regarding it, it also suggests that they were engaged with the process and chose to fix the datalogger, rather than stopping the experiment and waiting for the teacher. Evidence of motivation was also indicated when a student chose to take additional recordings.

(P) *"might aswell do it again to get a bit of experience.*"

Figure 17.4 shows the students looking at the datalogger when they have the unusual result.

Figure 17.4: Using the water flow sensor

A little later the student referred to the cost of the dataloggers and their value:

(P) *"I might need a hand there„„ alright you grab on that„„, you grab the sensitive valuables*"

It is clear that the student is aware of the monetary value of the datalogger, but also their confidence in using the device despite its value.

As the project continued the students started to think more about their data and started to query how the dataloggers worked, and potential improvements.

(P) *"How do we know which snapshots are which?,"*

(SM) *"there's a clock in there so that will connect the snapshot with the GPS."*

(T) *"It's cool innit"*

Part way through the day, one of the other student groups had problems with their equipment. The students with the dataloggers worked out how to change modes so that they could read off their snapshot data as well as record it. This enabled them to work alongside the other group and provide data recordings. This is shown in figure 17.5

Figure 17.5: datalogging students helping the other students with their data recording

During this stage of data collection the students decided their flow meter might have stopped working temporarily. They fixed it, and then chose to redo the snapshot. This all occurred without teacher intervention showing the autonomy of the students.

When the students walked to a faster patch of river (see Figure 17.6) Ms X indicated that only the datalogging students would be allowed into the water, assigning the students more responsibility and also indicating the faith the teacher had in the technology as now this would be the single measurement resource for the whole class.

Figure 17.6: Ms X helping the students in a rough area of water

Shortly after this, a decision was made for the class to separate and for the datalogging group to continue along the river route. The remaining students would walk with another teacher to the bay and continue their kick sampling there. This was partially due to the students having had little interaction with the river. This highlighted that the teacher was more confident using the dataloggers in the water, potentially because they could be used at distance. Despite this trust in the datalogging students it was still vitally important that the students worked together (see Figure 17.7). At one point it was particularly precarious and the students had to work well together to prevent the loggers falling into the water.

Figure 17.7: Students working together to take a recording in a section of fast flowing water

(P)"we're sampling buddies!"

(T) *"Now get safely out, equipment first!"*

This danger was handled with humour highlighting the awareness of the situation but without showing it as a problem.

As the students became more familiar with the loggers they were visibly more comfortable using them: see figure 17.8 of student with the cable slung around his neck. Similarly, there were fewer requests for help, and the students tended to keep their datalogger and individuals became the designated keeper of certain pieces of equipment.

Figure 17.8: Student 'wearing' the datalogger

At the end of the day one of the students spontaneously provided feedback:

(P)*"tell him he's designed it well".*

(SM) *"why, what are you saying?"*

(P) *"well you don't have to switch it back on to scroll between screens you can read off all the data and take samples at the same time"*

It was interesting to see that the students had discovered this early on, but still found this an important factor at the end of the session, even when this functionality was no longer required.

At one of the final data points the students were collecting data in the sea, the teacher commented that

"the tide's coming in, it will be good for your salinity"

it is clear that she was using this as an opportunity to highlight to the students that their environment would have an impact on the data and that they should remember it when they reviewed the data later. This example shows how collecting their own data gave them contextual experience to help support their learning.

Figures 17.9 and 17.10 show the pH measurements in two formats: Google Maps and Google Earth. The students reviewed these at a later date, with the teacher informing the researcher that the students had enjoyed using the dataloggers and had been impressed with the GPS tracking aspect.

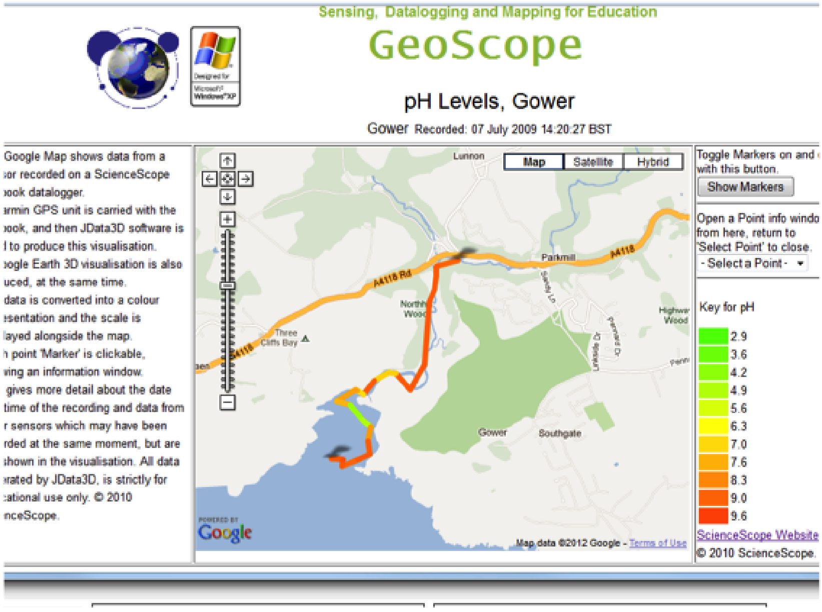


Figure 17.9: Google Maps image of the collected data

Figure 17.10: Graphical data visualisation using Google Earth

17.4 Discussion

Both of these observational studies highlighted that learners studying for important examinations enjoyed and appreciated the benefits of the dataloggers, such as the instant feedback on the result, and the removal of the need to manually record results. Minor issues arose due to the use of the dataloggers such as running out of battery, and weeds getting tangled, however these were easily overcome. Indeed these seams in the learning process allowed the teachers to encourage the students to reflect on their data and factors that might have affected their results, it also provided opportunity for spontaneous knowledge sharing, such as "lefty loosey".

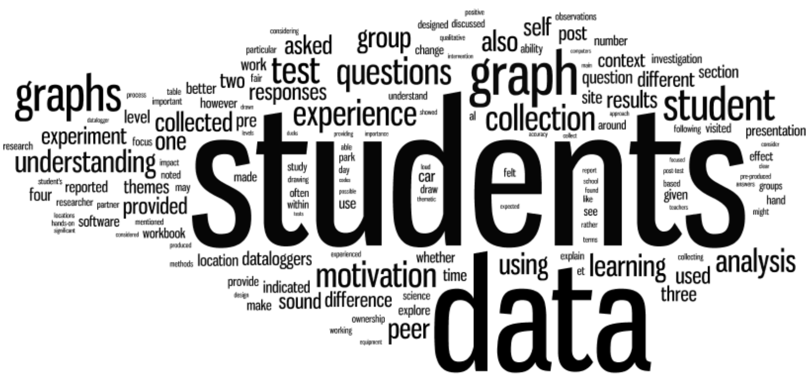
Classroom observations showed how the learners were both impressed with, and could utilise effectively, the combined data and context outputs which showed their river data superimposed upon a Google Earth map, through the use of GPS loggers, the students were clearly familiar with using Excel and Google Earth and were happy to work independently on their projects. In addition a number of other aspects became apparent: the learners often worked in groups and passed the dataloggers around resulting in their sharing all the data, and often worked together to produce a comprehensive data set and report rather than work individually. A review of the video provided a number of points to consider for future work, such as whether the collected data was seen to belong to the student "look look that's mine" or whether it was group ownership "we want to present all of our data". The importance of the teacher was also evident as the teacher was able to guide the students through the data collection process and keep students on task during the collection and analysis stages, in particular the ability of the teacher to take the student's interest in Google Earth and turn it into a discussion around reliability.

Observation in the classroom highlighted that the learners were often reporting on their data graphs without a clear understanding of what they represented, and that some students left other students to do the work for them. These observations suggest that it would be interesting to explore how students interact with data that they have not collected and whether automatic functions such as graphing hinder their ability to interpret the graph. Overall these pilot studies have provided an invaluable insight into how teachers currently support student learning with dataloggers, it also highlighted aspects for future research. The methodology undertaken for this study has proved to be a useful method for identifying points of interest without losing the context of the whole experience.

The observations from these two pilot studies informed the design of the Ownership and Automation study. Noting that sometimes students took ownership of the data, while at other points they shared their ideas and ownership, the Ownership and Automation study was designed to target differences in student learning when they have direct experience of data collection and data manipulation.

Part IV

Ownership and Automation



18 Collecting and presenting sound data

During the observation investigation, it became apparent that the students enjoyed working with the dataloggers, and had indicated a sense of ownership over the data, particularly during the analysis of the data. The students were able to interpret their data to an extent, but showed a preference for working with excel rather than the pre-generated graphs from the software. In particular the students were keen to explore data manipulation. The next experiment was designed to consider these factors further, using a quantitative design to explore these concepts of ownership and automation. In order to maintain experimental control over this investigation the study was designed to take place on the university campus. This enabled the research to be repeated with three schools, with minimal difference between each experiment. It was important that the tasks and the day felt like a school trip, rather than a psychology experiment, in order to explore the potential of the dataloggers within a realistic school experience. The event was marketed to the students as a field trip so they were clear that the focus was on their learning rather than on them partaking in a psychology experiment. It is quite typical for schools to take school trips to universities to not only act as a teaching exercise but also to introduce the students to higher education.

This investigation was run three times with three different schools. Using a mixed methods approach, the investigation explored student learning using pre and post tests. The session was video recorded, to allow the researchers to review the structure of the day, rather than with the intention to analyse. Students were split into counterbalanced groups and experienced different methods of data collection and data presentation: see Table 18.1 that shows the order of events and the conditions which the students experienced.

		Pre Test All Learners		
	SELF LEARNERS			PEER LEARNERS
Collection	1,3,5,7,9,11,13,15,17			2,4,6,8,10,12,14,16,18
Intervention	Pond	Field	Construction Site	Sound Class Room
	1,3,5	7,9,11	13,15,17	2,4,6,8,10,12,14,16,18
		Return to main classroom		
Presentation	SOFTWARE		MANUAL	PRE-PRODUCED
Intervention	1,2,7,8,13,14,		3,4,9,10,15,16	5,6,11,12,17,18
		Post Test All Learners		

Table 18.1: Timetable of events for each student

The focus of this investigation was primarily to understand the impact of contextual experience. This was subdivided into: ownership and automation. The pre and post assessments were based upon typical national curriculum questions. A workbook was designed to structure the day and generate a more 'school trip' like experience. This experiment was designed with three of the four aims in mind:

To what extent does automation, creating a seamless experience, affect the student's learning and motivation?

This experiment directly compared students who experienced automatically generated graphs (Pre-Produced) with students who produced their own. (Manual)

How does the addition of personal experience with a datalogger affect learning and motivation?

This was investigated by comparing students who collected the data (Self) with the students who stayed in the classroom (Peer)

How can we quantify learning?

In this investigation quantitative measures of learning were employed, based upon government SAT papers [32]

[32] see appendix F.1 for a list of SAT questions used to inform the design

18.1 Rationale

The use of technology can enhance a hands-on approach to learning. Advances in sensor hardware and mobile technologies, the easy transfer of data into graphs, and the ability to juxtapose this data onto locations using applications such as Google Maps and Google Earth all have the potential to create new opportunities for school science and cross-curricular learning (see Crook et al., 2010, Abergbengtsson, 2006 and Woodgate, Stanton Fraser, Crellin and Gower, 2008a, for examples of learning with technology). However, taking advantage of these new opportunities for the purpose of education requires significant work beyond technical development including: engaging teachers: understanding the pedagogical implications of the use of new designs: and engaging companies in design partnerships in order to make the resulting hardware and software appropriate for schools. It also requires the school management to be willing and able to support developments, for instance the willingness to add new software to the school network, and allowing teachers time to gain understanding of the technologies. It is therefore important to understand just what aspects of these technologies may be beneficial to children's learning.

Hands-on learning with mobile technology is often advocated as the way forward in engaging children in science, by enabling them to carry out their own studies of the real world, making scientific data less abstract and more meaningful to them personally, supporting the understanding of the scientific process, as well as the results (Pea, 2002; Resnick et al., 2000; Rogers, 2004; Stanton Fraser et al., 2005; Stanton et al., 2003.) However the majority of this work has been qualitative in nature and, while it has established positive effects of hands-on investigation, it is often not so clear where the advantage actually lies. The elusive causes of 'hands-on learning' benefits are partly due to the varied use of the term to mean for example: self-collection of data, carrying out experiments in the laboratory, or even group work. In this chapter work is reported which contributes to understanding the origin of hands-on learning benefits.

The two aspects that this research addresses are specifically concerned with:

1) self-collection of data – collecting one's own data in the real world,

2) 'working up' or transforming these data oneself to convey the process of translating from raw data to (scientific) concept.

An experimental design reveals some of the subtleties at play in these activities. This investigation explored issues such as: Does carrying out an investigation in the real world enhance motivation and learning? Does 'doing it yourself' - drawing your own graph in this case - give you a better conceptual grasp of skills such as interpreting the graph or plotting new graphs, or does one gain more from using software to produce graphs, or interpreting the pre-produced input of others?

Background

The idea that hands-on learning is beneficial is not new. Dewey (1964) advocates that science is best understood through carrying out one's own inquiry and experiencing scientific phenomena and processes. This is supported by more recent work emphasising the importance of personal experience for natural learning (Zoldosova & Prokop, 2006). Authentic work is important, students need to be able to relate to their work (Krajcik et al., 1998) and where possible experience the situation first hand (Johnson et al., 1997). Taking part in real world studies of science is considered crucial to students' understanding, the personal involvement in investigation enabling students some autonomy and experience of the process (Resnick et al., 2000). Such learning experiences are considered fundamental to understanding the basic representations and concepts that enable students to develop a more complex understanding of the world (Millar & Osborne, 1998).

Emerging 'pervasive' technologies such as mobile devices, sensors, and interactive systems have the potential to enhance learning and motivation by enabling innovative hands-on learning opportunities. However, while the use of sensors in science learning is clearly on the curriculum, actual use of the equipment in schools has been limited due to problems with the usability of the technology, time and effort of setup and the complexity of importing data into relevant formats, all these interfering with the rhythm and quality of the learning process (Woodgate & Stanton Fraser, 2005, 2006). In a study of how 13-year-olds carry out scientific investigations in the classroom, Krajcik et al (1998) found that the children did not choose to use the data they had collected to create graphs, even though it would help them to draw conclusions. Fishman, Soloway, Krajcik, Mark and Blumenfeld (2001) point to the importance of building engaging and motivating small-scale projects which mirror the complexity of science and also reflect larger issues. In this respect, many argue that technology in schools is not being used to promote critical thinking.

The Participate project (Woodgate et al., 2009) applied both bespoke educational sensors and Bluetooth enabled mobile phones in order to capture data in the field. Once back in the classroom, children explored and analysed their data using graphical representations over Google Earth or Google Maps to view the readings juxtaposed upon the actual locations visited. Images could also be attached to relevant parts of the graph/location as contextual cues. The authors noted that the 'seamlessness' of the experience did not always lead to fruitful discussion, and requiring children to put graphs, contextual data and location together led to more reflection upon the experience and the data itself. When graphs were automatically produced there was little discussion and a short reflection period. In comparison, when there were breakdowns in the automation of the experience, this initiated additional group discussion and reflection. In addition to considering seamfullness, in their 2008 report on the Participate project, Woodgate, Stanton Fraser, Crellin and Gower (2008b) reflect upon the importance of students obtaining context for their data, positing that by allowing students to collect their own data and gain understanding of the data environment, they will find this a more engaging method of learning. Others have reported inconclusive effects on students' cognitive achievements following hands-on activities, but state that they promote a more positive attitude towards science that the motivation literature suggests as beneficial. Salmi (2003) indicated that visiting a science centre increased students' intrinsic motivation. Some would argue that promoting positive attitudes towards learning is in itself a crucial educational outcome (Mee, 2002). While an educational policy report states that use of ICT across the curriculum can increase students' confidence and motivation in learning (Osborne & Hennessy, 2003).

This investigation also explores aspects of hands-on learning that involve carrying out work yourself – in this case either drawing your own graph, using software to create graphs, or annotating graphs already created for you. Barton (1998) highlights a number of problems with traditional practical work including: student difficulties linking their practical experience with abstract concepts, especially because the time taken to collect and process data leaves very limited time to 'relate the practical to the theory': and that "information clutter", including equipment used, measurements, calculations, graphs and the problems associated with these distract students from the task at hand. While the literature provides no evidence that students are at a disadvantage when drawing graphs manually there are a number of studies suggesting datalogging could aid the process. The following advantages have been found for datalogging over manual collection and recording of results: Friedler & McFarlane (1997) found evidence that for some age groups datalogging over traditional apparatus leads to improvement in children's ability to read, interpret and sketch line graphs. Barton found that the real-time production of computer graphs enabled younger, weaker students to explain, make predictions and make links to previous relevant knowledge, stating

> "manual graph plotting should be avoided when the main aim is to interpret relationships via graphical analysis" Barton (1998, p.367).

Furthermore Choo (2005) states that presenting a number of graphs simultaneously, or one at a time representing the same data in different ways, can aid a pupil's conceptual understanding. Recent work by Baggot le Velle et al. (2005) has indicated that students and teachers alike feel that instant graphing software can reduce drudgery. As noted by Lepper (1988), keeping students engaged is vital, while Mistler-Jackson & Butler Songer (2000) raised the importance of keeping students interested in the work. It was also noted that visualisation can be important for understanding, with teachers reporting that the use of simulations is highly motivating for students. These two ideas underlie the experiment design whereby the focus was to understand whether context and an ability to visualise the situation led to greater understanding of data, while simultaneously comparing instantaneous graph-drawing software with more traditional hand-drawn annotation methods. Work by Friel, Curcio and Bright (2001) highlights the different factors involved in graph comprehension as translation, interpretation and extrapolation. Translation is seen as the process of taking a table of data and representing it graphically, while interpretation is comprehending the important factors of the graph, with extrapolation taking this one step further and considering the wider implications of the graph and its meaning.

In order to explore these findings further an in-depth investigation was developed which manipulated the level of interaction required to maintain the benefits of dataloggers while also ensuring students understand the data transformation process. The experiment compared multiple levels of data collection (self, peer, pre-collected) and different methods of presenting the data (pre-presented, software-presented and hand-drawn). The study was designed to be as ecologically valid as possible, with children working in pairs and groups to collect and discuss data, but assessment was carried out on an individual basis.

Mee (2002) explored the impact of dataloggers on students' graph drawing skills using a mixed method approach, using Irish Leaving Certificate[33] papers to quantify the learning effect of her intervention. The pre and post tests employed in this research study followed a similar methodology by basing the pre and post test questions on SAT questions that assessed graphical

[33] A two year Irish qualification which is studied after leaving school, it can be the equivalent of the first year of a four year degree.

understanding in a range of ways appropriate to the curriculum. Through employing this method it is possible to begin to quantify the learning impact of dataloggers. Mee teamed this quantitative assessment with a questionnaire to assess the students' attitudes towards the experience, providing information on how the students' perceptions were affected by the intervention. This investigation was built upon, through providing the students with an in-depth motivation questionnaire to explore how their attitudes to learning and technology changed over the period of the investigation. Mee found that students who used dataloggers performed better at post test and were more positive towards practical experimentation. A key difference between this study and the one conducted by Mee is the interest in the two stages of datalogging: collection and presentation, Mee's study also used older students and was conducted in an all girls school. Thus this investigation looks to develop upon the findings of Mee and provide further insight into the benefits of using datalogging technology in school science.

Recent work by Woodgate, Stanton Fraser, Crellin and Gower (2008b), indicates that providing children with the opportunity and means to collect their own data and to discuss it can be an effective method to learn and engage in science. This experiment was developed from this observation by investigating the level to which students need to feel ownership of their data and how this impacts on their understanding of the data. In particular focus was placed on the extent to which processes should be automated. Often investigations have noted the immediacy of dataloggers as beneficial, noting that:

> "datalogging automates the recording and handling of experimental data through use of sensing equipment which offers immediate feedback and alleviates laborious data collection and graph production" (Hennessy et al., 2007, p139).

This experiment investigated the importance of students remaining connected to their work, ensuring that they understand how the real time data is firstly transformed into a table of data and then secondly into a graphical representation. If the data is collected automatically and then transformed into a graph using software, with the only interaction being students pressing buttons, then the students may lose a level of interaction that they previously had during the manual collection of data into tables and hand drawing the graphs.

Methods of Qualitative Analysis Selecting an appropriate qualitative analysis method is an integral part of the analysis process, it is important that the data corpus is explored using tools which allow it to be reviewed effectively.

Leech & Onwuegbuzie (2008) note that you should use multiple methods of analysis to triangulate your results. Furthermore it is vitally important that the methodology chosen to analyse the data is reported explicitly to allow other researchers to replicate the study. Braun & Clarke (2006) note that often insufficient detail is provided with articles often discussing themes 'emerging', they suggest that this over simplifies the analysis and fails to identify the role of the researcher in influencing the themes. Braun & Clarke suggest that their thematic analysis (TA) technique is an accessible qualitative methodology useful to those who are 'early in a qualitative career', noting that TA can be used within different theoretical frameworks and used to explore either the participants specifically, or the events and meanings more generally. This flexibility of the approach makes it ideal for the data collected from the students' workbook. In this research the analysis is focused upon participants and their answers specifically, as Braun & Clarke, pg 81 define it, it will be interested in "reflect[ing] reality" rather than "unravel[ing] the surface of reality". It is acceptable for a thematic analysis to be driven by an analytical question and Braun & Clarke indicate that as a researcher you can choose whether to present a rich description of the data set, or to provide a detailed account of one or more themes within the data. In this analysis the themes that are explored are mediated by the general research questions, which are exploring student learning and motivation with dataloggers. As the focus is on existing research questions the themes for the analysis are identified using a deductive approach, this is similar to the approach used by Stanton Fraser et al. (2005) in their SENSE project where they look for critical incidents, and Balaam, Fitzpatrick, Good and Luckin (2010) who perform a thematic analysis using four predetermined themes. The review of the literature has provided an insight into learning and motivation, so it is evident that looking for themes around these areas would be valuable for providing an understanding of the students' experiences. Braun & Clarke (2006) state that it is important to clarify if the themes are to be analysed at a semantic or latent level. At a semantic level the themes are explored at the surface of the data focusing on exactly what the participant reported, in contrast at the latent level the analysis starts to explore the underlying ideas and suggestions around why the participant has responded in a particular manner. In this research the analysis focuses on the explicit and semantic themes with the data organised to highlight the themes and suggest the implications and patterns of the themes. In summary the thematic analysis is based around predefined themes looking at exploring learning, motivation and understanding. It is analysed at the semantic level, focusing on the explicit and the results are presented in a manner which indicates the implications of the themes, each of the workbook sections will be considered individually with a summary at the end considering the workbook as a whole.

As Leech & Onwuegbuzie (2008) have noted that qualitative research benefits from using multiple techniques, the workbook sections will also be analysed using additional techniques such as a general word count and a key concept count/content analysis. It is valuable in some of the sections to explore whether there is a difference in the quantity written by the students, in particular this is useful when exploring the observation section to compare the collection intervention, and also the total word count for the final sections of the work book to explore whether those that were required to draw their own graphs, or to annotate, may have become frustrated with the quantity of work and therefore provided less information in the workbook. In some sections of the workbook the answers provided by the students are limited in length, in these cases the thematic analysis will be supported by a content analysis which will allow the exploration of how often the students discuss predefined concepts, again the concepts will be predefined from the research questions.

The analysis conducted in this research utilises the 6 stage methodology detailed by Braun & Clarke (2006) which supports thematic analysis.

Phase	Description of the process
1. Familiarise yourself with the data:	Transcribing data, reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing the themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Table 18.2: Phases of thematic analysis according to Braun & Clarke (2006, pg 87)

Motivation

The pre and Post test booklets included a section which was used to assess the student's motivation, this consisted of six questions which were answered on a 5 point likert scale:

1. I like working with data that I have collected
2. I find it useful to draw a graph by hand
3. I enjoy using computers to draw graphs
4. My understanding of a graph is better if I have drawn it myself
5. My understanding of a graph is better if someone else has drawn it
6. I think collecting data myself is a waste of time

As discussed in the literature review, a number of researchers have used self report surveys to document students motivation and engagement towards a topic (Mistler-Jackson & Butler Songer, 2000; Lai et al., 2007; Rau et al., 2008; Zurita et al., 2008). However a review of the literature suggested that a standardised test would not provide answers for the questions being asked in this research as the focus needed to be on graph drawing and data collection. Instead a tailored questionnaire was developed to provide an insight into the students' motivation, based on examples of similar style questions in the literature such as Huizenga et al. (2009) who asked student's questions such as "I like the subject of history" and work by Singh et al. (2002) who included questions about student motivation "looks forward to science class". Following discussion with the teacher involved in the earlier observation pilot study, a questionnaire was designed which was short to maintain student interest and used simple understandable language. The questions focused on three components within motivation: belief in ability to perform, belief about the value and affective reaction to the task as discussed by Pintrich (2003).

18.2 Hypotheses

- Motivation will change for data acquired in context.
- Understanding will change for data acquired in context.
- Understanding of Pre-generated graphs will be different dependent upon the student's collection experience.

18.3 Participants

A total of 46 students from 3 schools took part in the experiment, with a range of ability represented. Eight sets of data were discounted for statistical analysis purposes due to one child having learning difficulties and seven discontinuities within the groupings - some classes arrived with extra students that meant that a few students needed to work in larger groups. The students ranged in age from 12 to 14, with 14 girls and 24 boys participating. Half of the students had a 'hands-on' experience of using mobile sound dataloggers (which measured and recorded sound in decibels) at a location, while the other half were shown the potential use of a datalogger but did not personally use it. Fourteen students used computer software to generate graphs, 12 students were asked to annotate pre-produced graphs and 12 students were given data tables to display in line graph format by hand. Each student finished with two graphs, one of Location A (either they or their partner had visited this site) and one of Location B (data collected by the researcher from a location not visited by the students). In addition, each student completed three booklets: a pre-test, a workbook, and a post-test.

Design

The experiment used a 2x3 between subjects design. The independent variables were Collection (Self-Collected or Peer-Collected) and Production (Software-Produced, Manually-Produced or Pre-Produced), the dependent variable was the student's performance on the pre and post test. Students experienced different methods of data collection and data presentation dependent upon which group they were in. Sound was used in the experiment, as it was a concept that students of this age are already familiar with. It can be easily recorded, and most importantly students who experienced the locations can make connections between the sounds they hear and the graphical recordings that they take. The pre- and post-test booklets were counterbalanced to ensure that they did not differ in difficulty. Of the students who went out to collect data, students were counterbalanced to three different locations (Pond, Construction Site and Field), to ensure that it was the experience of taking the recordings that was important, and not the actual location. Students who self-collected the data were able to view graphs displayed on the dataloggers' screens as they collected the data. This allowed them to make contextual connections to the graph shape. The students were asked to take multiple recordings, and were then given the opportunity to reflect upon the graphs and choose which data to use when they returned to the classroom. Students who did not self-collect were given a talk in the classroom on dataloggers to ensure they were introduced to the dataloggers and that the only difference between the self-collected and the peer-collected group was that the self-group actually used the dataloggers themselves.

Materials

Dataloggers The study used Logbook GL dataloggers (see Figure 18.1) provided by ScienceScope with additional plug in Sound Sensors with the range (30dB-110dB).

Figure 18.1: Logbook GL with additional Sound Sensor

Software The students used ScienceScope's Datadisc PT software to generate their graphs. Datadisc Explore PT was also used to show sound levels to half the students. Datadisc is a software package designed specifically for science education in schools and provides the ability to download data from the Logbook dataloggers, create graphs and tables of the data, annotate with labels and perform appropriate manipulation of the data to allow students to analyse the data they have collected.

Pre/Post Test The pre- and post-tests consisted of questions designed to assess the students' ability to read a graph, draw a graph and correctly title and label graphs. These tests were based upon questions that arise in national Maths and Science examination papers for this age group. This meant that the question style would be familiar to the students. The language used in the questions also appropriately reflected this level. Teachers were consulted throughout the design of the pre/post questionnaires to ensure the questions were relevant and at the correct level for the students. The pre- and post-tests also included questions on data reliability and validity, asking students to explain their choices. For instance the students were asked to consider what to do about a missing data point: i.e. should they replace it to a specific location, suggest it goes within a range, or not replace it. Additionally, in the pre- and post-test booklet the students were asked to rate statements using a 5 point Likert scale varying from Strongly Agree to Strongly Disagree such as ‘My understanding of a graph is better if I have drawn it myself’. The post-test varied from the pre-test only in the numbers used for the graphs, the question phrasing was identical. The pre- and post-tests were counterbalanced across the students. The design of these questions was iterative with input from four teachers from different schools. The questions were based on level 5-7 SATs papers[34]. A selection of ten papers, from a five year period were analysed to develop a clear understanding of the terminology used and the level of understanding anticipated for a student of this age.

Science SATs tests cover a range of curriculum topics. As a result, the majority of the questions are not relevant to this topic of interest. On average a SATs paper has 13 questions that are then split into parts a, b, c and d. Each year students take two Science SAT papers, parts one and two. Consequently this review covered 10 papers, 134 questions. Of these, 21 questions were considered relevant in either topic or technique to this investigation. These 21 questions were used as the basis for the questions within the ownership and automation investigation see table (18.3).

[34]SATs are Standardised Assessment Tests given to students at a number of different times during their school experience. At the ages of 12-14 students are tested on levels 5-7 in science.

Year	Paper	Number of Questions	Number of Relevant Questions	% of Relevant Questions
2003	One	14	1	13.79 %
	Two	15	3	
2004	One	15	2	24.14 %
	Two	14	5	
2005	One	14	2	9.52 %
	Two	7	0	
2006	One	14	2	14.29 %
	Two	14	2	
2007	One	13	3	14.81 %
	Two	14	1	
Total		134	21	15.67 %

Table 18.3: Analysis of SAT Science papers for relevant questions

The twenty one questions were then grouped and used to guide the four key questions used within the pre and post-tests.

Question One required students to use a sound graph with three lines on it indicating three different locations. Students were asked to choose which location was the quietest and then report the sound level for each location at a set time. Students were also asked to consider whether they would replace a missing data point and explain their reasoning. This question was designed around a question which is common to exam papers at this stage "On the graph, circle the result which does not fit the pattern. Suggest one reason for this result." While the question used in this research was not identical, it uses the same underlying understanding by assessing how the students handle odd, anomalous and missing data. The students were also asked to explain their choice to gain insight into their reasoning, in contrast to many such questions in which students are often asked to make judgements without the chance to justify them.

Question Two provided students with a table of data and asked the students to plot the data points and draw a line of best fit. This reflects a type of question that is common to science examinations which asks students to finish plotting a graph or to plot a table of data. This question was included to see how students chose to scale their graphs and whether they would correctly label and title them.

Question Three followed on from question two by asking students to provide a graph with axis labels and a title. Analysis of exam papers shows that this is a skill students of this level should hold. Throughout the papers students are asked to add appropriate scales and labels to graphs.

Question Four took inspiration from exam questions that asked students to report what was happening at different times of the graph. The question was adapted, instead of focusing on differences within a graph, the students were asked to consider three lines on the same graph and use the shape of the graphs to infer which graph represented which location. Work book

The work book provided the students with a guide to what they were asked to do and was designed to provide an authentic 'lesson/school trip' experience. Initially it introduced the students to the locations. Location A represented the location that the student, or their partner would visit. The actual location varied dependent upon which counterbalancing group they were in: Construction Site, Pond or Field. They were told about Location B that was a Car Park, but none of the students actually visited the car park. The students were asked to make predictions about the two locations with regard to sound levels and they were also asked to explain their choices. The workbook also included space for observations that the students filled out following the datalogging. The next section asked them to answer questions by interpreting their graphs, and also to think about how the graphs matched their initial expectations. Finally the conclusions section asked them to consider if the study had been a fair test, how they might change it and what difference this might make.

18.4 Procedure

The study was held over three days with a different school attending each day. The procedure, however, remained identical. Ethical approval was gained for the study and each student and their parents/guardians gave their consent to participate and to be recorded. The activities were video recorded throughout. Four researchers facilitated the investigation with the aid of the teachers. The number of teachers present varied across the three iterations of the experiment; in each case there was at least two teachers present.

The experiment compared multiple levels of data collection (self, peer, pre-collected) and different methods of presenting the data (pre-generated, software presented and manual). The students were placed in pairs, in each pair one student was given the opportunity to go outside and use the dataloggers to collect sound level data (self collected). They were then asked to discuss this data with their partner, providing the partner with the data (peer collected). Each student was then asked to analyse their data/their partner's data, and data that had been collected by a researcher (pre collected). The pairs got to analyse and produce graphs from the data, this was carried out either using datalogging software (Software Presented), making posters from graphs of the data produced by the researchers (Pre-produced)[35] or by using the numerical data to

[35] Please note Pre-collected refers to data collected by the researcher while Pre-produced refers

produce hand drawn graphs (Manual). See Table 18.4 for an overview of how the conditions were managed.

The students were given a pre test prior to the experiment and a post test after the interventions, this enabled the evaluation of how their learning and motivation changed on a quantifiable scale. They also completed a workbook during the experiment.

Pair	Student	Collection Phase	Presentation Phase
1	1	Self (Pond)	Software (Own and PreCollected)
	2	Peer (Lab)	Software (Peer and PreCollected)
2	3	Self (Pond)	Manual (Own and PreCollected)
	4	Peer (Lab)	Manual (Peer and PreCollected)
3	5	Self (Pond)	PreProduced (Own and PreCollected)
	6	Peer (Lab)	PreProduced (Peer and PreCollected)
4	7	Self (Construction)	Software (Own and PreCollected)
	8	Peer (Lab)	Software (Peer and PreCollected)
5	9	Self (Construction)	Manual (Own and PreCollected)
	10	Peer (Lab)	Manual (Peer and PreCollected)
6	11	Self (Construction)	PreProduced (Own and PreCollected)
	12	Peer (Lab)	PreProduced (Peer and PreCollected)
7	13	Self (Field)	Software (Own and PreCollected)
	14	Peer (Lab)	Software (Peer and PreCollected)
8	15	Self (Field)	Manual (Own and PreCollected)
	16	Peer (Lab)	Manual (Peer and PreCollected)
9	17	Self (Field)	PreProduced (Own and PreCollected)
	18	Peer (Lab)	PreProduced (Peer and PreCollected)

Table 18.4: Table showing how the students were grouped for collection and presentation stages.

Introduction and Pre-Test

At the start of the day the students were given an introduction to the classroom and a summary of what they would be doing during the day. It was stressed that there were no right or wrong answers, and that we were interested in reasoning rather than correct answers. The students were placed into groups randomly (assigned a number, colour and shape) and each was asked to complete the first booklet (pre-test) and the first section of the main workbook. They were given 30 minutes to complete this individually.

Data Collection

The students were split into two groups, Self-Collected and Peer-Collected.

to data which was given to the students in graphical form

Self-Collected. These students were given individual dataloggers and were shown how to use them. Each student then visited one of three possible counterbalanced locations and spent 15 minutes taking a number of twelve-second recordings and choosing which recording they would like to analyse. At each site a researcher supported the students. In some cases, teachers also chose to visit the site. At the construction site location the students stood on one side of a high safety wall with construction workers on the other side. They took recordings of the sounds made at the site. The students who visited the pond took recordings of the ducks and the fish in the water (see figure 18.2). Finally the students who went to the field went to an area that is often quiet so they recorded sounds of birds, and the occasional person walking past.

Figure 18.2: Students taking sound recordings at the pond on campus

Peer-Collected. These students were given a talk by one of the researchers, on sound recording, and shown a datalogger connected to a computer (see figure 18.3 on the next page). They were given the opportunity to interact (without holding the logger) by seeing how the data display changed according to how loud and quiet they could be. This provided them with an opportunity to understand what a datalogger does without gaining the context of actually taking a recording themselves. When the 'Self' students returned they were asked to get into their pairs with the 'Peer' students. The students who had been outside to use the dataloggers were asked to describe to their partner what their experience had been like. All the students were asked to record these observations in their workbooks. The students were then given a break while the data was uploaded into the ScienceScope software to produce graphs and tables of data for the next stage.

Figure 18.3: Students participating in a sound lesson

Graph Production

The students were all given 40 minutes to explore their data and produce graphs. They were divided into three groups: Software-Produced, Manually-Produced and Pre-Produced. During this time the researchers visited the different pairs of students and asked the students if they understood the task and if they required any help, in some situations this led to discussions around the data and their experiences. This was similar to what you would expect to see in a classroom environment with the teacher responding to the students' queries. The researchers had discussed prior to the event the extent to which help would be given, this included asking the students questions and guiding their understanding, without providing exact answers or influencing the choices that the students made.

Software-Produced These students were shown how to connect dataloggers to computers, and to use ScienceScope software to upload their data files and explore their graphs. Each student was given the opportunity to upload data collected by them/their partner and data collected by the researcher. Students were encouraged to explore the software, and personalise their graphs by adding labels, titles and colour. See figure 18.4

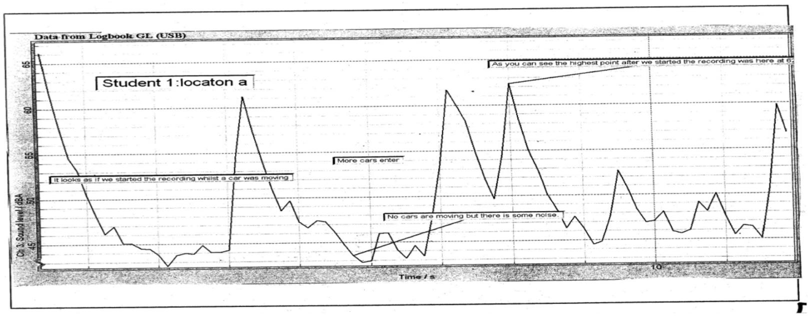


Figure 18.4: Example graph produced by the students using the software

Manually-Produced These students were given two tables of data: the data collected by them/their partner, and a second table of data collected by the researcher. The students were given all of the data points for each of the twelve-second recordings, but were told they could choose which data to display in each graph, and given ideas such as choosing every other point, randomly picking 10 points or choosing a section of time[36]. The original data table included 96 data points spanning 12 seconds of data. Providing the students with the whole data set allowed them to see all the available data while giving them control to graph what they felt was important (See figure 18.5 on the following page)

[36] for instance all the data collected between the 6th and 7th seconds in the 12 second recording

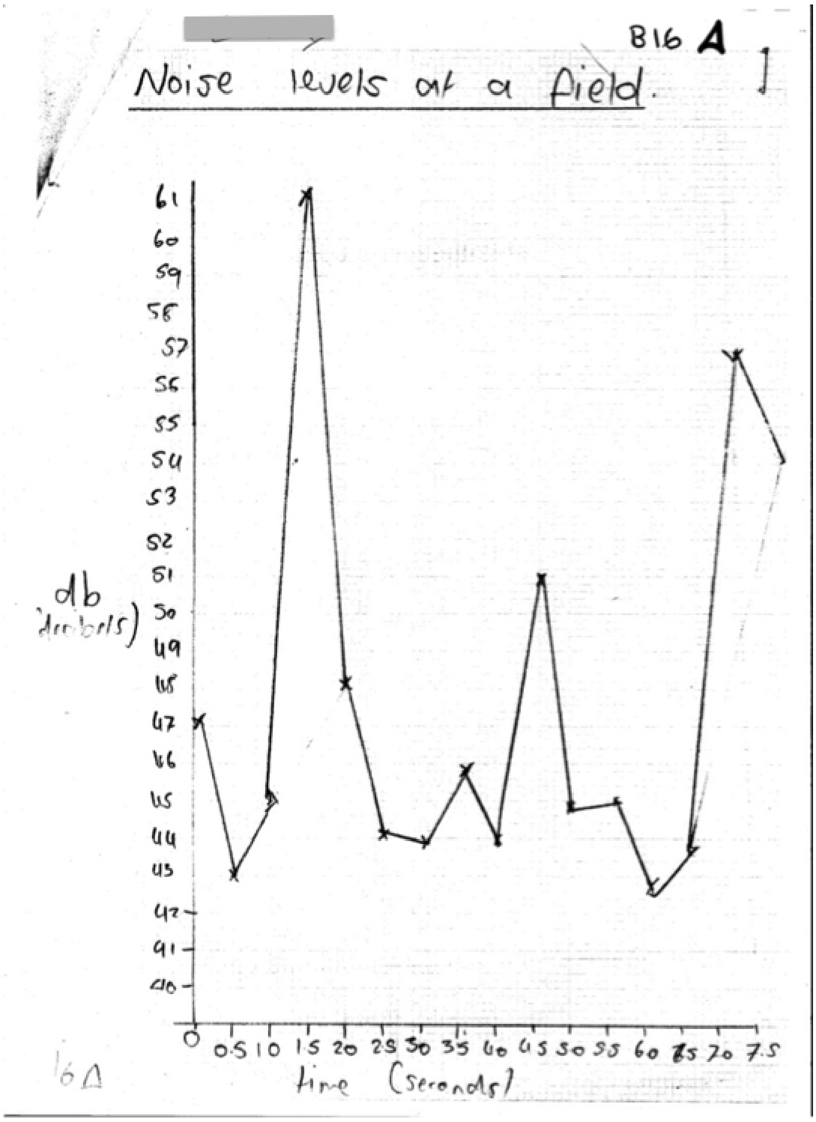


Figure 18.5: Example graph produced by a student in the manual condition

Pre-Produced The students in this group were given two graphs, one graph for Location A (data collected by them or their partner) and one graph for Location B (researcher collected). They were given poster paper and pens and asked to annotate each graph considering possible explanations for peaks and troughs (see figure 18.6).

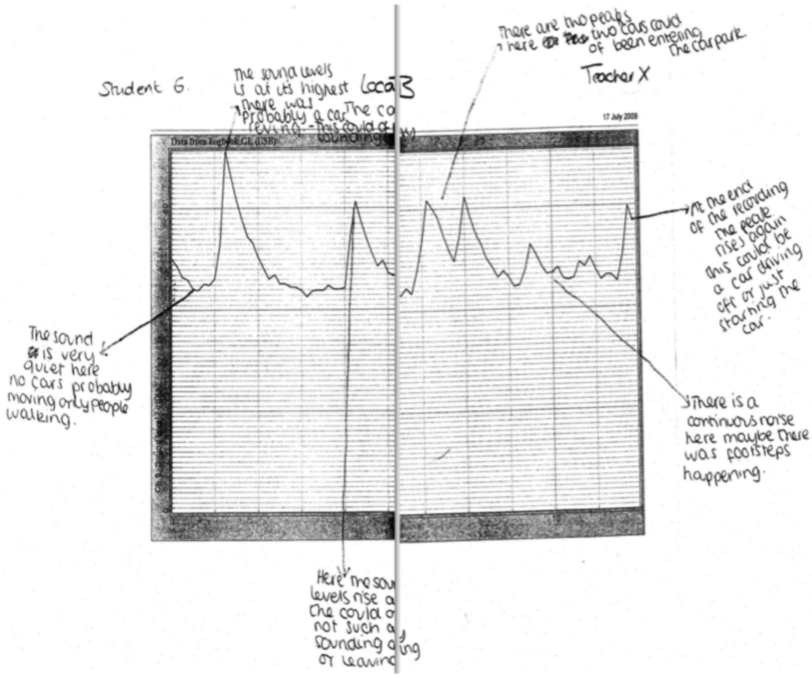


Figure 18.6: Example graph annotated by students

Workbook and Post Test

All students were asked to spend 45 minutes completing the workbook that asked questions about the graphs that they had been working on.They then completed the post-test booklet.

Debrief

Finally the students were given an overview of the research area highlighting their contribution and asked to make comments on the day.

18.5 Results

As this experiment was complex a range of resources was used during the study. The primary resource for analysis was a comparison of the pre and post test. While the workbook was designed as a tool for facilitating the day it also provides an insight into how the students engaged with the task. Finally the experiment was video taped, this was to provide a record for the researcher to review and understand the experiences the students had when they were with other researchers. The aim of the video was to provide an overview of the room rather than focusing on the talk and interaction of individual groups. In this next section the results from the pre and post test are presented, this is followed by an analysis of the content produced by the students in their workbooks.

Source	Analysed	Methodology
Pre-Post Test Likert Scale	Yes	Analysed using Wilcoxon tests
Pre-Post Test Learning	Yes	Analysed using 2x3 ANOVA and non parametric tests (Kruskal Wallis and Mann Whitney)
Pre-Post Test Qualitative	Yes	Analysed using a range of qualitative techniques including, thematic analysis, content analysis and word counts
Workbook	Yes	Analysed using a range of qualitative techniques including, thematic analysis, content analysis and word counts. Chi Square tests were also employed for the motivation questions.
Video	No	Not analysed as the video was not intended to be used for analysis.

Table 18.5: Summary of the results

Learning

Four questions in the pre and post tests were used to test understanding. Some students failed to complete all of the questions in the post test, these were marked as 0 as in a class situation.

There was no significant difference between the groups at pretest for collection or for presentation:

Question One; collection $F(1,32) = .151$, $p = .700$, presentation $F(2,32) = 1.014$, $p = .374$,

Question Two; collection $F(1,32) = .061$, $p = .807$, presentation $F(2,32) = .463$, $p = .633$,

Question Three; collection $F(1,32) = .799$, $p = .378$, presentation $F(2,32) = 3.174$, $p = .55$,

Question Four; collection $F(1,32) = 1.811$, $p = .188$, presentation $F(2,32) = .386$, $p = .683$.

Calculating the difference between the pre and post-test scores generated a change score. The change scores were assessed for normal distribution by calculating their skewed and kurtosis values. It is considered that a normal result will fall within ±2.58. The results indicated that question four did not meet the normal distribution requirements for students in the Self condition who experienced the manual presentation condition (there were 6 students who experienced this combination) with a skewness of 2.898 (SE = 0.845) and kurtosis of 3.446 (SE = 2.449). Attempts to normalise question four by transforming the data had no effect on the distribution[37]. Consequently Questions 1 to 3 were analysed using a 2x3 ANOVA, while Question 4 was

[37] Data was manipulated by transforming using the square root function, the log10 function and the inverse transformation.

analysed using the non parametric Kruskal-Wallis test for the presentation variable, and the Mann Whitney test for the collection variable.

Question One was developed to test the student's ability to read graphs. Levene's test indicated homogeneity of variance (F=1.644, p = .177). The main effect of Collection was non-significant, F(1,32) = .146, p = .705, partial $\eta 2$ = .005. The main effect of Presentation was also non-significant F(2,32) = .372, p = .692, partial $\eta 2$ = .023. The interaction effect was also non-significant F(2,32) = .258, p = .775, partial $\eta 2$ = .016.

Question One also asked students to consider whether you should replace lost data to a specific point, a range or not replace it. In total 7 students out of 38 changed their answer to this question from pre- to post-test. This happened more frequently with the Pre-Produced group and with the Peer group (25% and 26% changed their responses respectively). For example a student who was in the Peer group and experienced Pre-Produced graphs changed their response, initially the student selected the data should go in "One Location" and stated "Because it fits in" however, following the intervention they selected "Not Replaced" and explained their choice with "You do not know so you will just have to miss it out".

Question Two assessed ability to draw a graph and label it correctly. Levene's test indicated homogeneity of variance (F = 1.419, p = .244). The main effect of Collection yielded an F ratio of F(1,31) = 4.345, p <0 .05 , partial $\eta 2$ = .120, indicating that that while both groups performed worse at post test the Self group (M = -1.94, SD = 1.81) showed a significantly greater reduction in their scores than the Peer group (M = -0.42, SD = 2.59). On average the Peer students scored 6.21 at pre test which dropped to 5.31 at post test, while the Self students scored 6.26 at pre test and dropped to 4.82 at post test. The main effect of Presentation was non-significant F(2,31) = .652, p = .528, partial $\eta 2$ = .039. The interaction effect was also non-significant F(2,32) = .237, p = .790, partial $\eta 2$ = .015.

Question Three assessed the students' ability to label graphs. Levene's test indicated homogeneity of variance (F = 1.849, p = .131). The main effect of Presentation was non-significant F(2,31) = 1.302, p = .286, partial $\eta 2$ = .075. The main effect of Collection was non-significant F(1,31) = 1.748, p = .196, partial $\eta 2$ = .052. The interaction effect was also non-significant F(2,32) = .642, p = .533, partial $\eta 2$ = .039.

Question Four asked the students to match possible locations for data sets displayed with line graphs. A Mann-Whitney test indicated that there was no significant difference for Collection. U = 121, p = .085. A Kruskal-Wallis test indicated that there was no significant difference for Presentation $\chi 2(2)$ = .365,

$p = .833$.

Workbooks

The study was designed with two criteria, firstly to conduct an experiment which reflected a typical learning activity, and secondly, introduce conditions into the experiment to allow for a more controlled analysis of the impact of data collection and data production on the students' learning and motivation. As a result of this a workbook was designed, with the support of existing classroom documents and teachers. The purpose of the workbook was to structure the day in a manner that the students would be familiar with. The focus of the workbook was therefore to support the student in their data collection and interpretation during the day. However, it is clear that the responses provided by the students can provide additional insights into their experiences during the experiment, and their underlying scientific understanding[38]. In the following section the student responses are analysed using a mixture of qualitative techniques.

In the following section the qualitative analysis of the workbook is reviewed, followed by the analysis of the responses students provided to support their likert scale choice on the pre and post motivation questions. All of the data was transcribed from the students' hand written responses, in some instances the student handwriting is poor, in these cases judgement is made based upon the context of the missing word(s).

Workbook Analysis The work book can be split into a number of sections:

1) Observations
2) Graph Interpretation
3) Understanding the Results
4) Reflecting on Predictions
5) Future Experiments
6) Reflection - this section is discussed in greater detail during the motivation results section.

Section One: All of the students were asked to make predictions around which location they thought would be the loudest, students made this prediction based only on knowing the locations to be visited. [39] The students then experienced the collection intervention. Following this the students who had collected data (Self) were asked to tell their partners about their experiences.

[38] As the workbook was designed to structure the day, it does not directly relate to the research questions

[39] the predictions are discussed later in relation to the students reflection

All the students were then asked to complete the observations section and report what had been seen and experienced during the data collection stage.

A word count analysis (T-Test) indicated that there was no difference in the collection factor for the quantity written in the observation section by the students t(36) = 4.94, p = .624. [40]

The thematic analysis was guided by the principles suggested by Braun & Clarke (2006) and Attride-Stirling (2001). The student responses were coded by reviewing the data with the research questions in mind, regarding motivation and ownership. However to ensure that themes were not neglected, the data was also reviewed for unexpected items that were repeated. It was possible for a student's response to fit into multiple codes. The codes were reviewed to form themes:

Below is an example extract detailing the themes:

Data Extract	Coded For
my partner went to the pond and measured sound on the datalogger it was quiet but the ducks started making noise. she got quite wet, there was no-one there but there were fishes in the pond large gold ones. they also had to stay very quiet so they could hear the other sounds around them. her feet got wet due to rain the pond was a big puddle dip in the ground	1.Mentions Partner 2. Mentions the location 3. Describes the process 4. Mentions datalogger 5.Statement about sound level 6.Statement about the environment

Table 18.6: Example data extract with codes applied

The codes were then collated to develop four key themes.

Ownership	Equipment	Context	Confusion
Mentions Partner e.g. - 'She collected'	Mentions datalogger	Describes the collection process	Discusses sites which were not visited
Mentions themselves e.g. 'I saw'	Mentions some kind of tool	Relates context to graph or sound level	Discusses the lab experience.
Neutral - e.g. 'you could'		Statement about the sound	
Trust issues e.g. where a student reported "apparently it was noisy"		Statement about the environment- e.g. there were ducks	
		Statement about the location - e.g. went to the pond	

Table 18.7: Emerging Themes

In the following section the four themes will be discussed in detail, including the differences in how the Self students responded in comparison to the Peer students.

[40] Self (M = 41.7, SD = 27.4) Peer (M = 37.8, SD = 20.76)

Ownership: The experiment was designed partially to explore the impact of ownership upon the students' learning and motivation. Ownership has been defined in this thesis as relating to the idea of control and personal experience, with a particular focus on how collecting your own data may lead to increased feelings of motivation and a better understanding of the data and the surrounding context. The observations of the data collection, as recorded by the students were reviewed with reference to how the student ascribed ownership of the data. In particular the focus was on whether the students took ownership of the data and used phrases such as "I collected" "my data" or if the data was reported in a neutral manner, with no mention of the student. Emphasis was placed on the peer reports to explore whether they took personal ownership of the collection process or if they gave credit to their partner.

The findings indicated that the students responded in a variety of ways with little consistency within the two groups, self and peer. Within the peer group seven of the 19 students directly referenced their partner "my partner saw" "My partner went to the pond". Of the remaining 11, ten of the reports were written as if they could have been present "the field was very quiet" "it was raining but fun", the remaining statement is of particular interest as it reported "it was neither loud or quiet. there were apparently ducks and fish splashing and quacking. there were no people around." The use of apparently suggests that this student may be uncertain about trusting their partners account. As in the peer group, the self group also provided mixed responses to ownership, 11 of the 19 explicitly mentioned their experience "I went to the pond" "I noticed the more ducks" "I went outside". Of the remaining 8, seven of the students gave neutral statements "it was not loud but not quiet" "big pond, crowded with ducks" these statements are ambiguous about whether the student experienced the context or not. The remaining student provided a description of what their partner had experienced inside the lab. A more detailed description of this is provided in the 'Confusion' themes analysis.

Reviewing the workbooks in terms of data and ownership seems to imply a mix of responses, it is particularly interesting that some of the peer students provided observations which were ambiguous about the data collection experience. This may be because they are focusing on reporting the observation rather than the method of collecting the data. There is potential that as the students worked in pairs, they may have felt a sense of ownership of the data as a shared experience.

Equipment A key focus of this experiment was the use of dataloggers to facilitate the data capture. A review of the student observations indicated that three of the peer students mentioned some form of tool “they got the dataloggers” “Tom’s thing broke down” “my partner went outside with a microphone”. The limited number of descriptions with respect to the datalogger is not surprising as the students were instructed to report observations of the context, rather than the methodology of the data collection. The three students each provided a different level of information around the tool: Datalogger, Microphone and ‘Thing’. Within the Self group again only three students mentioned the tool, however in all three cases the student used the word datalogger. This may indicate that the student’s hands on experience with the datalogger gave them a better understanding of the equipment and its involvement in the collection process.

Context The key focus of the observation section was for the students to report characteristics of the site that might have an impact upon the sound level. The student observations were reviewed to explore how these characteristics were reported, and the extent to which the student made connections between the environments, sound level and the data collected by the datalogger. The majority of the peer students provided basic observations such as “rain construction site kind of loud (loud quiet loud) machines, not many people, lorrys went by, fat workmen doing nothing”. These descriptions provide context of the collection but do not show how the context might connect to the data. However three of the peer students do begin to form associations. For example

“the dataloggers recorded the different noises creating a graph [..] however the rain made a difference to the decibels detected”

This highlights how the students were starting to make a connection between the environment and the impact it would have on the data. Within the self group four of the students made connections between the context and the data:

“when I was recording a fish came up and made a loudish noise it made the graph go high”.

Of the three peer students who highlighted these connections two of them worked with students in the self group who also made the connections. The partner of the third peer student who made the connection mentioned the sound readings but did not attribute it directly to the context “the building site was actually quite quiet. There were not many people. The sound readings consistent”.

Confusion The final theme of confusion is discussed as it became apparent that 5 of the students provided descriptions about the peer students’ experiences. “they sat in a room....” “the other group had to”. This is potentially insightful as it is not what was asked for in the observation section. In particular in the four cases where the students reported both Self and Peer experiences, three of them provided a longer description for the indoor experience. The fourth report only mentioned the indoor experience.

A second form of confusion was also apparent in the data whereby the students reported characteristics of site that they did not visit, in particular discussing the car park (the researcher collected this data) and the construction site (this student visited the field location). The two students who made this mistake worked in a pair so it is likely that the peer student provided the detail as that is what the self student told them. It is unclear whether the car park was reported because the students arrived via a coach and therefore had experienced a car park on campus, or whether the student had based it on being able to see a car park in the distance.

Findings: This thematic analysis of the observations made by the two groups of students (peer and self) has highlighted the different focus and emphasis that the students provided in their observation descriptions. It was very common to provide information around the context, e.g. the sound level and the surrounding environment, this kind of detail is to be expected as the remit indicated that the students needed to provide detail around their observations. Interestingly some of the students have begun to extend this by forming connections between the context and the data collected, for instance noting that the ducks increased the sound level. It is apparent that both self and peer students formed these data connection, but that often they worked in pairs to do so.

Section Two Required the students to use the graphs that were created, as part of the presentation intervention, to answer 12 questions. Each student was given a score out of 12 assessing the accuracy of their answers, the student could obtain up to 6 marks for questions relating to Graph A and 6 marks for Graph B, one point per question. The results did not consider the drawing of the graph but the student’s ability to accurately read from it. Ten of the 38 students were marked by a second reviewer, the inter rater reliability was found to be .697 using Kappa’s statistic, this is considered to be substantial (Landis & Koch, 1977) consequently analysis of the initial reviewer’s data was undertaken. A 2x3 ANOVA was run to explore whether students scored differently dependent upon their intervention experience. The results indicated that there were no significant differences for the main effect of collection interaction $F(1, 32) =$

0.037, p = .848. The main effect of presentation was non-significant $F(2, 32)$ = 0.353, p = .706. The interaction effect was also non-significant $F(2, 32)$ = 0.150, p = .862. This suggests that all the students were able to read and interpret their graphs successfully.

Section Three Asked students whether the graphs were as expected and the types of observations they could make about the data. This was split into four questions:

- What observations can you make about the data (Student visited)
- Was the graph what you expected? (Student visited)
- What observations can you make about the data (Researcher visited)
- Was the graph what you expected? (Researcher visited)

As some of the students gave blank answers or referred to previous questions e.g "explained above" the questions were combined to form two categories:

1. Responses about the data and graph (student visited)
2. Responses about the data and graph (researcher visited)

Based upon the literature it was anticipated that there might be a difference in the students' ability to interpret the data based upon their experience of each site. A basic word count analysis indicated that while on average the Peer students wrote more, this was not statistically significant, $t(36) = -1.29$, p= .203. A comparison of the word count for sites A and B indicated that there was no significant difference in the quantity written about each site by the students', $t(37) = -.715$, p= .479.

	Site A	Site B	Total
Self	28	31	59
Peer	38	38	76
Total	66	69	

Table 18.8: Average word count for responses regarding Site A and Site B

A thematic analysis was conducted using the same approach as in section one, in this case as the focus was around data presentation, the coding was carried out using an inductive approach with the data guiding the themes, rather than looking for specific instances of ownership or motivation. Figure 18.7 shows how the codes were formed into three key themes: Presentation, Data and Explanation. In the following sections detailed descriptions of the themes are presented, supplemented with extracts from the data to provide examples of the themes.

Presentation: A number of the students provided responses to the questions with explicit reference to the graphs they had produced, in particular some students in the annotation group mentioned having made observations already "i've labelled on the graph" " there are observations on my graph" "on poster". Interestingly this happened exclusively in the peer annotation group with the self annotation students focusing more on describing trends in the graph and the relationship to their expectations. In the manual group a concern was raised around the accuracy of the graph, as it was hand drawn. There were also a number of mentions of correlation and the failure to find this, suggesting that the students understanding of the sound graphs might have been limited by their general understanding of graphs. One of the software students noted "the graph was a lot more complex and accurate than I expected. there are interesting patterns and you can almost guess what made which points on the graph."

Explaining: The majority of the students used this section to try and explain their data, making suggested connections between sound levels and the characteristics of the sites "no I thought it would be much quieter at the pond because no one was around and it was only the ducks, but ducks are really loud". The responses varied in whether they have obtained expected results or not, some students reported yes because they had correctly anticipated the difference in sound levels "yes because I expected the car park to be louder". While others highlighted where results had not been anticipated:

"no I thought it would be simpler",

" yes apart from the fact that it went much louder than I thought it would."

Some of the students were surprised by their graphs:

"I didn't expect the highes peak to be like it was so sudden i'm not quite sure what is happening to make it so loud"

Despite this student being a self student they are unable to make a connection between a peak on the graph and their personal experience collecting the data. In contrast some students made direct connections between their experiences and the data:

"When I was out at the pond a fish splashed in the water a few times which made the data change"

"there were a lot of little peaks from ducks quacking and bigger peaks from splashes and things".

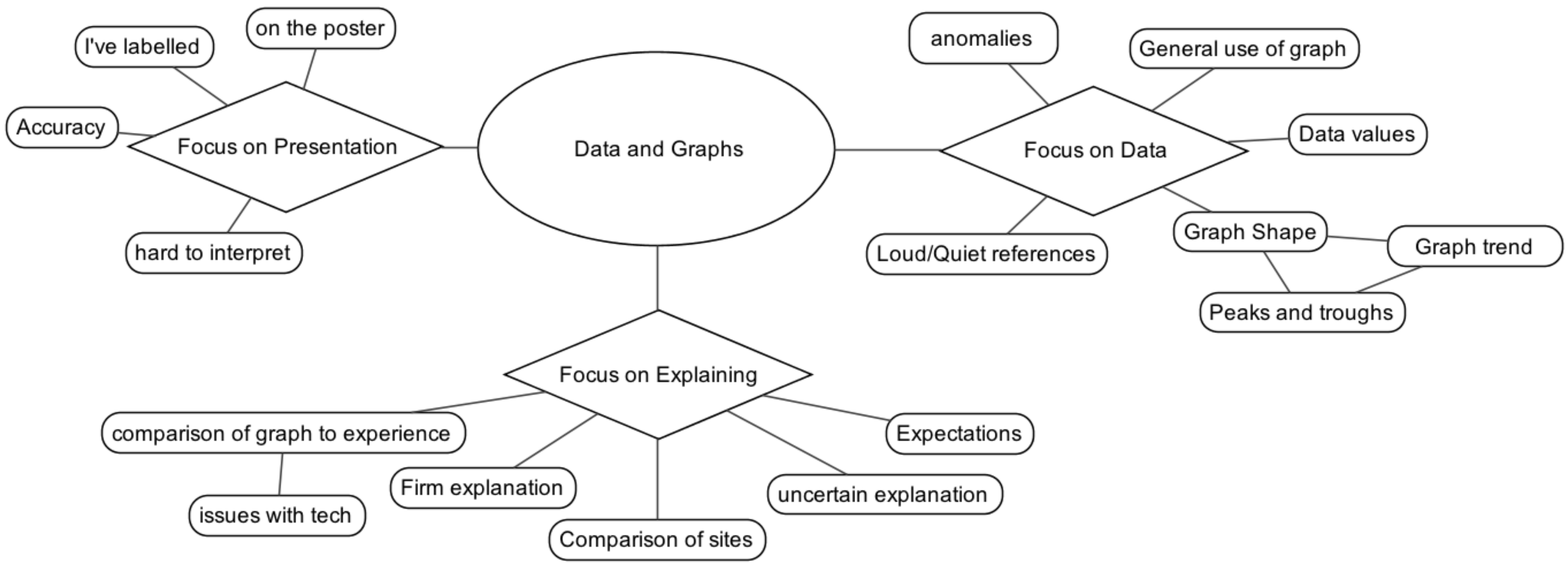


Figure 18.7: Themes in Section Three

Interestingly these assertions were also evident in the car park data where none of the students had experience “when a car enters or leaves its at its loudest it then changes quieter as cars turn off then and short quiet intervals as doors are open and people chat” this student has developed an explanation for their data based on what they anticipated happening but has written it in a manner which suggests fact and experience of the event, another student provided a similar account “when the noise was very loud I think a car alarm was going off”.

Data: When discussing the graphs and data a clear method that the students used was to refer directly to the graph, and in particular discuss its shape, and peaks and troughs. “I can see that it was quiet to start with and was always louder at the end but had its large peaks in the middle where it got louder”. This is to be expected as the question directly asked them to consider the graphs. It is interesting that the students combine discussing the data “about 42-45” and then follow this up with an explanation for the sound level:

“there is a background noise around at the car park always about 42-45 decibels there were many different peaks in the graph which shows their was a lot of activity going on (this i expected for a car park) after every peak the noise fades away slowly this will might be a car driving away in the distance of (??) the reverberating of the surrounding buildings from the large house. (altho) there no pattern as there to many variables to predict it”.

Other students gave much shorter answers

“it is fairly constant but sometimes it shoots up”

“it could have had people talking in it”.

The student responses to the different sites do not indicate a difference between a site that was visited by a student or a researcher. However when considering Site A (visited by a student) some of the students do attribute data points to events during data collection:

“this is probably down to our talking and the rain”

“it was only ducks but ducks are really loud”.

These examples indicate how some of the students tried to make sense of the data points based upon their data collection experience. However they were also able to do this with data out of context by using their existing understanding of car parks and providing suggestions based on prior knowledge.

Summary: These themes indicate that students considered the tasks in a number of different ways with some students writing the minimum “it is quieter than i thought it would be” while others have begun to consider the shape of the graph and provide explanations for peaks and troughs. It is evident that the students' understanding of graphs is somewhat confused with some students anticipating a correlation "it has no line of best fit and no correlation". It would appear that students are trying to apply scientific terms without a full appreciation and understanding of their meaning. The ability of the students to understand the car park data does not appear to have been limited by the reduced context, however this may be because car parks are a familiar location and the students were able to rely on an existing schema around car parks to deduce possible reasons for events in the graph.

Section Four Before the experiment began the students were asked to report their predictions, they were provided with the names of the two sites Field/Construction/Pond) and Car Park and asked to make predictions about the sound level, the shape of the graph and any similarities/differences between the two sites. Following their data collection and production the students were asked to reflect on their predictions and comment about whether the results are as they predicted. In the next section the student predictions and responses were analysed using a content analysis, this allows us to "determine which concepts are most cited through out the data" (Leech & Onwuegbuzie, 2008, pg 596). The codes are deductively produced with a focus on exploring when students refer to sound levels and graph shapes as this is what the students were instructed to consider. The responses are also coded to show whether the students felt their results matched their expectations, see table 18.9.

Collection	Production	Results as expected				Sound Level		Graph Shape	
		Yes	No	Mixed	No Response	Prediction	Discussion	Prediction	Discussion
Self	Annotated (6)	2	2	1	1	6	5	1	1
	Manual (6)	4	3	0	0	6	4	4	2
	Software (7)	3	2	2	0	7	4	4	1
	Total (19)	**8**	**7**	**3**	**1**	**19**	**13**	**7**	**4**
Peer	Annotated (6)	4	1	1	0	6	5	3	0
	Manual (6)	2	3	1	0	6	4	5	0
	Software(7)	3	1	2	1	7	2	3	0
	Total (19)	**9**	**5**	**4**	**1**	**19**	**11**	**11**	**0**
All	**Annotated (12)**	5	3	2	1	12	10	4	1
	Manual (12)	6	6	1	0	12	8	9	2
	Software (14)	6	3	4	1	14	6	7	1

Table 18.9: Content Analysis for Predictions

The content analysis suggests that the students more often discussed the sound level and the context of the sites rather than the anticipated graph shape. Interestingly while it appears the peer group discussed the shape more frequently prior to the experiment "the graph will be quite high" "the car park's graph will go up and down a lot" none of the peer students referred to the shape of their graphs after the experiment. The content analysis also indicates that the Software students provided less information in regard to the sound level at post test. A review of the responses indicates that the discussion answers were substantially shorter than the prediction responses. These results raise a question around the amount, and level of detail that the students provide after the experiment. It appears that the students provided substantially less detail in their discussions. The consequences of this are considered further in the chapter discussion.

Section Five Asked students to consider whether the experiment had been a fair test, and what they would change if they were to do it again. Stage one of the analysis involved coding the students' responses to whether it was a fair test: the response were coded and themes generated (see figure 18.8)

In the following section the themes are discussed with reference to how the collection intervention impacted upon the student's perception.

Was it a fair test? The student responses were coded into four groups: Yes, No, Unsure and no answer. Analysis focused on the difference between the two collection groups, as according to the AQA glossary of terms[41] "A fair test is one in which only the independent variable has been allowed to affect the dependent variable" consequently details about the way the graph was produced are not relevant to the concept of fair test, furthermore none of the students mentioned the production graphs in their responses.

Collection Experience	Yes	No	Unsure	No Answer
Self	5	11	2	1
Peer	11	6	2	0

Table 18.10: Fair Test Responses

It is clear from table 18.10 that the students in the peer group were more likely to respond that it was not a fair test. In the following section the analysis focuses on the types of explanation that the students provided, these are considered in terms of collection.

Experience: Within the peer group four of the students discussed the importance of context and experience for understanding whether it had been a

[41] http://store.aqa.org.uk/sciencelab/AQA-GCSE-SCIENCE-GLOSSARY.PDF accessed 17.03.2013

Figure 18.8: Codes and themes developed during analysis of Fair Test

fair test, one of them specifically mentioned that they had not been present "I guess so, i wasn't actually there though so I don't know what exactly happened during" while the other three were concerned about the actual context of the event, noting that if you visited the sites at different times then the sound levels might have been different: "they might be drilling at one time which could be loud, but on another they could be brick laying which would be much quieter". In the self group again four students mentioned the context of the data collection, three of the four focused upon the impact their collection could have had on sound: "some people were talking", "the number of people in the groups making the amount of voice interference very uneven". One student drew particular attention to their experience " sort of, because I did not do the car park so I do not know if they were making the loud or no sound at all". From these extracts it is apparent that some of the students were considering the impact of data collection upon their data, and in particular some of the students had noted that they did not have enough experience of the data collection to fully understand the data.

Tools: Nine of the students reported the equipment having an impact on whether the experiment was a fair test. Three students were in the peer group and they provided a positive opinion on the machines "used the same machine" "same equipment" "dataloggers were good and accurate". However in the Self group the responses were varied, with some students indicating the benefit of the dataloggers "tested by the same thing" "dataloggers were the same". Two of the students suggested that the experiments were performed with different equipment, "different people did it with different equipment" "no we used different machines to record". It is unclear whether their concern was that the machines were different and therefore might be calibrated differently, or if they believed a different type of equipment had been used to collect the car park data. Either way the self group place a greater focus on the equipment than the peer group.

Method/Technique By far the most common explanation for whether it was a fair test was around how the experiment was carried out. This is understandable, as mentioned before a fair test is defined by whether only the independent variable has affected the dependent variable. The students considered a number of factors which might have had an impact upon the dependent variable such as: length of the recording, time of day it was taken, not doing the recording at the same time, ensuring the test was repeated. Some factors which students felt made it an unfair test, were noted by others as making it a fair test “yes because they timed the same amount”

“ no as there was a longer amount of time” .

As the students were in charge of selecting the amount of time (up to 12 seconds) at the site they visited it is possible that in some cases the car park data might have been the same length as the site A data, while for others there might have been a difference. The topics discussed by the students suggest that they have a general understanding of what makes a fair test, but their level of involvement in the data collection does not appear to have affected this.

Misunderstanding As in the previous sections some of the responses provided by the students indicate that they may have misunderstood the experiment, for instance one student responded, “yes because everyone in the classes results were the same” we did not combine the results during the day, so unless the student reviewed all of the data this is a broad statement to make. Similarly another student responded “yes because we had an even number of dataloggers going to each area and we combined the results”. Again this is not what happened.

What would you change?

In the second stage of the analysis, the students’ suggested changes were coded and these formed five categories:

1. Talking about techniques or methods (M)
2. Talking about the tools (T)
3. Talking about experience and context (G)
4. Talking about the whole day (not the experiment) (E)
5. No response (-)

Table 18.11 provides the number of times each code occurred, 19 students took part in each condition so a direct comparison can be made between values. [42] If we focus on the three codes which referred specifically to the experiment: M, T and E it is apparent that the peer group were more concerned with changing the method while the Self group discussed the tools more. There is no difference between the two groups in terms of talking about experience; perhaps what is interesting is that only two students in each group noted the value of experience. In the peer group the focus was on understanding the data “record what it was

[42] Note two of the responses were coded as two codes.

so then we know what noise is making which wave/point" "I would change that both groups are allowed to see the sites that you are getting the data from" while in the self group the focus was on enjoyment and having a fair test "I would have liked to have tested both locations" "me doing both places".

Collection	M	T	G	E	-
Peer	14	1	1	2	3
Self	9	4	1	2	3

Table 18.11: Frequency of codes

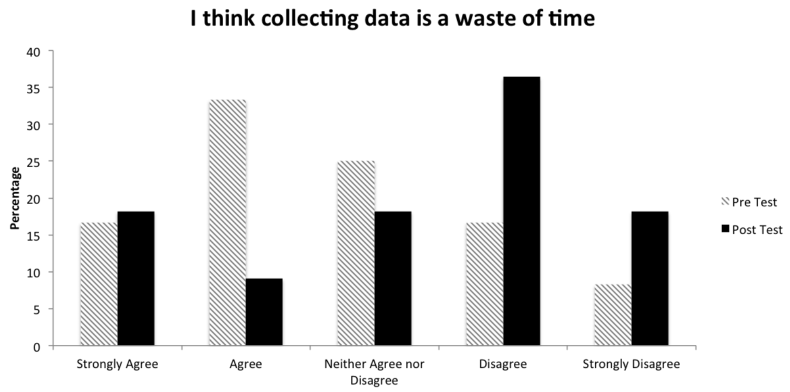
When reporting on the expected outcome of their change, a number of the students reported it would improve the accuracy "I would expect it to be a more accurate outcome" "a more accurate result". Some people reported anticipated sound levels e.g. 'the car park would be quieter', showing a focus on the results rather than the validity of the testing methodology. Four of the students noted that their suggested change would provide experience which would provide a better understanding, and that they would trust the data more. One of the four students was concerned with fairness suggesting "fairness in groups, everyone gets the experiences", it is clear here that the student was talking about the whole day, and that they felt it was important for the students to visit the sites.

Motivation Pre and Post

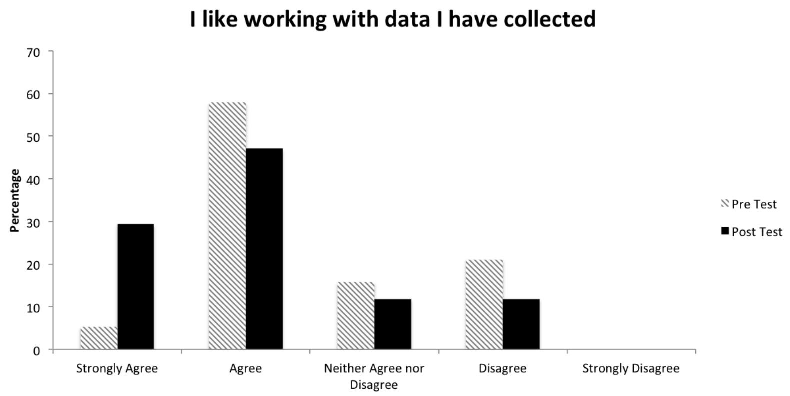
Six questions within the pre and post tests targeted students' motivation. These were assessed using a 5 point Likert Scale from 'strongly agree' to 'strongly disagree'. Of the 6 statements assessing motivation, four statements: were shown to be non significant[43], while the remaining two showed significant differences. *I think collecting data is a waste of time* and *I like working with data I have collected.*

Analysis using a Wilcoxon showed a difference within the presentation factor, with students who were in the pre-produced category shifting their responses for *I think collecting data is a waste of time* (Z = -2.041, p<.05) towards 'Disagree'(16.7% pre-test and 36.4% post-test) and '*Strongly* Disagree' (8.3% pre test, 18.2% post test), indicating a positive change in opinion.

[43] I find it useful to draw a graph by hand, I enjoy using computers to draw graphs, my understanding of a graph is better if I have drawn it myself, my understanding of a graph is better if someone else has drawn it.



(a) Graph showing percentage responses to 'I think collecting data is a waste of time'



(b) Graph showing percentage responses to 'I like working with data I have collected'

Figure 18.9: Graphs showing percentage responses

Analysis of *I like working with data I have collected* showed a significant change for students who self collected (Z = -2.460, $p < .05$). At post test they showed more 'Strongly Agree' responses than at pre test (29.4% of responses, compared to 5.3%).

In order to understand why differences were not found in the remaining four questions, the pre test data was reviewed to explore the students' base motivation level. Figure 18.10 shows the type of responses provided by the students for each of the 6 questions. Agree statements were coded as positive, while disagree statements were coded as negative. It is important to remember that questions 5 and 6 were worded in a manner that would lead us to anticipate the students responding in a negative way. It is evident from these results that the students are already positive towards collecting their own data and producing graphs, shown by at least 50% of the students providing a positive response at pretest to questions 1-4, and the anticipated negative responses[44] for

[44] These questions were negatively worded, so it was anticipated that the students would disagree

questions 5 and 6. Therefore the interventions may have had little effect due to the students' existing high levels of motivation.

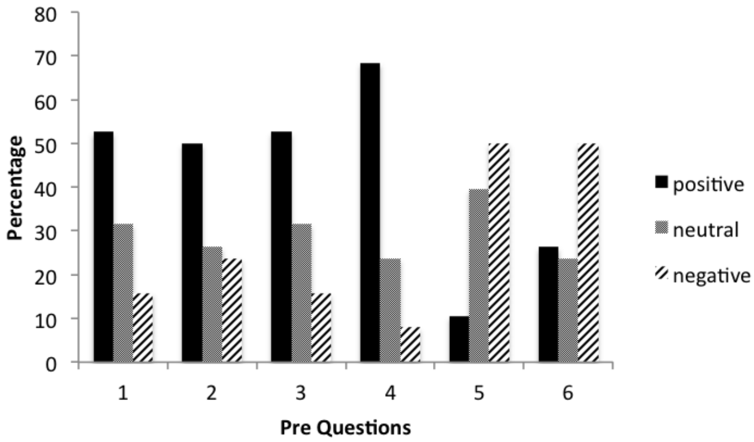


Figure 18.10: Graph showing pre test motivation responses

In addition to answering the 6 motivation questions using a likert scale, the students were also able to provide detail around their choices. A thematic analysis was conducted to explore the types of explanations provided by the students. Four key themes were identified: Ability to Understand, Motivation, Accuracy and Trust, Problems & Issues. In the following section the four themes are discussed with examples drawn from the student responses to illustrate the explanation.

Ability to Understand: A number of the explanations focused around the student's perception of how useful a method was, in particular the students often made connections between doing it for themselves and gaining context to help them learn:

"I like working with data I have collected as it means I can make a connection with the data on the graphs and the time that i spent collecting I think it also gives me a better understanding than using precollected data".

Some students discussed their understanding in terms of graph drawing, with some noting that graphs produced using a computer are easier to understand, while others found it more useful to draw a graph by hand presenting concerns about automated graphs:

"It's easier and quicker but it can mean you don't really take in what the graph is telling me."

" I just find i take in the information better while i'm drawing it, but it doesnt really matter."

Context was also highlighted when discussing using a graph provided by someone else

"I don't know anything about or have any information or thought behind it"

" you don't know where the peaks came from".

It is clear from the responses that the students were considering the impact of their own experience on their ability to understand graphs and that while they value tools for making it easier, some were concerned that they would lose the connection to the data.

Motivation: The students' level of engagement and interest was also a clear factor in their ratings on the likert scale. For instance when considering drawing a graph by hand one student compares enjoyment with simplicity "I like drawing graphs by hand but sometimes it is easier to do it on the computer" however this student stated at post test that "it is much easier" to draw a graph by hand. This is intriguing as this student was in the software condition.

When discussing data, students tended to report that if it was interesting data then they would like to collect it themselves but if it was boring they would prefer not to, this supports the idea of context and experience influencing the students' motivation:

"If it is something that interests me then i'm more likely to enjoy working on it"

" Unless it's football or rugby stats data collection doesn't inspire me"

These findings support the motivation literature tat notes the importance of interesting the students (Mistler-Jackson & Butler Songer, 2000) through making them curious and compelled to learn (Lepper, 1988).

There were mixed responses to using computers with some students being positive "doing it on the computer would be cooler" while others reported "I don't normally like to use computers". Some of the students reported not enjoying graph drawing, but that using a computer made the process quicker and easier.

Accuracy and Trust Accuracy was a major theme evident in the student responses. In particular the students often noted that using a computer would increase the accuracy of their graph

"if you've put the right data in you know it would be right"

"I can have everything exact".

Although one student in the software condition indicated that computers can go wrong, they mentioned this both pre and post test suggesting that this student was wary of computers prior to the experiment. In terms of data collection the students varied, some felt that collecting their own data would make it more accurate:

"if someone else collected it they could have gotten it wrong"

"I think it is more trustworthy if you collect it yourself".

While other students were concerned with the accuracy of their own data:

"my data is normally wrong"

"I would find it harder to recognise my own mistakes if I collected the data myself".

When discussing the graphs, accuracy was often discussed in relation to presentation with students being concerned with hand drawn graphs being "messy and not always correct" "It depends how neat I draw it". When considering using a graph produced by someone else, accuracy was again a concern:

"they could have done the graph wrong"

"you might not be able to read the handwriting"

"it doesn't make a difference unless the graph was drawn badly"

Only one student reported that "it's more reliable" to use someone else graph and this changed at post test to "I may not trust them" suggesting that they now valued the context more.

Problems and Issues: Throughout the responses the students frequently commented on factors such as whether it was a waste of time, and how easy it was do to the task. Often students were positive towards the task but noted that they might have difficulty "When I work with data i like plotting it into graphs but sometimes i get really confused on the graph". When discussing data collection time was often reported as a factor

"by hand is a waste of time but with a datalogger it isn't"

"it would take time to get it yourself but it would take the same time or longer to ask someone else to do it instead",

time was also mentioned when using somebody else graph

"I can spend more time looking at it than having to draw it aswell".

Using computers was mostly reported to make the task easier and quicker, although some students noted that it can "get complicated" and "sometimes computers don't work". Presentation on the computer was also mentioned "it is more fun, easier and you can show more information looking very professional". Presentation was also mentioned when discussing using a graph drawn by someone else "Sometimes it can be more clear if they have a better way or type of graph" "sometimes more easy to read".

Summary: The results indicated that the students' provided mixed explanations. Students focused upon how experience could help them understand their data better. Students also reported the importance of being motivated. Accuracy was shown to be a concern for the students when considering the methods of collection and presentation. It was reported that self collecting data could help them understand the context, but this was mediated by the extent to which the student believed the task was worthwhile.

Motivation Workbook:

Within the work book two questions assessed motivation: *Which set of data did you feel more comfortable working with?* and *Which set of data do you feel you can explain better?*. Initial analysis of responses to the 'comfortable' question indicated that students in the Self group more often indicated Location A (the Student Site) (68.8%) than students in the Peer group (18.8%) The majority of students in the Peer group indicated that they found no difference between the two locations (62.5%). Statistical analysis using Chi Square indicated a significant difference between the observed and expected frequency for collection type, and which data the students felt more comfortable with, $\chi^2(2, N = 32) = 8.541, p<0.05$.

Statistical analysis using a Chi Square test revealed a significant difference for the main effect of collection $\chi^2(2, N = 31) = 6.880, p<0.05$).

60% of Self students felt they could explain Location A best compared to only 18.8% of Peer students.

Both of these questions indicate that students who collected the data themselves felt more comfortable with that data and felt that they could explain it better. These results are supported by qualitative responses by the students. For example, in response to *Which data did you feel more comfortable with?* a student in the 'Self' group reported,

> "Location A- Because this was the one I tested and it took less time to draw a graph because I understood the data better"

compared to a student in the 'Peer' Group

> "No Difference-I didn't go and find any data so it doesn't really matter to me which one I worked with".

Similar responses were found for *Which set of data do you feel you can explain better?*: Student in the 'Self' Group

> "Location A-Because with this one I know why the data was varied, however I couldn't find out why the other set of data was varied"

compared with student from the 'Peer' Group

> "No Difference-I think I understand each both the same because I didn't go out and collect the data so I was just working with the data I got given and it didn't matter which one I had"

The student responses were reviewed to explore the reasons with reference to selecting either Site A, Site B or No Difference.

Site A: When explaining why they felt more comfortable and able to explain Site A (self/peer visited) the Self students focused predominantly on the fact they had collected the data and this meant they could understand the data better "because this was the data that I collected myself and know about already" "because I was there so I know what was happening". When the Peer students indicated they preferred Site A it was often in reference to the data itself "the graph was easier to read" "there are more things happening" "there was more noise so the graph has better results".

Site B: Both self and peer students who chose Site B, provided rationales based on the data "the graph was simpler" "because you could see the real difference of the sound level". Two of the peer students noted that because it was a car park they felt more able to explain it "because it is a car par you can be more sure of what's goin on" "for the car park I can say about the rise in noise" suggesting that these peer students preferred to base their understanding on their previous experience of car parks, in comparison to their partners experience of site A.

No difference: The students who reported that there was no difference between the sites, focused on the fact that they did not have experience of either so it did not make a difference, the second reason provided by the students was that you had to do the same task and the data was similar, so there was no difference in their comfort or ability to explain the data.

Summary: The results indicate that the intervention showed a clear effect on the students in terms of how confident they felt with the data, with students who collected their own data more often reporting that they felt more comfortable working with their data than with data collected by a researcher. Students who collected their data also felt they could explain their data better than that collected by the researcher. However the results failed to show a difference when the students were reporting enjoyment and their understanding of graphs. This is interesting as the students showed a difference in terms of their confidence for explaining data, but not for graphs. In terms of learning, students showed a change in perception of graph reading and data points from pre to post. Students who were asked to draw their own graphs performed significantly worse on the graph drawing aspects of the post test. It is suggested that this is most likely due to the students losing motivation rather than a shift in their ability to draw a graph.

18.6 Discussion

A review of the literature suggested that hands on learning with mobile technology can help to engage students in science through making the data less abstract, and providing more meaning (Pea, 2002; Resnick et al., 2000; Rogers et al., 2004). Furthermore Palmer (2005) and Weiner (1990) have both noted the relationship between students' motivation and their learning attainment. The majority of the work in this area has been qualitative in nature, thus this investigation was designed to explore a quantitative approach using pre and post measures to explore how student attainment and motivation changed. The motivation questions were designed to target the three components of motivation as discussed by Pintrich (2003) Table 18.12 shows how each of the three components is targeted by the questions. Asking more questions to ensure reliability could have generated a more reliable measure. However, it was considered important to keep the pre and post tests short to maintain student interest, consequently the motivation section was limited to 6 questions.

Motivation Question	Ability to perform	Value of the task	Affective Reaction
I like working with data that I have collected			✔
I find it useful to draw a graph by hand	✔	✔	
I enjoy using computers to draw graphs			✔
My understanding of a graph is better if I have drawn it myself	✔	✔	
My understanding of a graph is better if someone else has drawn it	✔	✔	
I think collecting data myself is a waste of time			✔

Table 18.12: Table showing how motivation questions fit to Pintrich's (2003) motivation components

This experiment was designed to answer three hypotheses:

- Motivation will change for data acquired in context.
- Understanding will change for data acquired in context.
- Understanding of Pre-generated graphs will be different dependent upon the student's collection experience.

Motivation will change for data acquired in context.

This hypothesis was confirmed in terms of motivation, with those who self-collect, regardless of graphing condition, providing significantly more positive results at post-test to '*I like working with data I have collected*'. The self-collected group was significantly more likely to state that they are more comfortable working with data from the location that they visited, compared with the peer-collected group. The self collected group also chose this location as the one they could explain better more often than those in the peer-collected group. This supports the motivation effect of dataloggers as reported by Mee (2002).

Understanding will change for data acquired in context.

The results concerning understanding were mixed with those in the self-collected group performing worse at post-test specifically on their ability to draw a graph. The results were not inline with previous results such as those found by Mee (2002) and Friedler & McFarlane (1997), who indicated that student's learning benefited from the use of dataloggers. This unexpected result appears, from observation, to be down to a fatigue issue, with two students failing to complete the post-test graph and a number of others only partially completing it. This leads to questions around methodology, which are addressed in the later studies.

Understanding of Pre-generated graphs will be different dependent upon the student's collection experience.

Interestingly, the results indicated that the students who collected the data showed no difference between production types, while students who used peer data showed a better post test score when they used pre-generated graphs. In the following sections, the implications of the findings are discussed, considering the importance of focusing on interpretation, methods and techniques for assessment, and the relevance of motivation for hands-on learning.

While the literature indicates that students need to be motivated to learn effectively, Palmer (2005), the results shows no immediately observable relationship between increasing motivation and an impact on student understanding. That such a relationship would emerge in the long term needs to be established if sensors are to be used more, and indeed if methods of assessment are to be redesigned to reflect this pedagogical change. The study design has enabled us to gain valuable insight into the subtleties of data collection and graph production. The data suggest that in terms of motivation, self-collection of data is important. However, within the current study this does not necessarily transfer into better performance on post-tests. The pre-produced group were more motivated about collecting data, potentially because they had the opportunity to annotate their graphs, and connected the graphs with the importance of knowing the context. The results have provided new insights around peer-collected data and the effect on interpretation. The results suggest advantages for software-produced graphs, although the workbook analysis highlighted that some students are wary of computers for this type of exercise, and may prefer to draw a graph by hand. The results suggest that drawing graphs by hand did not hinder students, , however this was time consuming and those students did not provide annotations on their graphs. This suggests that they may have missed out due to the amount of work required to produce a graph by hand. This may be affected by the length of the intervention period: in this experiment it was only a 30-minute intervention so some students may have felt unable to provide all the detail which they wished in the time provided.

When reviewing the qualitative data a number of differences were highlighted between peer and self students, it is possible that these differences are due to the change in level of centricity the students had with regard to the data collection. For instance, when considering their graphs the peer students focused on labelling, while the self students looked to report trends and explain relationships between the graph shape and their experience. It is possible that this is a consequence of increased centricity during the data collection phase. However it should be noted that the students also made a number of assertions about the car park data, which gave the impression that the student had experience of the site even though they did not. This supports research; such as

Pintrich (2004) into the validity of using students self reports to draw conclusions about the extent of their knowledge and understanding.

Work by Adams et al., 2011 indicated that students who collected data were focused on different data attributes, in comparison to students who stayed in the classroom. This suggests that different types and level of experience with the data may lead to different priorities. These difference start to emerge in the workbook answers provided by the students, with the peer group focusing on experience and methodology as indicators of a fair test, while the self group placed the emphasis on the role of technology and its use when defining a fair test.

This experiment looked to provide an insight into three of the four aims, and used a novel mixed methods approach in an effort to begin to quantify the learning effect of experience with hand held dataloggers.

To what extent does automation, creating a seamless experience, affect the student's learning and motivation? This experiment showed that students who did not collect their own data performed better when provided with pre generated graphs. However this may be because the students spent longer annotating their graphs rather than due to the experience of the automation, especially when it is noted that there was no difference between those who used the computer software and those that drew graphs by hand. Unlike the research presented by Friedler & McFarlane (1997), the results of this investigation did not show an improvement in students' ability to read an interpret graphs following experience with dataloggers.

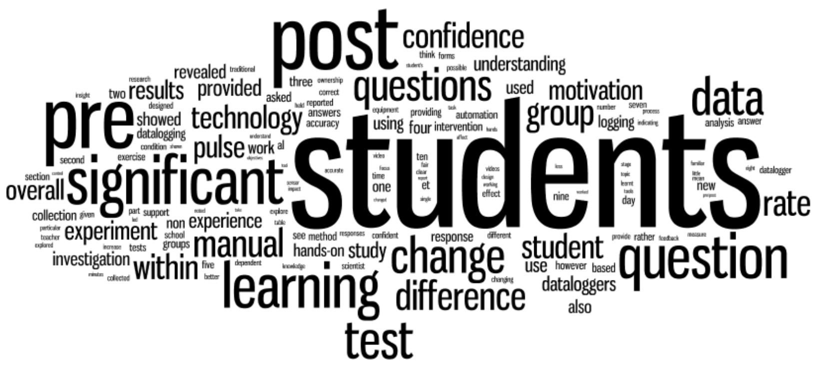
How does the addition of personal experience with a datalogger affect learning and motivation? Students who collected their own data reported that they felt more comfortable with their data and better able to explain it, whereas students who did not have direct experience of the data collection felt no difference between data collected by their partner and data collected by the researcher, suggesting that the personal experience had a positive effect upon the Self students in terms of their motivation and confidence in their understanding. The results of this investigation did not support work by Mee (2002), who reported that using dataloggers improved post test scores.

How can we quantify learning? This study highlighted the problems with the current academic tests of achievement. In particular noting that the students could provide incorrect answers but with logical reasoning is of particular interest when considering the design of future tests. Furthermore the qualitative questions highlighted differences in the students' confidence to explain their data. The idea of confidence in the students' understanding is explored further in the next chapter. Finally it should be noted that during this experiment it was found that the students became bored and tired by the end of the day which may have had an influence on their post test performance, highlighted by the fact that a number of the students did not complete their post test, and word count analysis indicated students also provided less content at post test. The impact of boredom can have a profound impact upon a student's test and results, so it is important that measures of learning are kept interesting and engaging to ensure that the student is able to reach their full potential during the testing experience.

This novel mixed methods study reveals the importance of breaking down the elements of hands-on learning to see where the advantages lie. The significance of constructing the data oneself was crucial to explore in terms of both motivation and learning benefit. This breakdown is key to designers for these kinds of activities, because without pinpointing the advantage clearly, it is difficult to design technologies in such a way that they can be tailored to effectively aid learning or motivation or both. If designers were to just access the results of qualitative research in this area, it would be very hard to separate the factors that are contributing to the 'advantage' of a hands-on approach. This study shows that the relationship between automation and learning is not simple at all – in fact, in this example, automating the process of graphing data highlighted an important change in performance under the subsequent post-test.

Part V

Technology Vs. Traditional



19 Using technology in the classroom

The Ownership and Automation study highlighted that the students found the hands on experience of using the dataloggers was motivating. Despite this general indicator, the attainment results were unclear, possibly due to fatigue on the part of the students undermining their ability to engage fully with the post test. It was noted that a number of the students failed to complete the post test, and many reported boredom and disengagement due to the length of the workbooks and their dislike of writing extended answers. In order to simplify the methodology, reduce fatigue effects and provide quantitative results the following study was designed to to minimise these factors. Primarily, this was achieved by simplifying the research design, providing the researcher with more time to interact with the students and ensure that students were on task and understood their focus. The questionnaires were also redesigned to allow them to be presented using an online system. This was more attractive to the students, as they could type their answers. It also allowed the researcher to ‘force’ the students to attempt every question, and provided typed responses that are easier to read than handwritten ones.

In addition to the general design of the study, the Technology vs Traditional also built upon the Ownership and Automation investigation, by continuing to assess the student motivation as well as learning. However this study also introduced a new factor: confidence in their own learning and understanding. All three aspects can have an impact upon a student’s overall ability to learn and retain scientific knowledge effectively.

Work by Quine (1987) [45] introduces the idea of the boundary problem; this

[45] cited in Hunt (2003)

refers to how certain one must be about a belief before it can be classed as 'knowing'. In this investigation the focus was to explore how confident the students were in their answer, and to use this as a measure of learning and understanding.

In the evaluation aspect of the Ownership and Automation study it was apparent that some of the questions had a ceiling effect. Therefore it was unclear if the students had progressed. It was also apparent from the explanations that sometimes the students had ticked the correct box for the wrong reasoning, or ticked the wrong box despite having correct reasoning. In order to reduce the incidence of that in this new study, the students were also asked to report how confident they were in their answer. This had two aims: firstly to encourage the student to evaluate their answer so they could double check it, and secondly to enable a measure of guessing.

This investigation looked to provide an insight into aims one and four:

To what extent does automation affect the student's learning and motivation?

This was explored by comparing the students use of automatic tools, dataloggers, to take pulse rate measurements, in comparison with using a traditional method, the wrist technique. Learning and motivation were assessed using pre and post tests designed in collaboration with teachers, and based upon the tests used in the earlier Ownership and Automation study.

How can we quantify learning?

Building on work from the previous study this experiment explored assessment results and students' self reported motivation as measures of learning. However this investigation also included a measure of confidence within the accuracy assessment in an effort to understand changes in a student's learning when they have not changed their answer from pre to post. This meant it was possible to establish if experience with the dataloggers provided the students with more confidence in their answers.

19.1 Rationale

In recent years there has been a focus upon providing students with the tools to direct their own learning, in particular following a speech in 2004 by David Miliband[46], quoted in his OECD report Personalising Education (Milliband, 2006), there has been a clear focus upon personalised learning. Anastopoulou et al. (2012) provide a visual frame work to explain how personal learning can be embedded into all sections of the learning cycle, see figure 19.1

[46]the schools minister at the time

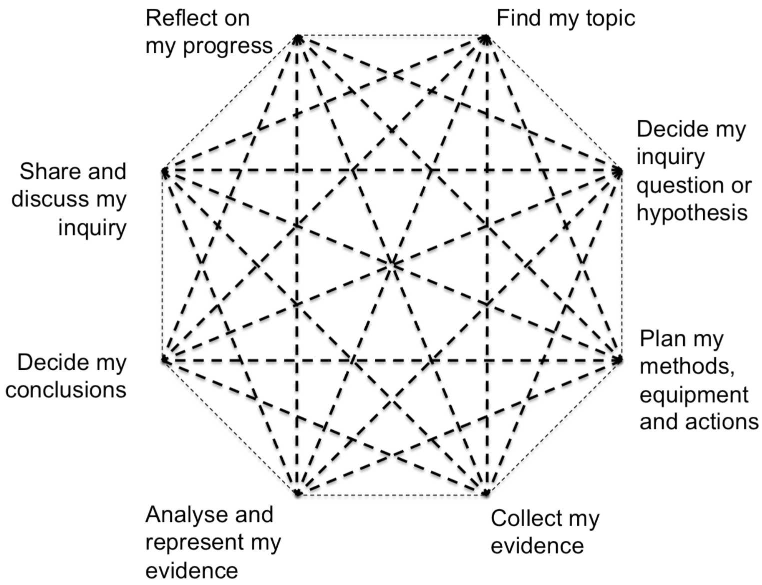


Figure 19.1: A visual framework to illustrate and guide personal inquiry learning Anastopoulou et al. (2012)

Dataloggers can be used to help students to collect their evidence, freeing up time to be spent on other stages of the framework. Use of dataloggers and mobile learning tools enable learners to explore, collect and evaluate their own scientific data with speed and efficiency[47] providing them with the potential to develop their understanding of the real world scientific research process (Cobcroft, Towers, Smith and Bruns and Sharples 2006, Corlet and Westmancott 2002). Hands-on technology can be used as a tool to support student learning (see for instance work by Choo, 2005; Facer et al., 2004; Gipps, 2002; Rogers & Wild, 1996). Furthermore, work by Gardner & Hatch (1989) notes that learners use a variety of different systems to learn. Consequently a variety of teaching methodologies needs to be employed to support the different learning styles. However not all schools are able to use hand held devices. This can be due to a number of reasons ranging from lack of availability to lack of expertise. In this investigation the differences between hands-on learning with and without technology were explored. The students were provided with the opportunity to take ownership of their learning at all stages, providing potential for personal inquiry to occur through either technological tools or traditional methods.

Inquiry learning allows students to generate their own goals and methods for exploration (LeBaron & Collier, 2001). Technology can be integrated into

[47] see Pedretti, Mayer-Smith and Woodrow (1998) and Traxler & Wishart (2011) for descriptions of research in this area

this to aid in the student's learning process. However at what point does "learning" become too technology driven and less about the learning process? This investigation was designed to explore the differences between hands-on learning per se and hands-on learning with technology. Similar to the previous work described, this study looked at the impact upon indicators of learning and motivation. Focusing on global learning: assessing how skills and methods develop and change, rather than the learning of specific content.

Keen to explore the use of technology in a genuine school environment, this project builds on work by Metcalf, Milrad, Cheek, Raasch and Hamilton (2008) who explored how technology, in particular mobile phones, can encourage student interaction and engagement with STEM[48] subjects. They used familiar sports topics as base points for asking science and maths questions to the students. The current study also used this approach by basing the students project on exercise and pulse rate. Through using familiar topics the students could concentrate on their experimentation methodologies and data collection rather than learning about a new topic, allowing the students to refine their existing skills and techniques.

19.2 Hypotheses

- There will be a change in accuracy from pre to post test dependent upon their data collection experience.
- There will be a change in motivation from pre to post test dependent upon their data collection experience.
- There will be a change in student confidence for learning from pre to post test dependent upon their data collection experience.

19.3 Participants

A total of 21 students from one school took part in the experiment, with a range of ability represented. Three sets of data were discounted for statistical analysis purposes due to students having to leave part way through the experiment. The students ranged in age from 13 to 14, with 9 girls and 9 boys participating. Half of the students had a 'traditional' experience of calculating their pulse rate using the fingers on the wrist technique, while the other half were shown how to use dataloggers with a pulse rate attachment that clipped onto their finger (see figure 19.2). Each student completed pre and post test online questionnaires.

[48] Science, technology, engineering and mathematics

Each student also completed a work book and produced a summary ‘60 Second Scientist’ movie. The students designed their experiments in pairs and produced their videos in groups of either 4 or 6.

Figure 19.2: Student using a pulse rate sensor

Design

The study employed a between subjects design, with the independent variable of collection (manual or datalogger) and a dependent measure of student performance on the pre and post tests. Students experienced different methods of data collection dependent upon which group they were in. Pulse rate was used in the experiment, as it was a concept with which students of this age are already familiar, the topic choice was discussed with the teacher. Pulse rate can be easily understood, and the students can easily link the numerical value to their own pulse rate experiences. The pre- and post-test questionnaires were counterbalanced to ensure that they did not differ in difficulty. The pre and post tests were again based on national tests designed for this age and attainment level of student. Students who used the dataloggers were able to see their pulse rate result on the datalogger screens providing them with an instantaneous reading. Students who used the traditional method were shown how to calculate their pulse rate by counting the beats for 10 seconds and then multiplying the value by 6.

Materials

Equipment The study used Logbook ML dataloggers (see figure 9.1a on page 59 for an example) provided by ScienceScope with additional plug in Pulse Rate Sensor (see figure 19.2 on the preceding page). The students also used stop watches, calculators, tape measures and cameras.

Software The students used a variety of media software to produce their 60 Second Scientist video. This included Movie Maker and Photo Story. The students chose software that they felt most comfortable with. The students were asked to produce a 60 second movie on anything they had learnt during their day investigating pulse rate. Students worked in groups of 4's and 6's. They were provided with digital cameras and movie making software. The students were encouraged to plan their videos before they filmed. This process was supported but unstructured enabling the student groups to decide what they wanted to report upon. The 60 second scientist was run in support of the class learning objectives and not a part of the experiment methodology.

Pre/Post Test The pre- and post-tests consisted of questions designed to assess the student's conceptual knowledge, domain specific knowledge, their motivation, and their confidence in their answers. The tests were based upon questions that arise in national Maths and Science examination papers for this age group. This ensured that the question style would be familiar to the students. The language used in the questions also appropriately reflected this level. Questions relating to the students' confidence were based upon a common school system of asking students to 'traffic light' their confidence in their learning[49], enabling the teacher to compare the students actual understanding with their perceived understanding. See table 19.1 on the next page for example questions, and appendix G.4 for an example of the pre test, which includes the multiple choice answers.

[49]this method was discussed with teachers prior to the experiment.

Section	Question
Conceptual	Is there any evidence to suggest that Lucy's prediction is correct?
	What was the range of lung capacity for the boys?
	What other factors might affect someone's lung capacity
	Do you think this is a good number of people to test?
	Did Lucy carry out a fair test?
Domain Specific	What is the average heart rate for a healthy adult?
	Do you think boys and girls will have a different average heart rate?
	Which do you think will be more accurate for measuring your pulse rate?
	Do you think doing exercise will affect your pulse rate?
	Do you think your pulse rate stays consistent?

Table 19.1: Questions asked during the pre/post test

Section A This section provided the students with a data collection scenario and asked them to consider whether the experiment was fair, whether the analysis was correct and to read values from the table. This scenario was based upon SATs/GCSE questions that expect students to be able to use general transferable skills to evaluate and explain an unfamiliar concept and enabled evaluation of the students' conceptual knowledge.

Section B This section asked specific questions about pulse rate, this provided information on the base level understanding that the students had, enabling comparison to see what was specifically learned during the intervention. As in section A, these were based upon SATs/GCSE questions, and were at a level that the students should have been able to answer, or attempt to answer, correctly. The inclusion of GCSE questions was chosen to reduce the possibility of a ceiling effect with the multiple choice questions.

Each question in Sections A and B was followed by a confidence question asking the students to rate their confidence on a 3 part scale: "I am certain I am correct", "I think I am correct" and "I am really not sure". Using this method enables comparison of the students' confidence in their own learning, regardless of whether their answer is correct, this can highlight if there is a perceptual change when the questions have had a ceiling effect, or if the student is incorrect, highlighting if the student's decision was a guess.

Section C

This section was focused on assessing the students' motivation towards technology and hands-on learning. The students rated 10 questions on a 5 point likert scale. The motivation questions in the pre/post test were adapted from the questionnaire that was used in the previous study. It was extended to make it more relevant to the topics the students studied in this task.

1. I like working with data I have collected
2. I do not find it useful to do an experiment myself (note this is the reverse of the question in the Ownership and Automation task)
3. I enjoy using technology to learn (adapted from, I enjoy using computers to draw graphs)
4. My understanding of an idea is better if I can try it out myself (adapted from My understanding of a graph is better if I have drawn it myself)
5. My understanding of an idea is better if someone tells me about it (adapted from My understanding of a graph is better if someone else has drawn it)
6. I think collecting data by hand is a waste of time
7. I prefer to do something myself rather than use a computer (new question)
8. Having technology makes my life easier (new question)
9. I think data collected using special equipment is more accurate (new question)
10. If I understand the method then I can explain my results better (new question)

Questions 7, 8, and 9 were new questions designed to explore the student's motivation around the use of technology, while question 10 was focused on the connection between understanding the method to interpret the results. The 10 questions can be categorised as focusing on three key areas for exploration: motivation for data collection, motivation and technology, and motivation and hands-on experience. Again the questions targeted the three areas identified by Pintrich, 2003: belief in ability to perform, belief about the value and affective reaction to the task.

Work book The work book provided the students with a guide to what they were expected to do during the intervention. The work book was split into four stages:

Stage One asked the students to find their resting pulse rate.

Stage Two asked the students to think about the impact of exercise upon their pulse rate and to design how they would like to test the effect.

Stage Three provided space for the students to record their experimental findings.

Stage Four asked the students to reflect upon their experiment and consider its validity and what they would change.

19.4 Procedure

The study was held over a single school day. Ethical approval was gained for the study and each student and their parents/guardians gave their consent to participate. Twelve of the students gave consent to be recorded, so the video camera focused on recording the activities of those students. The students were taken off timetable for the day, but took breaks at the same time as the other students. The teacher who supported the experiment was familiar to the students and took control in terms of telling the students what to do next and keeping them on task.

Introduction and Pre-Test

At the start of the day the students were given an introduction to the classroom and a summary of what they would be doing during the day. It was stressed that there were no right or wrong answers, and that we were interested in reasoning rather than correct answers. The students were placed into groups quasi-randomly (the groups were split to ensure students who did not wish to be video recorded worked together). Each student was asked to individually complete an online questionnaire (pre test) this took 30 minutes.

Intervention

The students were split into two groups: Datalogger and Traditional.

Stage One

Dataloggers These students were shown how to calculate their pulse rate using the dataloggers. The students were given 25 minutes to experiment with the datalogger and obtain base line recordings for their resting pulse rate.

Traditional These students were shown how to find and count their own pulse rate. The students were provided with stop watches, and had access to calculators. They were given 25 minutes to explore their pulse rate and discuss with their partner.

Students were allowed access to the Internet although not all students chose to use it.

Stage Two All the students were given 20 minutes to discuss and plan an experiment for testing the effect of exercise on pulse rate using the equipment provided. Students were encouraged to consider the type of exercise, how long to exercise for, repetition of tests, and considerations for making the test fair. Only students in the datalogging group were allowed to use the dataloggers. All students had access to tape measures, stop watches, and exercise equipment such as benches and stairs.

Stages Three and Four All the students were given 1 hour and 30 minutes to complete their experiment, write up the results and consider potential issues and future improvements. The students worked in pairs and collected their own data. Additional data was available in case students had problems during their experiment: however none of the students chose to use the additional data.

60 Second Scientist The 60 second scientist activity was completed to support the learning objectives of the class and not to collect data. The students were given 1 hour to design, film and produce a 60 second video detailing what they had learnt during the day. The students were encouraged to relate the video to what they had learnt, but the remit was open ended to allow the students to reflect themselves on what they thought was relevant.

Post Test and Videos The students were asked to complete the post test online: students were again given 30 minutes to complete the post test. Students then shared and watched the different 60 Second Scientist videos.

Debrief Finally the students were given an overview of the research area highlighting their contribution; students were free to ask questions and discuss the day. The school also chose to ask the students to fill out anonymous evaluation forms about the day and what they had learnt.

19.5 Results

In the following section the results from the pre- and post-tests are reported. As with the previous study, for the pulse rate study students completed a workbook. However in this case the workbook was provided in support of the learning objectives of the class and not to collect data. The experiment was video taped to provide a tool for explaining the day to fellow researchers who were unable to attend, the video provides little relevant data for the aims of this study, as it was directed to avoid capturing students directly. The students worked in groups to produce 60 second scientist videos, these were designed as a tool for structuring the day and supporting the learning objectives, rather than as a method of analysing the students. Two of the four groups provided consent to appear in videos and photos, while the remaining only gave consent to take part in the experiment. A description of each of the four videos is available in the appendix (J.1).

The results shown in this section refer to the students responses to the pre and post test which measured: accuracy, confidence and student motivation.

Source	Analysed	Methodology
Pre-Post Test Accuracy	Yes	Analysed using ANOVA and Wilcoxon tests
Pre-Post Test Confidence	Yes	The responses were coded and analysed using a Wilcoxon analysis.
Pre-Post Test Motivation	Yes	Analysed using a Wilcoxon analysis.
Workbook	No	Not analysed as the teacher kept the data
Feedback Forms	Partially	Anonymous, but reviewed and described in terms of general feedback for the day,
60 Second Scientist	No	The 60 second scientist was provided in support of the learning objectives of the class and not to collect data.
Video	No	Not analysed as the video was not intended to be used for analysis.

Table 19.2: Results Sources

Accuracy

The students were asked ten questions before and after the intervention (see table 19.3). The ten questions were based upon age and skill appropriate example questions. Questions one to five were conceptual questions where the students evaluated data and provided answers based on the information available, these questions were counterbalanced across pre and post tests.

Section	Question
Conceptual	Is there any evidence to suggest that Lucy's prediction is correct?
	What was the range of lung capacity for the boys?
	What other factors might affect someone's lung capacity
	Do you think this is a good number of people to test?
	Did Lucy carry out a fair test?
Domain Specific	What is the average heart rate for a healthy adult?
	Do you think boys and girls will have a different average heart rate?
	Which do you think will be more accurate for measuring your pulse rate?
	Do you think doing exercise will affect your pulse rate?
	Do you think your pulse rate stays consistent?

Table 19.3: Questions asked during the pre/post test

Questions six to ten were designed to test the domain specific knowledge each student held with respect to pulse rate, asking general questions rather than in relation to the provided data.

Questions two, three and six were graded based on their accuracy to a mark scheme. The remaining questions (one, four, five, seven, eight, nine and ten) were open questions with no correct answer. Consequently change in the students' response from pre to post tests was analysed rather than accuracy.

Questions two, three and six were combined and graded to give a score out of 9. Analysis using a one way ANOVA revealed no significant difference between students at pre test $F(1, 16) = 2.685$, $p = .121$. Analysis of the post test scores indicated that the intervention was non significant $F(1, 16) = 1.69$, $p = .212$,

For the remaining questions a Wilcoxon test was used to compare the students' pre test response with their post test response.

Question One: Question one revealed that overall the change from pre to post was non significant ($Z= -1.0$, $p = .317$), within the data logging group there was no significant difference from pre to post ($Z= .0$, $p = 1.0$), within the manual group there was no significant difference from pre to post ($Z= -1.0$, $p = .317$).

Question Four: Question four revealed that overall the change from pre to post was non significant ($Z= -.577$, $p = .564$), within the data logging group there was no significant difference from pre to post ($Z= -.577$, $p = .564$), within the manual group there was no significant difference from pre to post ($Z= 0.0$, $p = 1.00$).

Question Five: Question five revealed that overall the change from pre to post was significant ($Z= -2.0$, $p = .046$)*, further investigation revealed that four students changed their answer from no to yes, two students from each condition. Within the data logging group there was no significant difference from pre to post (Z= -1.414, p = .157), within the manual group there was no significant difference from pre to post (Z= -1.414, p = .157).

Question Seven: Question seven revealed that overall the change from pre to post was non significant (Z= -.723, p = .470), within the data logging group there was no significant difference from pre to post (Z= -.272 p = .785), within the manual group there was no significant difference from pre to post (Z= -1.0, p = .317).

Question Eight: Question eight revealed that overall the change from pre to post was non significant (Z= -1.732, p = .083), within the data logging group there was no significant difference from pre to post (Z= -1.414, p = .157), within the manual group there was no significant difference from pre to post (Z= -1.0, p = .317).

Question Nine: Question nine revealed that overall the change from pre to post was non significant (Z= 0.0, p = 1.0), within the data logging group there was no significant difference from pre to post (Z= .0, p = 1.0), within the manual group there was no significant difference from pre to post (Z= 0.0, p = 1.0). In question nine all the students reported the same answer pre and post test indicating that this question had a ceiling effect[50]

Question Ten: Question ten revealed that overall the change from pre to post was non significant (Z= -1.633, p = .102), within the data logging group there was no significant difference from pre to post (Z= -1.00, p = 3.17), within the manual group there was no significant difference from pre to post (Z= -1.342, p = .180).

Confidence

The confidence responses were coded as shown in table 19.4.

Response	Coding Scale
I am certain I am correct	3
I think I am correct	2
I am really not sure	1

Table 19.4: Coding for confidence self reporting.

[50]A ceiling effect occurs when the majority obtain the top mark and it is impossible to distinguish further, in this instance if a question was too easy the students would get the correct answer both pre and post making it impossible to tell if learning has occurred.

A non parametric wilcoxon test was conducted to analyse the change in confidence for the ten questions.

Question One: Question one revealed that overall the change from pre to post was non significant (Z= -1.265, p = .206), within the data logging group there was no significant difference from pre to post (Z= -1.342, p = .18), within the manual group there was no significant difference from pre to post (Z= -.447, p = .655).

Question Two: Question two revealed that overall the change from pre to post was non significant (Z= -1.387, p = .166), within the data logging group there was no significant difference from pre to post (Z= -1.63, p = .102), within the manual group there was no significant difference from pre to post (Z= -.378, p = .705).

Question Three: Question three revealed that overall the change from pre to post was non significant (Z= -.707, p = .480), within the data logging group there was no significant difference from pre to post (Z= -1.0, p = .317), within the manual group there was no significant difference from pre to post (Z= 0, p = 1.0).

Question Four: Question four revealed that overall the change from pre to post was non significant (Z= -1.89, p = .059), within the data logging group there was no significant difference from pre to post (Z= -.577, p = .564), within the manual group there was a significant difference from pre to post (Z= -2.0, p = .046)*.

Question Five: Question five revealed that overall the change from pre to post was significant (Z= -2.828, p = .005)*, within the data logging group there was no significant difference from pre to post (Z= -1.732, p = .083), within the manual group there was a significant difference from pre to post (Z= -2.236, p = .025)*.

Question Six: Question six revealed that overall the change from pre to post was non significant (Z= -1.0, p = .317), within the data logging group there was no significant difference from pre to post (Z= -1.342, p = .180), within the manual group there was no significant difference from pre to post (Z= 0.0, p = 1.0).

Question Seven: Question seven revealed that overall the change from pre to post was significant (Z= -3.127, p = .002), within the data logging group there was a significant difference from pre to post (Z= -2.121, p = .034), within the manual group there was a significant difference from pre to post (Z= -2.33, p = .020)*.

Question Eight: Question eight revealed that overall the change from pre to post was significant (Z= -2.271, p = .023)*, within the data logging group there was no significant difference from pre to post (Z= -1.342, p = .180), within the manual group there was no significant difference from pre to post (Z= -1.89, p = .059).

Question Nine: Question nine revealed that overall the change from pre to post was significant (Z= -3.162, p = .002), within the data logging group there was a significant difference from pre to post (Z= -2.0, p = .046), within the manual group there was a significant difference from pre to post (Z= -2.45, p = .014)*.

Question Ten: Question ten revealed that overall the change from pre to post was non significant (Z= -.302, p = .763), within the data logging group there was no significant difference from pre to post (Z= -.816, p = .414), within the manual group there was no significant difference from pre to post (Z= -1.342, p = .180).

In summary:

Question Four showed a significant change from pre to post in the manual condition (p = .046) with the mean response changing from 2.56 at pre test to 2.11 at post test indicating a decline in confidence.

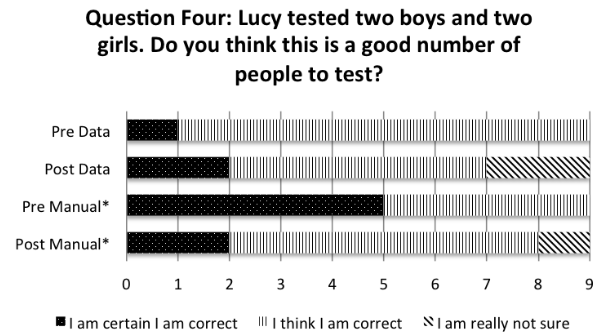
Question Five showed a significant change from pre to post in the manual condition (p = .025) with the mean response changing from 2.11 at pre test to 2.67 at post test indicating an increase in confidence.

Question Seven showed a significant change from pre to post in the datalogger condition (p = .034) with the mean response changing from 2 at pre test to 2.67 at post test indicating an increase in confidence. Question Seven also showed a change from pre to post in the manual condition (p = .020) with the mean response changing from 1.56 at pre test to 2.33 at post test indicating an increase in confidence.

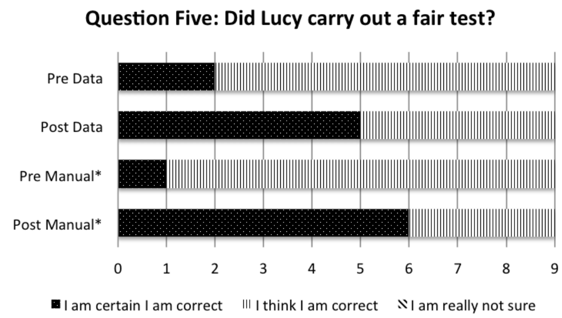
Question Eight showed a significant change from pre to post when considering all of the students (p = .023) with the mean response increasing from 2.44 at pre test to 2.89 at post test. However analysis of the intervention did not show a significant change.

Question Nine showed a significant change from pre to post in the datalogger condition (p = .046) with the mean response changing from 2.89 at pre test to 2.44 at post test indicating a decrease in confidence. Question Nine also showed a change from pre to post in the manual condition (p = .014) with the mean response changing from 2.89 at pre test to 2.22 at post test indicating a decrease in confidence.

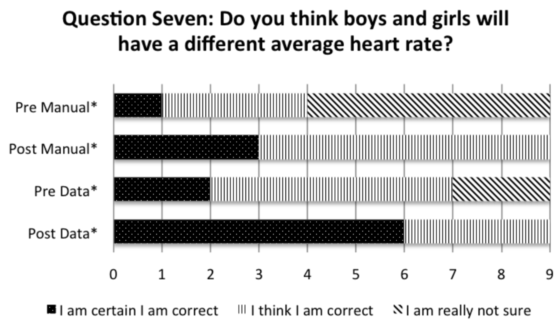
The charts in figure 19.3 on the following page show how the students' responses to their confidence changed for questions 4, 5, 7 and 9.



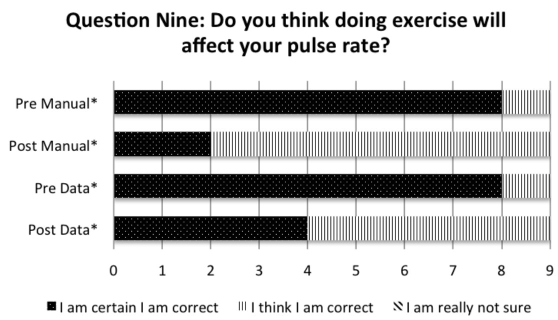
(a) Question Four - Number of responses in each category. *significant result



(b) Question Five - Number of responses in each category. *significant result



(c) Question Seven - Number of responses in each category *significant result



(d) Question Nine - Number of responses in each category. *significant result

Figure 19.3: Confidence responses at pre and post test.

Motivation

The ten questions used to assess motivation can be split into three subcategories: Data Collection, Technology, and Hands-On, see table 19.5 . Non Parametric analysis of the change in response from pre test to post test is described in the next section (see table J.7 on page 304 in appendix for table of results.

Category	Question
Data Collection	I like working with data that I have collected
	I think collecting data by hand is a waste of time
	I think data collected using special equipment is more accurate
Technology	I enjoy using technology to learn
	I prefer to do something myself rather than use a computer
	Having technology makes my life easier
Hands-On	I do not find it useful to do an experiment myself
	My understanding of an idea is better if I can try it out myself
	My understanding of an idea is better if someone tells me about it
	If I understand the method then I can explain my results better

Table 19.5: Motivation questions in their categories

Data Collection There was a significant difference overall in response change for *I like working with data that I have collected* (Z= -2.157 *p*= .012) and for manual (Z= -2.126, *p*= 0.033) but not for datalogging (p= .180). With students becoming more positive at post test.

In response to *I think collecting data by hand is a waste of time* there was no significant difference overall (p= .793) or for intervention (manual, p= .317, datalogging, *p*= .527).

Finally there was a significant difference overall (Z= -2.081 *p*= .037) for *I think data collected using special equipment is more accurate*, but not for intervention (manual, p= .317, datalogging, p= .052). Further analysis showed students tended to shift from Strongly Agree to Neither Agree nor Disagree. The datalogging group are nearing significance, suggesting that experience with dataloggers has led them to believe that equipment is not always accurate.

Technology There were no significant differences for any of the questions in this section: *I enjoy using technology to learn* (overall, p= .429, manual, p= .180, datalogging, p= 1.00), *I prefer to do something myself rather than use a computer* (overall, p= .951, manual, p= .589, datalogging, p= .414), *Having technology makes my life easier.* (overall, p= .527, manual, p= .317, datalogging, p= 1.00)

Hands-On There was a significant difference overall (Z= -2.360 *p*=.018) for *I do not find it useful to do an experiment myself,* with students becoming more positive at post test, reporting more often that they disagree with the statement, however analysis of the intervention did not show a significant difference (manual, p= .102, datalogging, p= .071).

No significant differences were found for the remaining three questions: *My understanding of an idea is better if I can try it out myself* (overall, p= .739, manual, p= .655, datalogging, p= .317), *My understanding of an idea is better if someone tells me about it* (overall, p= 1.00, manual, p= 1.00, datalogging, p= 1.00), *If I understand the method then I can explain my results better* (overall, p= 0.166, manual, p= 1.00, datalogging, p= .132)

Feedback Forms

The school involved in this experiment has an evaluation procedure for the students to provide feedback on their experiences when they take part in an atypical learning experience. The school kindly provided copies of the feedback forms and while formal analysis is not possible as the forms are anonymised, making it impossible to draw conclusions based upon the intervention. The feedback forms can be used to provide insight into the experience of the students.

The students were asked five questions:

1. Describe what has been good about the event today and how do you think you have benefited.
2. Describe what didn’t go well and why you think it happened?
3. List some of the new facts you have learnt.
4. How do you feel about the day/event?
5. If you were able to do the day again what would you change and how would you change it?

The quality and quantity of response to these questions varied considerably with some students providing extensive answers to each question while others only answered a single question or provided answers that were off topic to the question. Seventeen forms were returned. Evaluation of the feedback forms provided by the school indicated that on the whole the students enjoyed the day, while some students would have liked more structure, other students appreciated the independence the task gave them. Of the 17 students who responded nine students mentioned the 60 Second Scientist activity. Students either commented that they enjoyed the activity or reported that they would have liked to spend more time on it. Ten of the students mentioned the dataloggers, students were positive, or noted that they would have liked more time with the dataloggers. This may indicate that the students enjoyed the hands-on aspect and in particular liked to learn about new technologies and skills. One statement was "It was fun and we learned more because we enjoyed it" - this quote in particular highlights how the students felt they learnt more, so even though the student's pre-post tests showed little evidence for a change in learning, the students felt they knew more. Another key message from the feedback forms was the students disliking the groups that they worked in, only one student reported enjoying working with different students to normal. While this could not be changed as the groups were based on issues with consent, this highlights the importance of the students feeling happy and comfortable while they work.

19.6 Discussion

Research has suggested that hands on learning is beneficial to students in a number of ways (Johnson et al., 1997; Krajcik et al., 1998), while work by Kolb has highlighted the importance of active experimentation. This investigation explored whether hands on learning could be improved by the presence of hand held technology. The easy collection of data suggested that hand held technology has the potential to support learning and student engagement (Crook et al., 2010; Abergbengtsson, 2006; Woodgate et al., 2008b).

The main focus of this investigation was to establish if there were differences between hands-on learning and hands-on learning with technology. The experiment focused upon three hypotheses:

- There will be a change in accuracy from pre to post test dependent upon their data collection experience.
- There will be a change in motivation from pre to post test dependent upon their data collection experience.
- There will be a change in student confidence for learning from pre to post test dependent upon their data collection experience.

It is clear from the results that the role of technology in hands-on learning is not clear cut. When assessing accuracy, the use of technology showed no effect. Indeed the students showed only one significant change in accuracy, which was for question five, which asked the students about fair tests. The responses here suggested that a hands-on experience led the students to reassess their understanding of a fair test. However, as the same number of students from both conditions changed it would suggest that the method of hands-on learning with technology was not the important factor for this change. Suggesting that the pulse rate exercise as a whole had little impact upon the students actual knowledge. While this is disappointing, it is, to an extent, to be expected as teachers often spend multiple lessons on a single topic to aid the students in their learning, rather than a single event. While these results do not indicate a benefit for hands on learning with technology, they do support the literature in terms of the benefit of taking part in hands on activities (Rosenbaum et al., 2006; Choo, 2005).

Despite the lack of a change with regard to accuracy, the students did show a change in the confidence of their answers. However, again this is not clear cut, with students sometimes becoming more confident and sometimes less confident following the intervention.

Questions seven and nine showed significant changes for both manual recording and datalogging, with question seven (does gender affect heart rate) showing an increase in confidence whereas question nine (does exercise affect heart rate) showed a decline. This is interesting, as it would seem that, despite exercise being the focus of the experiment, the students became less confident in their response regardless of the intervention. A review of the students' responses to the original question shows that all the students pre and post responded that exercise would affect heart rate. However, while the students did not change their responses, they did become less confident in their answers, suggesting that the hands-on experience has provided an insight into the link between exercise and heart rate that they had not previously considered.

Perhaps more interesting is that the students became more confident for question seven with regard to gender. While researching gender was not an aim of the student's investigation it is possible that during their hands-on experience the students formed new ideas around this concept. This accidental learning is something which would arguably not have occurred without the freedom for the students to conduct real research and explore additional factors. This type of learning supports the work by Sinha et al. (2008) who explored how different types of interaction would impact upon other aspects of the learning process. In particular this result suggests that the opportunity to have a hands on experience, and providing control to the student for making decisions about the research topic, has led to the student considering topics outside of the initial remit.

Questions four and five also showed changes in confidence but only for students in the manual category. Question four (number of people to test) showed a decline in confidence, whereas question five (is this a fair test) showed an increase. It could be argued that these two questions are dealing with very similar concepts. Perhaps the students' experience of experimenting had led them to formulate a new understanding of fair test, which was not solely based upon the number of participants. It is possible that the manual students had to think more about their data collection and its subjective validity, causing them to consider new definitions of fair test. As these two results go in opposite directions, despite being about similar themes, these results highlight the risk of self report questionnaires rather than interviewing the students. It is possible that had a critical incident technique been used that the research could have gained not only an insight into why the students were changing their minds, but also explored why the students are providing different levels of confidence for two similar topics.

Analysis of motivation also provided mixed results, with only one of the nine statements showing a significant difference based on the intervention: with the increase in positivity for manual students with regard to *'I like working with data that I have collected'* suggesting that the manual hands-on approach led to increased motivation.

Interesting results come from 'I think data collected using special equipment is more accurate' where there was an overall shift to disagreeing with the statement. This suggests that both groups became wary of the dataloggers, either through experience of issues, or for the manual group an awareness that their method was as accurate as they needed. Work by Chen et al. (2008) noted the value that PDAs could have on the learning process, if they were appropriately supported by the teacher. The results found in this study support this argument, as the students understanding of the loggers was limited by the use of pulse rate sensors. In particular, it became clear during the experiment that the use of a pulse rate sensor was providing the students with a level of detail that confused the students[51]. It is possible that had the students been provided more support for understanding the pulse rate sensor, they may not have felt that the loggers were inaccurate.

'I do not find it useful to do an experiment myself' Students as a whole disagreed with this statement more at post test, which is a positive change as it suggests that the students found the experimental process a useful method for learning.

Jarvela et al. (2010) noted that groups who struggle to interact show less

[51]The students were expecting the pulse rate to be a single number (for instance 86) however the sensitivity of the dataloggers meant that the pulse rate measurement was constantly changing, leading the students confused about their pulse rate value.

motivation. In the pulse rate study some students noted that they did not enjoy being placed in groups, it is possible that this may influence the student motivation and consequently impact upon their learning experience.

If we return to the three original hypotheses, we can summarise, that while the technology had a limited effect upon the students' accuracy, it did affect the confidence they held in their answers. Unfortunately this was not in a consistent direction with students sometimes becoming more confident and other times less confident. What is obvious is that the investigation provided the students with an opportunity to evaluate their learning and understanding, as highlighted in some of the comments left on the feedback forms. This suggested that they felt they had learnt more because it was a fun event. Motivation results revealed little change, but it was interesting to see that manual students reported an increase in enjoyment to collecting their own data.

This investigation sought to provide an insight into two of the four aims:

To what extent does automation affect the student's learning and motivation?

By comparing dataloggers directly with a non technological alternative it was possible to explore the effect automation has on learning and motivation. The results indicated that there was no effect of automation on the accuracy or the confidence levels held by the students, indeed analysis of the confidence factor led to mixed findings with students in the manual condition reporting different levels of confidence, but with little consistency for direction. It is clear that further analysis is required in this area to understand how the use of automatic tools in schools can be supported to ensure that the students benefit from them. Results for motivation were limited to the statement *'I like working with data that I have collected'* and again students in the manual condition showed increased motivation whereas students who experience automation showed no change. This needs further investigation as it is unexpected and it is important to understand the factors that lead to this change. It is important to note that the students reported that they did not believe special equipment was more accurate, this belief may have been influenced by the use of dataloggers that presented data that was contrary to expectation, leading the students to comment that the datalogger was inaccurate. This assumption that the datalogger was wrong, may have affected the student motivation towards datalogging and automatic tools. This work would benefit from the investigation being repeated with an alternative datalogger that was more familiar to the students.

How can we quantify learning?

This investigation employed a new method of assessing student understanding by introducing the confidence measure into the study. Providing an insight into this kind of behaviour is valuable as it adds depth to results when there is no change from pre to post test in the students' assessment score. While the results from the confidence measure were unclear in this investigation, they provided a new measure of student understanding, highlighting how multifaceted learning is and the importance of not reducing measures of learning to a single test. Future work could take this further by exploring how teachers can use measures of confidence with the class to understand aspects of the syllabus that need repeating. They could also be used to flag up where a student has incorrect knowledge that needs to be discussed, rather than presuming the student has taken a guess. This investigation also used online testing to reduce the boredom and fatigue factor reported by the students during the Ownership and Automation investigation, this change in methodology benefited the study as the students completed the pre and post test providing a full data set, in addition the students did not report fatigue or boredom with the paperwork.

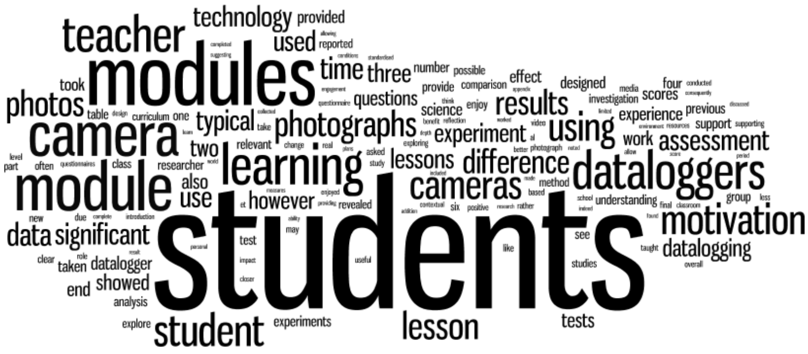
In summary, this experiment showed little difference between hands-on learning with technology and without, highlighting that it is not always the technology that benefits the students but the topic area and the skill of the teacher, supporting the work of Chen et al. (2008). In particular the students reported enjoying having control over their learning, although some would have liked more structure, the importance of control is noted by Lepper (1988) in his list of four characteristics needed for motivation and learning. The results of this study fit with constructivist ideas of the student forming their own ideas and explanations. It was clear during this experiment that a cognitive apprenticeship style of teaching would be beneficial, whereby the teacher could guide the student through their misunderstanding of the datalogger data and lead the student to a more detailed and in depth understanding of pulse rate.

This experiment highlighted the need for testing over a longer period, with the support of the school to embed the investigation within the school environment. Working directly with a teacher over a sustained amount of time the students could be given a chance to have increased exposure to the technology, and this would allow for the use of multiple sensors with the dataloggers reducing the chance that the results are influenced by the sensor chosen. Furthermore sustained interaction with the researchers and the technology would reduce the novelty of the event and provide a more accurate representation of a typical classroom experience with dataloggers. While the 60 second scientist was employed to support the learning objectives, it has provided an insight into how students respond to generating their own context.

Building upon the outcomes of this experiment, the next investigation looked at the roles of two different types of technology; dataloggers as a tool for learning, and cameras as a tool for reflection and the generation of contextual media. These are built into a series of lessons reducing the novelty factor of the experiment, and enabling the teacher to have control of the lessons.

Part VI

Ownership and Technology



20 Technology for learning and technology for reflecting.

This final project aimed to establish how changing the level of interaction with resources in a module may impact upon a student in terms of their reflection and engagement with the subject. Experience from the previous studies highlighted the importance of working within the classroom in a real life environment. The Technology vs Traditional study also highlighted the importance of exploring the effect of dataloggers over an extended timescale. An invitation from a lead science teacher to work with a school enabled the development of a long term intervention to consider the benefits of dataloggers. This provided an opportunity to build upon the previous studies through exploring the impact of the dataloggers over a sustained period in a realistic environment.

Working directly with the teacher and technicians gave an opportunity for the interventions to be designed alongside the curriculum with advice from the people who are responsible for supporting students. As with the previous studies, this investigation used motivation and assessment scores as indicators of learning and engagement. The key difference was that the researchers did not provide the assessments, but used government approved curriculum tests which the students were familiar with. This not only provided a chance to use tests that are used across the country as measures of the students' academic ability, but it also limited the disruption to the students by using tests that they would be taking anyway. It was also possible to obtain this data as secondary data from the school allowing access to the data for the entire class. In comparison, the motivation questions were replicated from previous studies, and parental consent was obtained to use the data. As a consequence the motivation findings are limited to 20 students.

This experiment was concerned with exploring aims Two, Three and Four:

How does the addition of personal experience with a datalogger affect learning and motivation? - There were six modules; in two of these modules (3 & 6) the students were taught with dataloggers as a fundamental aspect of each lesson, allowing for exploration of personal experience.

Is it beneficial to generate your own contextual media? - This experiment introduced the use of cameras for the student's to document their own learning. These were used alone in modules two and five, and in conjunction with dataloggers in three and six. The novelty of the cameras was explored to see if it decreased over time, and whether the students benefited from the chance to document their learning and create materials that could be used for reflection.

How can we quantify learning? Using previous methods this experiment again used a motivation questionnaire to establish the students' engagement with the lessons. Assessment was also used to provide an insight into the students' learning. The key difference in this study was the use of pre-developed assessment tools, which meant that the teacher, who used a predefined rubric to provide standardised assessment scores, undertook the grading and assessment. Using this method meant that the modules could be compared despite potential differences in their difficulty as the standardised assessment took this into account during the grading process.

20.1 Rationale

Work by Johnson et al. (1997) suggested that students who experienced greater interaction with a topic (i.e. hands-on activities vs worksheets) showed a more positive attitude towards the subject matter. However, as Newton (2000) noted, the implementation of data-logging during lessons can be restricted by a number of factors: teacher support, resources, and teacher understanding of the equipment. The use of technology to allow students to conduct real world experiments has been discussed in a wide range of literature, (see Pedretti et al., 1998; Cobcroft et al., 2006; Sharples et al., 2002 for examples of students using technology to support their learning of secondary science.) The development of hand held technology enables the student to act as an 'active scientist'[52] taking control of their learning and providing an opportunity for the student to gain real world experience. This form of inquiry learning can be supported through

[52] see Bruner & Weinreich-Haste (1987) for an introduction to the concept of 'active scientist'

the use of dataloggers (Gipps, 2002).

Kwon (2002) notes that dataloggers can provide students with instantaneous results, facilitating the student in their ability to link an event with a graphical representation. Choo (2005) discusses the benefits of using dataloggers to support students in the classroom, in particular how the dataloggers can encourage discussion and facilitate the understanding of real time data collection. Furthermore the literature review discussed the value of students learning through enquiry and exploration. However as Choo (2005) also notes teachers can face difficulties when trying to implement the use of dataloggers in the class room, with the key problems being a lack of training and time to develop appropriate lesson plans and resources. In order to explore the benefit of dataloggers, this experiment aimed to support the teacher through collaborating on the development of the lesson plans and offering technical support. Through the removal of these burdens from the teacher, it was possible to explore how the students responded to modules that were designed around dataloggers. It was hoped that this could prove highly beneficial: Ng & Nicholas (2007) discussed how teachers often feel forced to use a piece of equipment, but do not have the time to develop supporting lesson plans. This results in the teachers considering what can the student do with the technology, rather than how can the student use the technology for real time learning. By providing the teacher with time and support to develop their own understanding of the datalogger, the teacher will be able to employ a cognitive apprenticeship style teaching method, which allows the teacher to support the student as they explore and construct their own understanding while using the dataloggers.

This experiment focused on the latter allowing the teacher to develop a lesson that supported the students and used the datalogger, rather than trying to use a datalogger for the sake of including technology.

In a study by Lai et al. (2007) the use of photographs to document learning was compared to that of student sketches. It was found that the photographs were initially engaging but that the sketching group showed a more sustained interest. However the photograph group created more ‘knowledge’ as their post tests showed greater depth and information. It was also noted during the previous study that the students reported enjoying the 60 second scientist activity suggesting that the active generation of media might support the students in their reflection. This idea fits with the work by Kolb (1984) who emphasised that it is important for learners to not only see a new concept but also to take part in and reflect, the use of cameras may facilitate the students in this process. This study aimed to further explore the role of photographs and the generation of contextual media while simultaneously exploring the role of the datalogger as a tool for supporting student learning and engagement during secondary level science.

20.2 Hypotheses

- Students will show a change in motivation during the camera modules, and the datalogging with camera modules.
- There will be a difference in the assessment scores for the three conditions.
- The type of photos taken by the students will change over time.

20.3 Participants

A total of 31 students took part in the 6 modules, 11 boys and 20 girls. Of the 31 students, 20 students consented to providing data based on their motivation. The school collected the assessment data independently and the class teacher gave consent for its analysis as part of the project. As a consequence, academic results were available for all 31 students. Of the twenty students who consented to contribute to the motivation data, 8 were male and 12 female. All the students were in Year 8, so their ages ranged from 12-13. The investigation was conducted to run in conjunction with the students' typical lessons. Every student experienced the three conditions, Typical, Camera, and Datalogger with Camera. As the experiment was conducted over an extended period of time, there were instances when students were sometimes absent. As a result some data sets for comparison are incomplete. Furthermore, during the experiment time period, a limited number of students changed groups resulting in the loss and gain of students during the experiment. In these situations data was disregarded but the students were still invited to take part.

Design

The design was a repeated measure within participants design comparing three levels of interaction for the students (Typical, Camera, Datalogger with Camera). Their usual teacher taught the students the six science modules. Two modules were used to collect control data, during two other modules the students were provided with cameras to generate their own media, and in the final two modules the syllabus was taught with a focus on datalogging activities. At the end of each module students took a standardised assessment task, designed by the curriculum authors, Longman Resources. These are designed to be comparable across modules, so allow for an accurate reflection on change in academic level. The students also completed motivation questionnaires. The experiment was video recorded throughout.

Each lesson plan was designed in collaboration with the teacher, extra attention being given to the lessons that would include dataloggers. In these lessons, discussions between the researcher and the teacher were held to plan how the lesson would typically be taught and the kind of experiments that the students would normally conduct. The researcher then collaborated with ScienceScope designers to produce example experiments that would utilise the dataloggers and support the curriculum. These ideas were then shown to the teacher. Often this included trialling the experiment to ensure it worked. During these two modules the researcher worked closely with the teacher and the science technicians to prepare relevant resources and ensure that the inclusion of the dataloggers was effective and problem free and thus did not affect the teacher's ability to provide a normal lesson.

Materials

Motivation Questionnaire: The motivation questionnaires were developed from previous investigations, with two questions being removed and four more appropriate questions being asked instead.

1. I do not find it useful to do an experiment myself
2. I enjoy using technology to learn
3. My understanding is better if I can try it out myself
4. I worked hard in this module (new)
5. I think collecting data by hand is a waste of time
6. If I understand the method then I can explain my results better
7. Having technology makes my life easier
8. I think data collected using specially designed equipment is more accurate
9. I would like to do less science (new)
10. I enjoyed this module (new)
11. I would like to do more experiments (new)

As in the previous studies the motivation questions reflect the three categories defined by Pintrich (2003): belief in ability to perform, belief about the value, and affective reaction. In particular the four new questions focused on the students belief about the value (I worked hard in this module, I would like to do less science) and their affective reaction (I enjoyed this module, I would like to do more experiments). Students were again asked to respond on a 5 point likert scale. The four new questions were introduced based upon reflection of the two previous studies; in particular the questions were designed to focus on the students broader experience of science and the individual modules. As with the earlier questionnaires the new questions were discussed with the science teacher during the design phase of the experiment.

In the following section an overview of the lessons and their relevant materials are provided.

Modules One and Four During these modules the teacher used his normal lesson plans to teach modules on Compounds & Mixtures and Light. During these modules the researcher was present in the room to observe, but took no role in the design of the lessons. At the end of each module the students completed the motivation questionnaire and took part in a typical end of module test.

Modules Two and Five The students were provided with digital cameras during the modules on Materials & Recycling and Changes of State. Six cameras were provided to the classroom, one per table. This roughly equated to one camera for every 5 students. However often the students shared the cameras across tables. The students were provided with name labels to include in their photos so that they could be traced back to them. The photos were printed and provided to the students in their next lesson, allowing the students to stick the photos into their books, and provide an opportunity for discussion and reflection.

Modules Three and Six Dataloggers were used in all lessons under modules three and six, in the following tables 20.1 and 20.2 the topics covered and the use of the dataloggers are listed.

Lesson One	Introducing the concept of sound and sound waves - datalogger and sound sensor used by the teacher in a demonstration
Lesson Two	Pitch, Frequency and Volume- datalogger and sound sensor used by the teacher in a demonstration
Lesson Three	Insulating a house from sound - Students used the dataloggers and sound sensors
Lesson Four	Speed of Sound - Students and teacher used the dataloggers and sound sensors outdoors to measure speed of sound, then looked at the data in the classroom
Lesson Five	Test

Table 20.1: Module Three - Sound

Lesson One	Forces and drag, students use light gates with the datalogger.
Lesson Two	Magnetic force, students used dataloggers with force sensors.
Lesson Three	Students used dataloggers to explore the force needed to pull different sized weights out of a tray of sand and record the force required - a substitute teacher who chose to use the school equipment rather than Science Scope dataloggers taught this class.
Lesson Four	There was not enough time for the students to take a test for the final module, instead the teacher provided marks based on his interpretation of the students' understanding and level. This is not unusual as teachers often decide to remove the testing part of the syllabus in favour of teaching more content

Table 20.2: Module Six - Forces and Transport

Final Questionnaire At the end of the course the students were also asked four additional questions:

- Did you enjoy using the cameras?
- Did you enjoy using the dataloggers?
- Which module did you enjoy the most?
- Which module do you think you learnt the most in?

20.4 Procedure

The investigation was conducted over a period of four months, as the students were taught 6 modules of science. The researcher attended and recorded 27 science lessons of a possible 34, of 1 hour in length.[53] The final lesson (27) was disregarded for analysis as it was taught by a supply teacher who chose not to

[53] See H.1 in the appendix for a detailed timetable.

take part in the investigation. The researcher took a classroom assistant role. Generally this meant that the researcher was free to roam around the classroom making observations and discussing the science with the students. In certain instances the students asked questions of the researcher. During the datalogging lessons the researcher was required to take a more active role in supporting the teacher. This was primarily as a second pair of hands for helping the students, rather than as a teaching role.

In the modules that included the use of cameras, the students were invited to take photographs during the lessons. They were provided with name labels so that they could place this next to the object that they wished to photograph, it was also intended that this would allow the researcher to identify which student had taken which photograph. However, the students did not consistently label their photographs. The students were told to take photographs of items/events during the lesson that they could use to reflect upon their learning. At the end of each lesson the researcher collected all the cameras, transferred the photographs to a computer and printed out small photographs (approximately 2.5 x 3 cm) these were returned to the students in the following lesson by placing batches of the photographs on the student desks, where it was not possible to identify which student took the photograph, every student on the table was provided with a copy[54].

The lesson plans were discussed with the teacher, but were designed primarily by the teacher. Each lesson began with a summary from the teacher about what was to be covered. The main teaching segment followed this, and when there was time, the lesson was concluded with an overview. However often experiments took longer than predicted[55] and as a consequence lessons often finished abruptly. Each module was based on the Longman Resource kit[56]. Consequently some modules were allocated more lesson time than others. At the end of each module the students were assessed using a standardised Longman assessment, ranging from class tests to extended homework assessments. As the weeks progressed, it became clear that there was more content in the curriculum than the teacher would be able to cover. As a result decisions were made to cover all the modules, but with the later modules covered in less depth due to time constraints[57]. This issue often arises. Part of the reason for this is that the curriculum packs are based upon an ideal school

[54]Students did not always take these photographs

[55]This was not just in the case of dataloggers but in all experiments

[56]A curriculum kit used by the school to structure their lessons

[57]The alternative was to drop a module from the syllabus and cover the others in more depth, this would mean the students would not have the basic knowledge required for the next years programme of work

environment whereby the teacher is never absent, students do their homework, school trips and events do not disrupt the lessons and the students understand the material from a single lesson. Observation showed that this is incredibly unlikely to occur and therefore the teacher is required to make a judgment call: on depth of understanding vs breadth of understanding.

20.5 Results

Source	Analysed	Methodology
End of Module Motivation	Yes	Analysed using repeated measures ANOVA.
End of Module Assessment	Yes	Analysed using repeated measures ANOVA.
Photographs	Yes	Analysed using a Chi Square, and frequency scores.
Video	No	Not analysed as the video was not intended to be used for analysis.

Table 20.3: Results Sources

Video

During the final study the lessons were video taped. It was thought that the video would provide additional data for this experiment and allow other researchers to understand how the lessons had been run. However it became clear during the first lesson that the video would be unable to capture the whole class, indeed not all of the students provided consent to be filmed (note the camera was often pointed at a table rather than at student faces). It was also clear that the audio quality was poor and that moving the camera closer to the students would result in disruption of their lesson, something that this experiment aimed to avoid. However as the camera was used during the first module it was decided that the video camera should remain in the room for the remaining modules to ensure that the environment and the relationship with the research was as standardised as possible. Consequently the data recorded by the video camera has not been analysed.

Motivation

Each of the students was provided with a 12 question, 5 choice likert scale questionnaire at the end of each module. Due to absences a number of children did not complete each module questionnaire. The results were combined so that modules that used the same intervention were collated and averaged, e.g. modules 1 and 4. This resulted in every student having a more complete set of data. Where a student missed two questionnaires for the same scenario, their data was listed as missing and excluded from the analysis. Where a student was present for one of the two tests their single score was used. Where both results are available, an average was used. The scores ranged from 0 to 5 with 5 being closer to strongly agree, while the closer to 0 being a strongly disagree answer.

The 12 questions were analysed using a repeated measures ANOVA, questions seven, eight, ten and twelve failed Mauchly's test of Sphericity so the Greenhouse-Geisser was employed for those questions, means and p values can be found in table in the appendix. Significant differences were found for four of the questions. Further analysis was conducted using a paired samples t-test to explore the differences between the three conditions for the significant four questions.[58]

	Intervention		
	Typical	Camera	Datalogger with Camera
I do not find it useful to do an experiment myself	1.85	2.33	2.9
I enjoy using technology to learn	4.08	3.53	4.1
If I understand the method then I can explain my results better	4.23	3.8	4.28
I would like to do more experiments	4.55	4.1	4.68

Table 20.4: Table showing mean scores, the closer to 5 the closer the student strongly agreed with the statement

Q1 - I like working with data that I have collected. Revealed no significant difference between the modules, $F(2, 34) = 1.350$, $p = .273$.

Q2 - I do not find it useful to do an experiment myself. The results showed a significant difference overall $F(2, 34) = 8.247$, $p = .001$. Further analysis revealed a significant difference between the Typical module (M = 1.85) and the Datalogging with Camera module (M = 2.9), $t(19) = -4.58$, $p = .000$, The results indicated that students disagreed more with the statement in the Typical modules, suggesting that they did find it useful to do an experiment themselves.

Q3 - I enjoy using technology to learn. The results showed a significant difference overall $F(2,34) = 7.677$, $p = .002$. Further analysis revealed a significant difference between the typical module (M = 4.08) and the Camera

[58] For in-depth results see table K.3 in appendix K.2 on page 308.

module (M = 3.53), t(19) = 3.19, *p* = .005, and between the Camera module and the Datalogging with Camera module (M = 4.1), t(19), = -3.49, *p* = .003. Interestingly the students were more positive towards technology in the Typical module and in the Datalogging with Camera module than in the Camera module, suggesting perhaps that while the Camera module showed a negative effect, the introduction of the datalogger in the Datalogging with Camera module reversed this apparent effect of the Camera to bring the results back in line with the Typical module.

Q4 - My understanding is better if I can try it out myself. Revealed no significant difference between the modules, F(2, 34) = .836, *p* = .442.

Q5 - I worked hard in this module. Revealed no significant difference between the modules, F(2, 34) = .041, *p* = .960.

Q6 - I think collecting data by hand is a waste of time. Revealed no significant difference between the modules, F(2, 34) = .222, *p* = .802.

Q7- If I understand the method then I can explain my results better. The results showed a significant difference overall, F(2,34) = 4.126, *p* = .039. Further analysis showed a significant difference between the Typical (M = 4.23) and Camera (M = 3.8) modules t(19) = 2.48, *p* =.023, as well as between the Camera (M = 3.8) and the Dataloggers and Camera (M = 4.28) modules, t(19) = -2.65, *p* = .016. Again the Typical, and the Datalogging with Camera modules showed a greater positive response to this question..

Q8 - Having technology makes my life easier. Revealed no significant difference between the modules, F(2, 34) = .433, *p* = .652.

Q9 - I think data collected using specially designed equipment is more accurate. Revealed no significant difference between the modules, F(2, 34) = 1.767, *p* = .186.

Q10 - I would like to do less science. Revealed no significant difference between the modules, F(2, 34) = 1.000, *p* = .378

Q11 - I enjoyed this module. Revealed no significant difference between the modules, F(2, 34) = .845, *p* = .438.

Q12 - I would like to do more experiments. The results showed a significant difference overall, F(2,34) = 9.520, *p* = .002. Further analysis showed a significant difference between the Typical (M = 4.55) and Camera (M = 4.1) modules, t(19) = 3.6, *p* =.002, as well as between the Camera and the Datalogging with Camera (M = 4.68) modules, t(19) = -3.81, *p*= .001 again the Typical (M = 4.55), and the Datalogging with Camera (M = 4.68) modules showed a greater positive response to this question than the Camera (M = 4.1) module. This would suggest that the cameras had a negative effect upon this question and that the introduction of dataloggers reduced this effect.

These results suggest that the introduction of the cameras had a negative effect upon the students' motivation, and while the further introduction of the dataloggers counterbalanced this effect, during the dataloggers with camera modules, it was not enough to raise the students' motivation higher.

After the final lesson the students were asked to answer four further questions:

- Did you enjoy using the cameras?
- Did you enjoy using the dataloggers,
- Which module did you enjoy the most?
- Which module do you think you learnt the most in?

The response frequencies are shown in tables 20.5 and 20.6. It is interesting to note that while the cameras showed a negative effect upon motivation for the individual modules, the students reported enjoying using the cameras. They also reported learning the most in the typical and the camera modules. Clearly although the students enjoyed using the cameras and dataloggers, they had little overall effect on the modules which the students reported enjoying.

	No Response	Yes	No
Did you enjoy using Cameras?	4	16	0
Did you enjoy using Dataloggers?	4	15	1

Table 20.5: Frequencies for motivation

	Typical	Camera	Datalogger with Camera	No Response
Which module did you enjoy the most?	8	4	3	5
Which module did you learn the most in?	6	6	3	5

Table 20.6: Enjoyment and learning frequencies

Assessment

At the end of each module the students completed an end of unit test. The teacher used tests designed for the syllabus that enabled comparison of test level across the modules. Due to student absence, some students did not complete all of the tests[59]. The modules were combined and averaged to provide three

[59]There were only 12 students who could provide scores for all 6 of the modules

groups for comparison, Typical, Camera, and Datalogger with Camera. Where a student (example B or C in table 20.7) only completed one of the two tests for an intervention the single score was taken. For example, Student A completed Modules 2 and 5 so his scores were averaged to provide an overall level for the Camera group, however Student C was absent for the test in module 5 so only his score from module 2 was considered. Where a student (D) missed both tests their data was excluded from that conditions analysis, see table 20.7.

Student	Module Two Result	Module Five Result	Camera Module Result
A	5 (4a)	7 (5b)	6 (5c)
B	5 (4a)	Absent	5 (4a)
C	Absent	7 (5b)	7 (5b)
D	Absent	Absent	Excluded

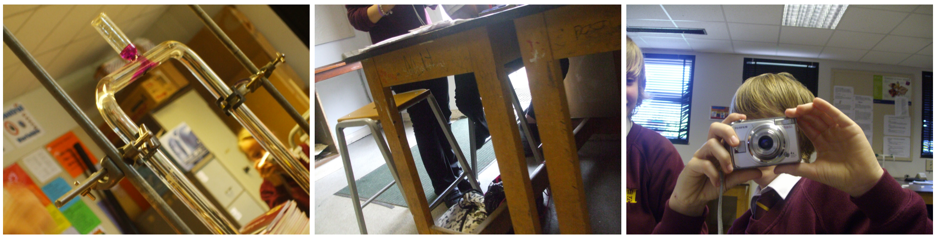
Table 20.7: Example method for calculating module results

Due to time constraints the students did not complete a test for the final module (Forces). Instead the teacher graded the students based on their classwork. This is common practice within schools, where often there is not enough time to complete the curriculum and test the students. For all of the modules the students were graded on a scale shown in table K.1 on page 307 in the appendix. This was then converted into a numerical scale for analysis, the higher the number the better the students result.

A repeated measures ANOVA was conducted to compare the three module interventions. The results indicated a significant difference between groups $F(46,2) = 5.286$, $p = 0.009$. Further analysis using paired samples t-tests showed there to be no significant difference in assessment scores for the Typical module in comparison to the Camera module $t(25) = 0.00$, $p = 1.002$, with the results in the Typical group ($M = 5.54$) being the same as in the Camera group ($M = 5.54$). However, there was a significant difference between the Typical group and the Datalogging with Camera group $t(26) = -2.690$, $p = .012$, with the Typical group ($M = 5.59$) having a lower score compared to the Datalogging with Camera group ($M = 6.48$). A significant difference was also found for the comparison between the Camera group (mean = 5.52) and the Datalogging with Camera group (mean = 6.52), $t(24) = -2.43$, $p = .023$. This indicates that on average, the students obtained higher test scores during the Datalogging with Camera intervention modules. This implies that the Dataloggers with Cameras had a positive effect upon the student assessment. As the Cameras alone did not have the same effect, it can be inferred that it was the introduction of the Dataloggers that led to this increase in the student assessment results.

Photographs

A random selection of the photographs (222 out of a possible 823, 27%) was analysed by three independent reviewers to categorise them under three categories as: lesson relevant photos; friends and faces; or lesson irrelevant photos (see figure 20.1). Kappa's statistic showed interrater reliability of .848 between coder one and two, and reliability of .806 between coder one and three, both of these are considered to be high reliability, indicating that coder one coded to the same criteria as coders two and three. A single reviewer, coder one, coded the remaining photos.



(a) Relevant (b) Irrelevant (c) Friends and Faces

Figure 20.1: Example photograph categories

From Table 20.8 on the following page it is clear that the students took a large number of photographs during these four modules. While students take a different number of pictures in each module, there is no evidence of students taking fewer photographs as time progresses. While module six shows a reduction in the number of photographs taken this can be explained by the reduced number of lessons the students experienced in this module (two lessons). The frequencies suggest that while students took more photos in the camera modules, there is not a huge difference between the percentages of relevant photos (47% and 53%). It is apparent that students took fewer photos of faces during the modules which included dataloggers.

However it does appear that fewer photographs are taken during the datalogging lessons. This may be because the students were experiencing a more hands-on style of lesson and therefore had less time to record their learning (see Appendix 1, table K.4 on page 310 for more in depth results). A Chi-squared test of independence of categorical variables indicated a significant difference between the two conditions. $\chi^2(2, N{=}823) = 6.74$, $p<0.05$.

It is interesting to note that an increase in quantity during the heat module did not lead to an increase in relevant photos, while the module with the least photos, Forces, actually showed the highest level of relevant photos and the least number of photos of faces.

Module	Intervention	# Photographs	% of useful photos	% of photos of faces
Module Two - Materials	Camera	170	57	20
Module Three - Sound	Camera & datalogger	177	48	30
Module Five - Heat	Camera	343	42	41
Module Six - Forces	Camera & datalogger	133	59	19
Camera Total		513	47	34
Camera & datalogger Total		310	53	25

Table 20.8: Percentages for photos taken and useful photos.

20.6 Discussion

It was noted that implementing datalogging into typical science lessons can be limited by a number of factors (Newton, 2000), this investigation looked to support a teacher in using dataloggers, and to explore the impact that they had on the students' learning and motivation.

This experiment was designed to answer three specific hypotheses:

- Students will show a change in motivation during the camera modules, and the datalogging with camera modules.
- There will be a difference in the assessment scores for the three interventions.
- The type of photos taken by the students will change over time.

The motivation results were somewhat contradictory. During the Datalogging with Camera modules, students reported that they did not find it useful to do an experiment themselves. However they also reported a desire to do more experiments suggesting that perhaps the students enjoyed taking part in experiments but did not see the learning benefit. In addition to this, during the Camera module the students were more negative towards the statement *'I enjoy using technology to learn'*. Yet when asked at the end of the term if they enjoyed using cameras and dataloggers, the majority of the students reported yes. This may suggest that the students attitudes towards technology change over time, and are dependent upon the situation. However as the wording between the two questionnaires differed a direct comparison cannot be made. Furthermore, the students may have not recognised the cameras as technology during the *'I enjoy technology to learn'* statement. As noted in the Technology vs Traditional study, it may have been useful to utilise a critical interview technique here to explore with the students their interest in technology and its role in the learning. Indeed the main reason why follow up interviews were not conducted was because the teacher involved in this research went on sick leave, consequently access to the students and the teacher was withdrawn. Events like this can have a major effect when conducting studies in the 'real world', however the value of exploring dataloggers and students in a typical environment outweighs the risks and limitations it places on the research design.

The students reported learning more in the Typical and Camera modules in comparison to the Datalogger with Camera modules. However the assessment results do not support this, with students performing significantly better in their end of module test during the Datalogging with Camera module. This is an exciting finding as it supports the assumption that dataloggers can aid students in their understanding of scientific processes supporting the work of Mee (2002); Barton (1998); Deaney et al. (2006). However, it seems that the students were unaware of the level of learning which they were experiencing. It is possible that the students were unaware of their 'learning' during the Datalogger with Camera modules due to their engagement resulting in them reporting that less learning had occurred, again this shows the potential relationship between motivation and learning, with students becoming so engaged in the topic that they no longer associate it with the learning they would commonly experience in the classroom, Deaney et al. (2006) made similar comments in their work noting that the students liked the way dataloggers could make a dull topic interesting.

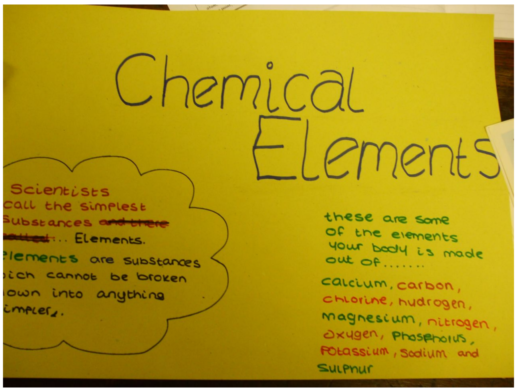
The students reported enjoying using the cameras and this is apparent from the quantity of photos taken, 823 during 13 lessons, averaging 63 photos per lesson, 405 of which were rated as relevant to their learning. A number of the photos rated as irrelevant was due to the poor quality of the photograph rather than the students' intention. Consequently it is possible that, given training, the students could have taken a larger proportion of relevant photos. It is also worth noting that there was no significant difference in assessment score for modules with or without cameras suggesting that while cameras have not added to the learning experience in terms of attainment, nor have they compromised the students' attainment.

Anecdotally, the teacher was happy with the students using the cameras and found that were not adversely distracting. Indeed during one lesson, the students were required to give presentations and the students asked to use their cameras to aid this process. The students were seen sticking copies of their photos into their books and there was clear anticipation for receiving copies of their photographs.

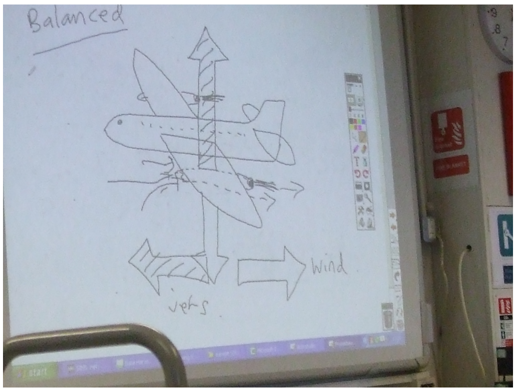
In terms of using cameras as a realistic learning tool, it requires a lot of effort from the teacher to coordinate the cameras and print out the photographs in time for the following lesson. However, there is potential to allow students to gather photos over a module, and then provide the students with a collection of the photographs as a revision aid at the end of the module. Indeed, with the prevalence of computer and Internet use in schools, it is possible that the teacher could choose to upload the photographs and allow the students to review their work online, reducing the time and monetary costs of printing out the photos.

The students were provided with name tags to place into their photos so that they could claim ownership of their work. However, over time the students stopped using these, making it harder to establish who had taken which photo, but conversely allowing students to share their photos more freely. From this we can see that the students did not feel a need to control their photos, and were happy for others to see them and have access to them, this is similar to the observation made in the pilot studies whereby it was noted that students often referred to ‘our data’ and the results took on a communal ownership.

While a number of photographs were taken of each other, it is clear from the photos that this was due to actions of only some, and not all of the students. Indeed during one lesson a student with the camera took over 40 pictures of the same student, who was seemingly unaware that the photographs were being taken. Figure 20.2 shows a variety of the photographs taken by the students that were recorded as relevant to their learning.

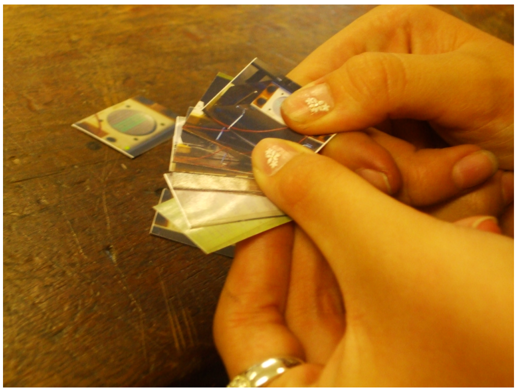


(a) Photo of a student poster



(b) Student photograph of the board

(c) Student Photo of Teacher Demonstration



(d) Student photographing their photographs from a previous lesson

Figure 20.2: Example photographs taken by the students

In this investigation it was not possible to collect data about how the student used the printed photographs, as access to the student workbooks was limited. It may be insightful for future work to explore how the students included the photographs in their work, and to evaluate whether students used the cameras differently when dataloggers were also used. Furthermore follow up research could involve informal interviews with the students to reflect upon their experiences with the cameras and the potential long term benefit of contextual media for recording a learning experience.

This investigation was designed to contribute to three of the four aims:

- How does the addition of personal experience with a datalogger affect learning and motivation?
- Is it beneficial to generate your own contextual media?
- How can we quantify learning?

How does the addition of personal experience with a datalogger affect learning and motivation? - This was explored in modules three and six where the students were taught with dataloggers as a fundamental aspect of each lesson. It was shown that during the modules that included dataloggers, the students had increased assessment scores, showing a direct positive effect of dataloggers on the students learning, supporting the work of Barton (1998); Mee (2002). The impact of personal experience with a datalogger on motivation was less clear cut with students providing different responses after the individuals modules in comparison to when they were asked at the end of term. This suggests that further work needs to be designed to explore students' understanding of their own learning and motivation, as well as additional work exploring tests of motivation and the reliability of self reported tests, it may be useful to extend this work with the motivation measures employed in the gaming literature, whereby the students' motivation is monitored based on factors such as time spent with the tool and attempts made to utilise the tool in new ways by using alternative measures of motivation, the investigation would not be reliant on student self reports which was open to student misinterpretation.

Is it beneficial to generate your own contextual media? - This experiment introduced the use of cameras for the students to document their own learning; these were used on their own in modules two and five, and in conjunction with dataloggers in three and six. From the assessment results it is clear that use of the cameras did not inhibit the student learning. However they also had no clear benefit in terms of assessment scores. The students took a large proportion of lesson relevant photos and were observed reflecting on their photographs. Despite this, the motivation results showed that in response to questions around conducting experiments, the use of cameras appeared to reduce the motivation slightly, although not dramatically as the students were still broadly in favour of experiments and using technology. This is interesting as it was predicted that using cameras would lead to an overall increase in motivation. However, the photographs were an insightful addition to the class experience, and did not hinder the students in their learning. Further work needs to be done to explore the long term benefits of producing contextual media, in particular the delayed use of photographs as a revision aid for end of year tests, rather than the immediate end of module tests.

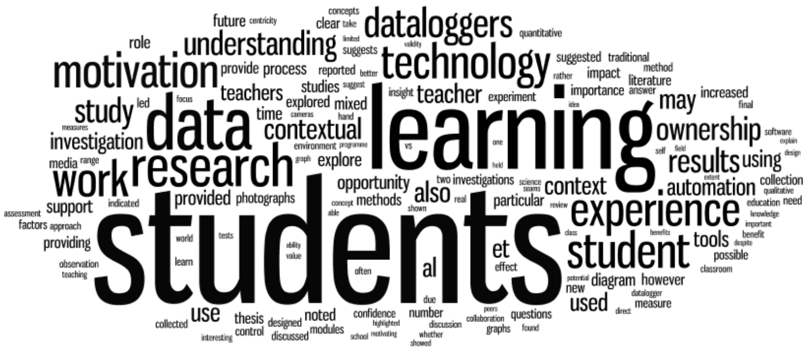
How can we quantify learning? This investigation looked to quantify learning through the use of motivation questionnaires and through teacher assessment. This investigation was different to the previous studies as it used the teacher as a resource for providing accurate data about the student's learning. The teacher assessed the students using a range of resources including class tests, extended homework and observation. This method of assessment is closer to a typical class experience than the previous tests which were employed during this research. Despite the use of the teacher, the assessment method still relied upon the student's ability to answer questions in relation to a prescribed mark scheme (class tests and homework), therefore while this methodology benefited from using the teachers expertise, and represented a more realistic class experience, the testing method is not substantially different from those applied earlier which were based on existing curriculum tests. Consequently the result of the datalogger improving attainment (in comparison to the previous investigations) is likely to be due to the prolonged exposure to the loggers, rather than due to a drastic change in the method of assessment.

In summary this experiment has explored the impact of two forms of technology on student learning and motivation. According to constructivist theory, students learn through constructing their own understanding and interpretation of the world. Dataloggers facilitate this learning by supporting the student as they make connections between abstract data and real world phenomena. Through using dataloggers the teacher and the students were able to benefit from instantaneous results and allowed the students to see immediate visual representations of their data. The use of cameras and informal sharing of photographs emphasises the collaborative nature of schools, and suggests that future work would benefit from exploring the social impact of dataloggers and hand held tools on students.

Finally, this experiment has provided evidence of the datalogging experience having a positive effect upon students' end of module test scores, indicating that dataloggers can support the students in their learning, when supported by the teacher over a sustained period of time.

Part VII

Implications and Conclusions



At the beginning of this thesis, the literature surrounding context, mobile learning and datalogging was discussed. It was found that relatively little research into the benefits of hand held technology had been carried out using a quantitative methodology. Possible reasons for this include the limitations in extrapolating findings from assessment tasks, and the difficulties in designing experiments which allow control and reliability while respecting the need for validity and an authentic experiment. This thesis used innovative studies to provide the first step towards a body of future research using quantitative measures. Through using a mixed methods approach, a novel insight was provided into the relationship between the qualitative and quantitative findings of learning and motivation when using technology in a real school context.

Through the use of a mixed methods approach it was possible to expand the field of knowledge around mobile contextual data while simultaneously respecting and learning from the plethora of relevant research already available. Of fundamental importance is the attention drawn to failures in the current education system, which relies upon single measure quantitative assessments to grade students in a single event, through the use of end of module and end of year tests, this is of particular importance given that education is now being driven further in this direction. This research highlights the problems with basing our understanding upon a single quantitative result, and reveals the value in using a mixed methods approach to gain a greater insight into the learning phenomenon under investigation.

The use of a mixed methods approach has provided a new angle to contribute to the existing research in this area. Through conducting both one off and longitudinal studies the current research has shown the importance of working in conjunction with teachers over an extended period of time.

The pilot studies supported existing research that indicates hand held technology can be motivating for the students, while the ownership and automation study revealed that students who collected their own data were significantly more likely to report a preference for their own data. However, the results also indicated that students who collected their own data performed worse during the graph drawing measure in comparison to those who used their partner's data.

The results of the Technology vs. Traditional study indicated that there was no significant difference between the groups during the accuracy measure. The confidence measure yielded interesting results with students' confidence varying between the questions, in particular two questions showed a decline in confidence, while a further two questions revealed an increase in confidence. The motivation results indicated that manual students became more positive about data collection at post test, while both groups became more negative about using specially designed equipment to take measurements. Despite this all the groups became more positive about performing an experiment themselves.

In the final investigation the motivation responses reported during the modules suggested that students were positive about experiments and technology during the typical modules and the modules which included both dataloggers and cameras, decreased motivation was reported during the modules that included only cameras. However, a final motivation measure at the end of the experiment indicated that the students had enjoyed using the cameras and more often selected camera and typical modules as the module that they had learnt the most in. Importantly the results of this longitudinal investigation revealed that students performed significantly better in assessment tasks in the modules which included the use of dataloggers.

In summary: the students' attainment scores were not affected by minimal exposure to dataloggers, this was true in the Ownership and Automation study and the Technology vs Traditional study. However, prolonged exposure to dataloggers, such as in the Ownership and Technology study, did lead to an improvement in test scores. This indicates that dataloggers can have a positive effect on the students' learning experience. However, the exposure needs to be prolonged and consistent, a single lesson may not show an impact.

The following chapter will begin with a summary of the thesis. This is followed by a discussion of the key concepts and thesis aims discussed in conjunction with the investigations. In each case, consideration will be given to the novelty of the research, potential limitations and ideas for future work. This is followed by a final discussion into the importance of this work and its contribution to the field concluding with ideas for the future.

21 Summary of the research

This thesis has explored the effect of context and technology upon children's learning, and their motivation to learn. Previous research has indicated a benefit for students in experiencing real world environments when learning,[60] and the potential for new hand held technology to support this learning process[61]. The majority of previous work has had a qualitative focus, leaving a gap to explore in quantifying the benefits. Building on work by Smith et al. (2006); Woodgate et al. (2008a); Rogers and Price et al. (2004) this research programme attempted to address this.

Chapter one introduced the topics of learning, education theory, and technology through reviewing the literature on mobile learning, authentic learning and the history of the education system. A short history of education provided the background for testing and assessment through discussion of Galton's intelligence testing and seminal work by Piaget, Vygotsky and Dewey who explored how learning occurs and the requirements for this to happen. This included authentic and situated learning, and a discussion on motivation and methods to assess student motivation. This led to an overview of current government policy regarding education and assessment with a particular focus upon science education. This was followed by an overview of mobile learning discussing the differences in the definitions and introducing a wide range of projects which have explored mobile learning. The concept of context was discussed and redefined for this research, and finally, the technology of dataloggers and their software was introduced providing a technical overview of the equipment used in this research.

Chapter Two provided an introduction to the research methods which informed this programme, including a discussion on ethnography and the advantages and disadvantages of quantitative and qualitative approaches, concluding that a mixed methods approach would allow this work to bridge the gap between the extensive qualitative literature and the limited quantitative research in the field. Through using mixed methods, it was possible to build upon the previous work and present new data, without disregarding the clear benefits of in depth, thick descriptions of the events. Chapter Two also provided an overview of the investigations (two pilot, and three experimental) and

[60] for example: Zoldosova & Prokop (2006); Johnson et al. (1997); Krajcik et al. (1998)

[61] All of the following studies explore technology use in the classroom Uzunboylu, Cavus and Ercag (2009); Traxler & Wishart (2011); Tanner & Jones (2007); Stanton Fraser et al. (2005); Spikol & Milrad (2008); Smith, Luckin, Fitzpatrick, Avramides and Underwood(2005); Roschelle et al. (2007) ; Roschelle, Rafanan, Estrella, Nussbaum and Claro (2010); Rogers et al. (2002, 2005); Rogers & Wild (1996);Robertson (2007); Newton (1999, 2000); Tangney et al. (2010)

explained how they aimed to answer the four key questions which underlie this thesis:

1. To what extent does automation affect the student's learning and motivation?
2. How does the addition of personal experience with a datalogger affect learning and motivation?
3. Is it beneficial to generate your own contextual media?
4. How can we quantify learning?

Chapter Three detailed the two pilot observation studies conducted in the early stages of this research. Observation one followed a group of GCSE students as they worked on a module that explored how the characteristics of a river change as it flows downstream. The students used ScienceScope dataloggers to take a range of measurements at a variety of points along the river's path. They combined this with other environmental techniques, such as kick sampling to build an in-depth understanding of the river's ecology. They used the GPS recording to plot their data measurements onto Google Earth and used this geographical information to inform their understanding.

The experience of working with the students and their teachers provided an invaluable insight into how schools use dataloggers and the educational requirements. Through undertaking a critical incident technique it was apparent that the students valued the opportunity to take control of their learning and to be involved in 'real science'. The teachers found the dataloggers easy to use, even those who had not used them before. The dynamic between the teachers and students changed when they were outside of the classroom, enabling the students to lead their exploration and learning while the teachers responded by facilitating the learning experience and teaching 'on the fly' when opportunity arose. The students collaborated closely and were keen to discuss data and share ideas once they had returned to the classroom. Indeed the students used a lot of 'think out loud' techniques to discuss their data and to collaboratively evaluate and form a group understanding of their data.

The second observation study followed a group of students as they took environmental measurements along the Gower in Swansea as part of their AS level course. A critical incident technique was used to analyse the video data. The analysis revealed that the students were unfamiliar with the dataloggers but were keen to use them, and quickly acquired the skills to use the dataloggers effectively, to such an extent that they were able to help a second group of students whose equipment had broken. In addition to this, the students showed awareness when they had anomalous results and were quick to check their data and fix any issues which they faced. As the time passed the students became increasingly confident in their use of the dataloggers and collaborated closely to ensure that they had valid and reliable data. The students appreciated the speed of the dataloggers and the reduction of time spent on manual tasks such as data recording.

It was clear from both of these observations that the students responded positively to the dataloggers and were consequently motivated to do their work, this supplements the work by Fearn (2006); Barton (1998); Davies & Connor (2005) who all discuss the value of technology for student motivation. These two pilot investigations revealed that students varied in the extent to which they expressed ownership of the collected data. Observation in the classroom suggested that sometimes the students were unclear about the transition between the data they had collected and its representation on the screen. These two key observations led to the design of the first mixed methods experiment, which was designed to specifically explore how different levels of experience with data collection and data presentation may impact upon the students' academic performance and their motivation. This research also explored whether the automation of data collection to data presentation changed the students' understanding.

Chapter Four introduced the first mixed methods investigation conducted as part of this programme of work. The study focused on understanding the level of interaction required to maintain the benefits of dataloggers while also ensuring students understand the data transformation process. This was explored through investigation into the role of "hands-on" learning during the collection and data presentation stages of children's science experiences. This project used an innovative methodology as the experiment required both control, and a traditional design to gather quantitative data, yet it was focused on work outside the lab to maintain ecological validity of everyday learning. Analysis revealed that ability to draw a graph differed significantly within the collection factor: the self students (those who collected data) showed a larger drop in performance from pre to post than the peer students. The remaining measures did not show a significant difference between the two groups suggesting that the hands on experience of datalogging did not improve the student's academic performance, this contrasts with work by Mee (2002) who found that experience with dataloggers led to improved academic performance, in a graph drawing task. In terms of motivation the results indicated that those who collected their own data felt more comfortable when working with their data, which supports the work by Choo (2005) who discussed the value of instantaneous results for motivating students. This study suggests that the link between automation and learning is not clear cut and further investigations need to reflect this important point. Overall this investigation revealed that while students can be more motivated by hands-on experience this does not necessarily translate directly to improved assessment scores. In order to explore the factor of motivation in more depth the next study was designed to focus upon the impact of hands on experience compared to hands on experience with technology. The methodology was simplified in the next study and the measures of learning and motivation were refined.

Chapter Five explored the difference between hands-on learning with and without technology enabling exploration of aims one and two with a particular focus on exploring the role of technology on the learner. This investigation also provided additional insight into aim four, which was concerned with methods of measuring learning. In this investigation three measures were used as indicators of the learning experience: accuracy, motivation and the student's confidence in their learning. This third choice was added after reflection on the Ownership and Automation study, which highlighted that students could often explain the logic for their answers even if the answer was incorrect. Consequently, the confidence measure was designed to provide information on whether the students were taking a guess or felt confident that they knew the answer. This built on work by Hunt (2003) based on the philosophical discussions of Quine (1987) who explored the idea that when you are wrong this can be due to being "uninformed", whereby you do not know the answer, or "misinformed" which occurs when you provide an incorrect answer but you have confidence in it. By using this measure it was possible to explore whether students transitioned from guessing/uninformed behaviour to an informed behaviour. The results indicated that there was no measurable difference for the use of technology in terms of accuracy. However, the measure of confidence produced mixed results, in particular it was noted that students became less confident in the assumed relationship between exercise and heart rate. This was interesting, as it suggests, that through exploring these two factors, the students may have begun to think about alternative reasons for changing heart rate. Indeed, their confidence in response to the question around the role of gender increased. This may suggest that the students, through experimentation, became more aware of the multiple factors involved. While there was no difference between the experimental conditions, the study provides evidence of the multiplicity of learning and the importance of ensuring that the measure of learning employed accurately measures what one is trying to measure. In order to develop this research further, the next study was designed as a longitudinal investigation. Through working closely with a class of students, the potential for a fatigue or novelty effect was reduced. Building on the previous investigations, this final study used standardised assessments in conjunction with self reported measures of motivation.

Chapter Six reported on a longitudinal, real world investigation designed in collaboration with a school teacher to explore and compare the benefits of using dataloggers for learning, and cameras for reflection. The study took place over a term and a half and followed a group of thirty one students as they were taught and tested on 6 modules of their year 8 secondary science course. Focusing on aims 2, 3 and 4, this investigation explored the benefit of creating one's own contextual media in the form of photographs, and of the difference between experimenting with and without the support of dataloggers. This study was a within subjects investigation with all the students taking part in all of the interventions, with comparisons being drawn across the modules rather than between the individuals. As before, the students' motivation and their academic progress were explored. The motivation measures were self reported by the students at the end of each module, while academic progress was determined by standardised tests regularly used by the school; consequently there was minimal disruption to the students' typical learning process. The results of this experiment indicated that the modules which included dataloggers led to improved assessment scores, providing new evidence and building on the work by Mee (2002), Deaney et al. (2006), Gipps (2002) and Woodgate et al. (2008b) who all discussed the value of dataloggers in the classroom.

22 Reflecting on the Literature

In the literature review learning theories based on constructivist ideas and the concepts of scaffolding were discussed introducing the idea that students can progress by forming connections between their existing understanding and new concepts. It is suggested that support for this can come from teachers, peers and even learning tools. The current research suggests that dataloggers and other tools may help students to form connections not only between their existing knowledge and the new concepts, but also facilitate the understanding of the new concepts by enabling them to collect relevant data in context, and therefore generate connections between the environmental context and their abstract data. Evidence supporting this was shown in the early pilot studies, where students were able to identify specific data points and discuss their context, for instance when they identified their own recordings, and when they noted that a logger was recording on a road rather than in the river.

Mayer (2004) noted the importance of guiding a student, rather than allowing pure discovery learning. He suggested that students will develop a better understanding after they have seen how a process works. Again, this is something that was observed during the pilot studies, with the teachers providing tools for students to learn. By providing the dataloggers they guided the direction and topic for the student to learn while providing them with the control to make decisions about what to record. This is similar to the idea of cognitive apprenticeship (Vrasidas, 2000). Often, the teacher will have something which they want the student to learn, but it is more effective to support them to discover it themselves rather than just telling them. The pilot studies suggest that dataloggers can support this discovery learning with the teachers giving the students tools and a remit. The Ownership and Technology study used cameras as tools for guiding the student, the cameras (and photographs) were provided but the teacher did not enforce their use. Despite this the students frequently used the camera and often discussed their photographs with the teacher. As learning is presented as an active process, it is apparent that students need to propel themselves through the process and actively engage in learning; therefore they must be motivated to contribute to the class and to explore new concepts and topics (Von Glasersfeld, 1989).

Work by Sinha et al. (2008) suggested that a learning interaction with a tablet device led to increased interaction between the learner and the teacher, supporting active learning. It is possible that the dataloggers and cameras worked in a similar way. In both the pilot studies and the Ownership and Technology study the dataloggers and cameras often led to impromptu discussions with the teacher about science and related topics. As the adapted ZPA diagram (3.4 on page 25) suggested, tools can have an overlap with the teacher, allowing the student to benefit from the teacher, the tool and the combined environment that the interaction generates.

Research suggests that personal involvement in data collection leads to students finding the data less abstract (Resnick et al., 2000; Rogers; Stanton et al., 2003; Stanton Fraser et al., 2005). It is further suggested that this will help in the learning process. The results of the Ownership and Automation study supported this, with students who self collected reporting that they felt more comfortable with their own data and more able to explain it, than other data, which they did not personally collect. In the literature review it was noted that dataloggers should support the learner two fold: firstly by reducing the amount of mundane work in which the student has to be involved, and secondly through providing an engaging tool with which to interact. Both of these, it was suggested, should result in the student having a better learning experience, and feeling more motivated. The experiments reported in this thesis vary in their support for this idea, with results suggesting increased motivation, but not always showing an impact on this measure of attainment. The qualitative responses of the students in the Ownership and Automation study suggest that many of them would have liked to have experience of data collection; it is possible that students felt value was added to the task by being trusted to collect data.

Research into the impact of motivation has suggested that students need to apply effort to learn, and that to apply effort the student needs to be motivated (Palmer, 2005). It is possible that through personal involvement with data collection, the student is better able to appreciate their ability to perform the task, and the value of it. This in consequence will increase the student's motivation and ultimately their potential to learn. An area that is not investigated in detail in this thesis is the role of collaboration and communication of ideas for supporting learning. Cole & Engestrom (1993) discuss how Munsterberg (1914) (cited in Cole & Engestrom, 1993) considered knowledge development to be shaped not only by internal thoughts and understanding, but also through the interaction the learner has with others. This supports Vygotsky's conceptualisation of ZPD, and shows how progress can be made through peer, as well as teacher support. More recently, Sinha et al. (2008) noted that interaction with a tablet increased student interaction with the teacher, but showed no effect on interaction with peers. Future work could explore how technology such as dataloggers might help support collaboration by generating conversation topics. For example the Ownership and Automation study could be extended to explore how the pairs of self and peer students communicated their experiences, and the extent to which the peer students trusted the experience of their partner.

The student feedback provided in the Technology vs Traditional study suggested that some of the students did not enjoy being placed in groups. Research by Jarvela et al. (2010) indicated that groups who struggle to interact show less motivation.It is possible that the groups affected student motivation, and again, further research would be valuable here to explore the impact that this can have upon the student and their learning experience.

Brown et al. (2010) noted that learners benefit from constructing their own knowledge, within a realistic context, this current work has supported this to an extent dependent upon how the benefit is measured. During this research two of the quantitative studies showed no improvement in academic performance when students used dataloggers, however the final study, which employed a longer term intervention, did reveal an improvement. This final study also used a potentially more accurate measure of attainment by using the skills and experience of the class teacher. In addition to investigating the attainment results, the focus in this work has also been on the impact on the students' motivation. The motivation research (Pintrich, 2003; Palmer, 2005; White, 1959) suggests that students who are motivated and inspired to learn will often perform better. The results of these studies suggest that dataloggers do help to improve the motivation but, as with attainment, this is not clear cut. Research by Yen et al. (2010) and Weiner (1990) indicated a connection between motivation and attainment. However, in each of the studies the motivation questions have resulted in mixed answers, with students sometimes showing an increased interest, while in other situations motivation appears to have decreased. In the case of the Technology vs Traditional study the students in fact became more negative towards dataloggers. The results from the Ownership and Technology study were equally conflicting, with students reporting high motivation levels when asked immediately but indicating different responses when asked at the end of term.

23 The Aims

During the literature review a range of learning theories was considered, in particular it was noted how Herbart (discussed in Bigge & Shermis, 1992) suggested that you can learn through forming connections between new and existing knowledge. Theoretical work by Dewey focused upon the importance of the student carrying out his or her own enquiry. More recent work including research by Johnson et al. (1997) and Krajcik et al. (1998) also noted the importance of authentic work for a student to learn. Work by Mayer (2004) was discussed with regard to using guided construction as a method for teaching. A review of the literature led to a discussion about the value of hand held devices for providing context for seemingly abstract data (Resnick et al., 2000; Rogers, 2004; Stanton Fraser et al., 2005). This reflection on the literature led to the development of four clear aims.This programme of research built upon a foundation of qualitative research providing a novel mixed method insight into four clear questions. The four aims highlight areas of interest in the mobile and contextual learning field. This body of works provides answers and raises questions for future work.

1. To what extent does automation affect the student's learning and motivation?

2. How does the addition of personal experience with a datalogger affect learning and motivation?

3. Is it beneficial to generate your own contextual media?

4. How can we quantify learning?

In the following section each aim will be evaluated against the evidence collected during this research programme.

23.1 To what extent does automation affect the student's learning and motivation?

Building on work by Chalmers et al. (2008); Boticki & So (2010) into seamful design, and Rogers & Wild (1996) and Choo's 2005 investigations into the benefits of automatic tools for data collection this research programme explored how the automation aspects of dataloggers affected students' learning and motivation. Initially this was explored using observation studies where it was shown that the students found the automation of the dataloggers to be motivating and reported enjoying using them as their workload was reduced. This fits with the current literature around the role of technology for reducing cognitive load, thereby enabling students to concentrate on evaluation and reflection, see Gipps (2002); Kravcik et al. (2004); as well as work by Davies & Connor (2005) who also note that real data can be more motivating. However, it was also apparent that, to an extent, the automation of the process behind the scenes led some of the students to feel disconnected and unable to explain their data.

Despite this disconnection, the students enjoyed the opportunity to see their data overlaid on Google Earth and this prompted discussion of the validity and reliability of Google Earth as it was showing outdated photographs. The automation of the data upload process enabled the students and teachers to spend their class time discussing and reflecting upon their data. This kind of discussion may not have occurred had the students not had the chance to see the visualisation. This ability to see the visualisation is of particular importance linking with Evans & Gibbons (2007) report of increased motivation levels from students who used interactive software. Further investigation into the role of visualisation for improving data interpretation, and ultimately, student motivation would provide a valuable insight for software developers into how to produce effective and supportive learning tools.

The automation of the tools reduced the need for the teachers to check that the students were recording the correct details, giving an opportunity for them to focus on providing additional educational information rather than data handling requirements. This allowed the teacher to use a guided construction approach, allowing the student to make discoveries but being on hand to respond to queries and to keep the students on task. It can also be connected to the adapted ZPD diagram (see page 25) that was developed to highlight how the teacher could work with the tool to provide an improved learning experience for the student. The speed of the dataloggers was also beneficial, in particular during the second observation study, when during the trip the teachers were concerned about time. The group was split with the students who had dataloggers continuing to collect data as it was quicker than doing so by hand while the other students continued to a rendezvous point. This meant that those using the dataloggers had an extended educational experience as a direct benefit of the automation of the dataloggers.

The results from the Ownership and Automation, mixed method experiment explored the extent to which automation can affect student learning and motivation. It was shown that students who were provided with the automatically generated preproduced graphs reported higher motivation levels than those who produced the graphs either by hand or through using the software. It is possible that this was due to the reduction in task load, providing the student with the opportunity to focus on annotating their graphs and connecting their contextual knowledge to the graphical representation. Barton (1998) noted that spending time drawing graphs can hinder students, especially when they struggle to produce the graph. Furthermore, problems can lead to the student becoming demotivated, which is not conducive for learning (Pintrich, 2003). Therefore it is not surprising that students with preproduced graphs displayed higher motivation than those who had to spend time producing graphs. It is also possible that the students who annotated their graphs collaborated more closely with their partners as the graphs produced were shown on larger A3 paper to allow for shared annotation. In contrast, students who used the software, although sat next to their partners, worked on a one pupil to one computer ratio. Similarly, the students who drew their graphs by hand each had a single sheet of A4 graph paper to produce their graphs on. This opportunity to collaborate may have impacted upon the students' learning and motivation experience. Luckin (2010) notes that collaboration can improve learning through the opportunity to discuss and share ideas. Future work could explore more closely the importance of collaboration and discussion for data handling, building on work by Liu (2008) who discussed hand held devices and their role in transforming the learning process into a social and collaborative experience. Furthermore, analysis of the workbook suggested that sometimes the student pairs would provide similar responses, and consequently, errors.

Despite the preproduced students reporting higher motivation, the students who used the graph software did not seem demotivated, indeed, they each spent a long time learning the functions of the software to change colours, add notes and to manipulate the axis. This suggests that the automatic software tools supported the students in their chance to explore the data. However, it is possible that the ability to use additional software tools extended the amount of time needed by the students to reflect to the same depth as the students who experienced the preproduced condition. Of course, if they used it regularly this might change, as they grew more familiar with it.

In contrast to the Ownership and Automation study, the Technology vs Traditional study found that the use of the automatic data collection tools had no effect upon the students' learning. This indicates that, in this situation, it may be the hands-on experience rather than an automatic experience which increases students' learning. However, it should be noted that the students found it hard to relate the pulse rate results shown on the datalogger to their conceptual understanding of pulse rate, often reporting that the datalogger was broken. This was due to the pulse rate sensor presenting a constantly changing number, which conflicted with their previous understanding of pulse rate as a static number. All the students showed an increase in their dislike for the use of specialised equipment. Student misunderstanding is a risk with the automation of processes, and there is a need for further research to establish whether students miss out on aspects of the learning when the process is automated. An initial study into this could be carried out by repeating the Technology vs Traditional study using an alternative datalogger that may not produce the same levels of confusion, such as using the Pressure Precision Differential sensor connected to a Spirometer to record the student's lung capacity. Alternatively the study could be repeated, but with more time provided to familiarise the students with the data loggers and the pulse rate concept.

In summary, the results have indicated that the use of automatic dataloggers reduces student effort, allowing the students to spend more time considering the implications of the data. It is also clear that the students appreciated the use of preproduced graphs, as this enabled them to concentrate on evaluating and annotating their graphs. This research provides perhaps the first example of quantitative results for the exploration of automation and learning and motivation. It was found that, in some instances, the automation of the technology led to confusion with students unable to interpret their results and in the case of the Technology vs Traditional study, feeling that their results were inaccurate. However, these were factors that could be easily overcome in future work. It is clear that automation can benefit the students when the aim is to collect data and interpret the results quickly and easily.

The evidence provided in this thesis suggests that automatic tools are valuable for improving student learning and motivation in situations where the teacher can provide appropriate support for the tools and their output. The speed and ease of the use of tools appears to reduce the amount of data handling, enabling students to concentrate on reflection and evaluation. The benefits of this arguably outweigh the infrequent risks of misinterpretation due to the automation.

23.2 How does contextual experience with a datalogger affect learning and motivation?

This question arose in response to discussion in the literature around authentic experiences, situated learning and the role of context. Lombardi & Oblinger (2007) discussed the idea of authentic learning as learning with real world experiences and role play. Knapp & Barrie (2001) advocated the benefits of field trips for engaging students and improving their scientific learning. The concept of contextual experience was defined during the literature review as the personal experience that is gained through active experience of the situation. In this research, it refers to the student taking an active role in the data collection, and appreciating the environment from which the data was collected. It was hypothesised that increased contextual experience will benefit the student in terms of their academic achievements and in their motivation to learn.

This programme of research responded to this question through a variety of methods; initially through the two observation studies; the feedback from the students and teachers, and observations made by the researcher suggest that the students found the contextual experience provided by dataloggers to be an incredibly motivating experience. The students taught themselves to use the tools and all were keen to take part. By providing the students with the opportunity to collect their own data the teacher was able to discuss the data in terms of its provenance and validity. The students' experience of the data collection enabled them to make informed decisions about how to handle the data and how much trust to place upon the results. It was apparent that the students were guided in their learning by the logger and the teacher, again highlighting how the learning can be constructed and scaffolded through the support of the teacher and the available tools. This thesis built upon this qualitative finding through developing a mixed method investigation, which allowed for the role of contextual experience to be explored directly. In the

Ownership and Automation study there was a direct comparison between students who collected their own data (self) and those that used their partner's data (peer). The results here showed a positive increase for self students with regard to their enjoyment of working with the data and with their confidence in their ability to explain the data, with 68.8% of the self students reporting a preference for explaining their own data compared to researcher data. In contrast, the majority of the peer students reported no difference in their ability to explain partner data and researcher data. This suggests that the contextual experience provided by the datalogger led the student to feel a greater connection to their data, and consequently their belief in their understanding. While this effect was not borne out in the quantitative post tests it indicates a connection which may benefit the student in future learning. This is supported by research that indicates that motivation is essential for successful learning (Palmer, 2005; Pintrich, 2003; White, 1959). Contextual experience is clearly motivating, and while it appeared here limited in its immediate effect upon learning, the act of motivating the student can provide an opportunity for the teacher to inspire the student (Von Glasersfeld, 1989). The failure during this earlier investigation to show an impact on student learning may be due to the limited time the students spent with the dataloggers gaining contextual experience, and the fatigue factor discussed in Chapter IV.

The final investigation was designed to reduce these factors. The results provided evidence of the contextual experience with dataloggers having a direct effect on the students' learning. Students performed significantly better in modules which included dataloggers as learning tools than in those which did not. This suggests that a sustained exposure to dataloggers and a specifically designed syllabus for their inclusion may result in direct improvement in students' assessment scores. This supports the work of Chen et al. (2008) who note the importance of the teacher for increasing the effectiveness of technology for learning. These findings not only highlight that contextual experience can have a positive effect on student learning and motivation, but also draw attention to the importance of using an appropriate methodology to uncover the relationships between these factors.

23.3 Is it beneficial to generate your own contextual media?

The idea of contextual media arose in response to the question: What is context and how does it influence the learning experience? It was noted that aspects of context could, to an extent, be recorded and then later reflected upon. Contextual media is a manifestation of this concept. Defined as the media that support data collection (Stanton Fraser et al., 2005), in this research the contextual media were generated by the students.

While this aim was explored solely in the final investigation through providing the students with cameras to reflect upon their learning, the initial inspiration for this question came from the first observation study where it was noted that a student chose to bring a personal camera on the school trips and to document details of the locations of his measurements. This observation was further supported during the Technology vs Traditional study, which provided the students with an opportunity to create a short movie to document their learning. The students often reported this as a favourite part of the day and all seemed to enjoy the opportunity to create something that reflected their learning experience. Consequently, the fifth investigation included a condition that would allow the exploration of the generation of contextual media. The results suggested that the students enjoyed the opportunity to document their learning, with over 800 photos being taken over the four modules, with approximately 50% being rated as directly relevant to the students learning.

During the Ownership and Technology study, the focus was to understand whether this opportunity to create their own contextual media would lead to improved motivation and learning for the students. While the average number of photos did not decline, the students took fewer photographs of friends' faces during the datalogging modules suggesting that they were more focused upon their work and encouraged to take photographs that documented it. A number of the students were observed sticking the photographs into their workbooks, and all enjoyed reviewing their photographs in the following lessons.

This investigation suggests that there is a motivational benefit for the students in generating their own contextual media. The questionnaires suggest that the students did not initially recognise this, the analysis suggesting less motivation in camera modules. However, the final questionnaire indicated an increased enjoyment for the modules that included cameras. It is clear that while using self report questionnaires provided an insight into perceived motivation, it is apparent that a student's motivation and their understanding of it may vary when considering their immediate as opposed to retrospective experiences.

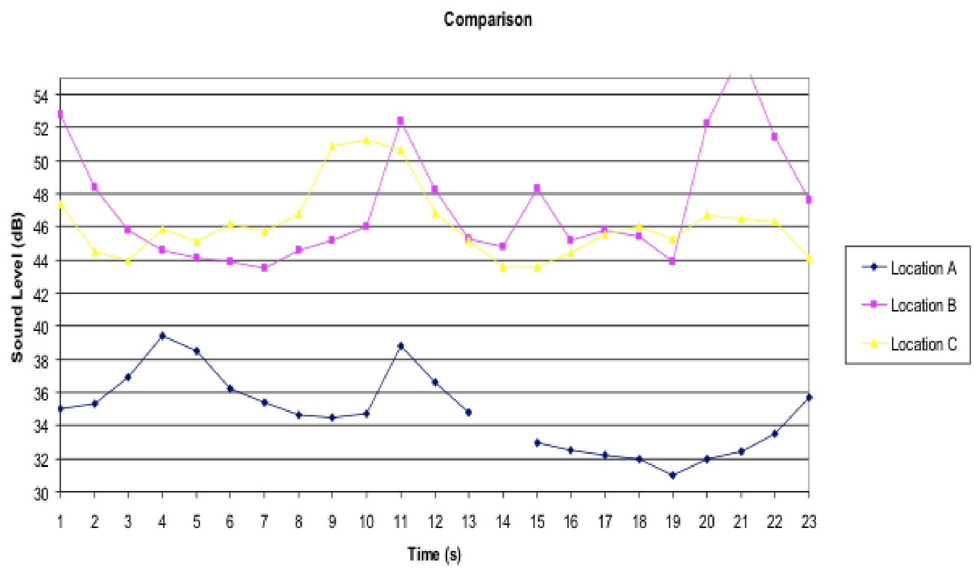
As a final point, the teacher also enjoyed reviewing the students' photographs, and in the future there could be the potential for allowing the students to take photographs to generate a class library of images. This would be particularly useful for students who have been absent and may be able to better understand another student's notes with the added contextual images.

This research has opened up the potential for investigating the role of contextual media for supporting learning and reflection. It is clear that further work over an extended time period is needed to see whether photographs in class are a sustainable option, as it is unclear whether the students would continue to take the same quantity and quality of photographs if the practice became more everyday and mundane. If we refer to Lepper's (1988) four C's (curiosity, control, contextualisation and challenge) which are needed to encourage motivation, it is possible that extended use of the cameras may mean that the students are no longer curious. However, the cameras would continue to provide control to the student, so there is potential for the motivation effect to be maintained. Future work could explore the extent to which contextual media can be used to provide students with a limited contextual experience of an event in cases where direct experience is not possible. Insights into this would be incredibly useful for the study of virtual field trips, and the ability to simulate a learning experience in locations that are inaccessible to the typical student and teacher. As Crook et al. (2010) noted, technology can change the learning space: perhaps it is the case that artefacts of context such as contextual media can also generate a new sphere of learning opportunity.

23.4 How can we quantify learning?

Throughout this programme of research a number of factors regarding quantifying learning have become apparent. Firstly, and perhaps most importantly, current government tests are not effective for the quantitative measure of a student's learning and understanding of a topic: indeed, as Stears & Gopal (2010) note a wide range of student knowledge cannot be accurately measured through assessment alone. This was highlighted here first during the Ownership and Automation experiment with concern around the effectiveness of standardised tests for measuring learning. A decision was made to supplement the questions with an opportunity for the students to explain their reasoning. This is something that rarely occurs in standardised tests currently. By providing this opportunity, this research highlighted an interesting phenomenon whereby students were often seen to select the incorrect answer yet be able to present a logical reason for their response. For example the students were asked to consider the following question (see figure 23.1)

Question One



Data was lost for 14s for location A please consider whether:
a) The data should go in one place (mark where)
b) The data could go in a range of place (mark where)
c) The data should not be replaced.
Please explain your answer

Figure 23.1: Example question from pre/post test

The correct answer is response C. However, a number of the students provided an alternative answer with interesting explanations for their choices, for instance:

- B-A Range, it should be in the same area as the rest of the marks as the sound wouldn't of increased by a huge number in that small space of time
- B-A Range, I have marked an area for where the data could go because there are many possibilities looking at the other graphs they do not just go up and down gradually they have random areas where the sound level drastically goes up or down
- B-A Range, well it could be anything making it impossible to mark upwards or downwards but you know it must be inline with 14s

It is clear from these responses that the students have an understanding that missing data should not be replaced, yet they have also acknowledged that it is possible to make an educated guess, and that the range of possible positions for their missing data point would be limited by the time range. Despite this evident understanding, if the students had been marked only on their a, b, or c answer, then this would be marked as incorrect. This is similar to the issues discussed by Hunt (2003) and Quine (1987) who highlighted the difference between being uninformed and being misinformed, which can both lead to incorrect responses. Clearly in these instances the students are misinformed which needs to be recognised by the education system as different to uninformed.

This distinction between uninformed and misinformed was explored further in the Technology vs Traditional experiment through the introduction of the confidence scale which enabled the exploration of how confident the students felt about their answers. During the evaluation of this experiment, it was noted that some of the students became less confident in their answers while others become more so, without changing their answers. This highlights that often students will make an educated guess and may not actually know the answer. This again highlights the necessity for assessment strategies which allow students to be able to explain their reasoning rather than tests that have a simplistic correct or incorrect response. A review of the students' data suggested that there was no obvious connection between the students' confidence and their rate of accuracy, suggesting that some of them may have made correct guesses while others would have felt certain of the answer yet got it incorrect. Again, this emphasises the potential flaws with self reporting and questions the ability of students to successfully monitor their own understanding. This highlights the need for a greater understanding of the relationship between what a student knows and what they think they know.

This distinction was also highlighted in the final investigation that explored ownership and technology whereby the students were asked to report the modules in which they felt they had learned the most. The students reported the datalogging module the least often, yet the tests of learning and accuracy suggested the opposite, with students performing best in their end of unit tests when the module had included datalogging. It is clear that the students' perception of their understanding is not directly comparable to their performance. Finally it should be noted that in addition to class tests, the expertise of the teacher was also used as a method for assessing the students' understanding. This is something which is commonly done internally in the school environment, yet is currently missing in formal assessment.Context: Ownership, Centricity and Seams.

During the literature review a number of terms were defined and highlighted as concepts of interest to this study. The following section returns to these concepts and considers how they relate to the findings of this body of work and what this may mean for future research. A model suggesting relationships between the investigated concepts is proposed.

23.5 Centricity

This thesis began by defining context and proposing that for the present purpose context be split into 'contextual experience' and 'contextual media'.

Building on work by Brown et al. (2010) who reported that learners benefit from generating their own knowledge; Barton (1998) who identified three clear benefits of practical work as: time, information clutter and connecting data with practical experience; and Hartley (2007) who discussed the importance of the student being at the centre of the learning experience, this work looked at the role of centricity. Centricity was defined as the level of involvement a student has with a particular piece of data, be it through collection, analysis or presentation. This research has shown that it is more complicated than this; it is not just the opportunity to interact with the data, but also providing the student with the desire to interact through a motivating and engaging mechanism.

Results from the Ownership and Automation experiment showed that contrary to expectation, the students who did not collect their own data (allocentric) performed better when given the opportunity to annotate pre produced graphs rather than producing their own graphs (an egocentric task).

It was predicted that drawing their own graph would lead to an increased understanding of it, and result in the student feeling more confident to explain it. While this prediction proved to be inaccurate, it is possible that this was due to the effort taken to produce one's own graph. It is feasible that limiting the initial centricity during the collection phase made it hard to appreciate and understand the context of the information. Furthermore, producing a relevant representation can be time consuming and involves a heavy cognitive load (Barton, 1998). While it has been argued that graph drawing software can reduce the cognitive load (Rogers & Wild, 1996; Choo, 2005) it seems that even the use of software to semi automate this process did not help the students in this task. This is possibly because they still needed to spend time understanding what the graph represents. Instead, the results suggest that students without the egocentric contextual experience benefited from the opportunity to evaluate the information in detail, enabling them to develop hypotheses and formulate explanations for the results. This is interesting in terms of centricity as it may suggest that students who lack experience might be able to compensate for this through an increased level of interaction during the evaluation stage. Further exploration into the value of student evaluation of data would provide an insight into the role personal experience plays in reducing cognitive load during data analysis and graph generation. In particular, it would be interesting to see whether experience at the data collection stage is more or less valuable than during the evaluation stage for supporting the learning experience.

23.6 Seams

As defined by Chalmers et al. (2008), seams are breaks in a process. In this research, they were taken to be anything which paused or disrupted the learning during the data collection to data representation transition. It was noted that there were conflicting ideas around seams and their impact, with Boticki & So (2010) advocating a seamless approach to learning, with the process being automated and smooth. In contrast, work by Chalmers et al. (2008) suggested that a seamful design provided opportunity for reflection and discussion. Indeed during the Participate project, Woodgate et al. (2008a) noted that disruptions to the automatic process led to the students reflecting upon their work and focusing on aspects which otherwise may have been overlooked. The studies presented in this thesis have extended this work.

During the Technology vs Traditional experiment, it was noted that the students struggled to overcome the perceived conflict between the data provided by the datalogger and their existing understanding of pulse rate. In particular a number of students believed their dataloggers to be inaccurate and requested new equipment. This factor presented a problem for the investigation as it acted as a confounding variable when considering the Technology vs Traditional intervention. However, it has serendipitously provided an insight into seamless learning, and links back to the earlier discussion on constructivist learning. It was proposed that a guided construction or cognitive apprenticeship style may be the optimum method for a teacher to support the student in their learning. As this research has highlighted, while students enjoy taking control of their learning, there can be consequences when issues or misunderstandings arise. Through using a cognitive apprenticeship style of teaching, the teacher can guide the student through their learning, and support them when disruptions in their experiences prevent the student from constructing their own understanding.

The problems faced by the students indicate that seams can be generated in a supposedly seamless interaction, through problems with the student comprehending the meaning of their results, and the relationship between the environment and the data. In particular, this disruption to the process resulted in the students questioning the validity of their experiment and the reliability of the results. Furthermore the mistrust of the technology was communicated to the 'no technology' group who also showed an increasing mistrust of the equipment, despite having not used it. This may have demotivated the students. In this case, the disruption had a notable effect upon the students' understanding of pulse mesurement. In a typical classroom environment this seam would allow the teacher to encourage reflection on the experimentation process, and also highlight to the teacher a gap in the students' understanding, thereby providing an opportunity to discuss the relationship between reported values and what they represent.

While it would be useful to repeat this experiment with a different datalogger to gain a better insight into the Technology vs Traditional, this accidental insight also warrants further research to explore the value of seams as a method for opportunistic teaching, in particular around scientific methodology. It is important to note that this is one example of seams being disruptive due primarily to a misunderstanding of the technology. In both the observation studies the students reported an appreciation for the automation of the loggers for data collection and the subsequent reduction in their workload. Furthermore, during the Ownership and Technology investigation the teacher used the ability to repeatedly record on the same graph as a method for teaching the students about sound insulation. The seamlessness of this process enabled the teacher to use the datalogger to support his teaching and focus on the content rather than having the datalogger as the focus and a distraction from the lesson aim. Seamless designs can help or hinder the students dependent upon how the equipment is used within the learning experience. The potential for the technology is mediated by the teacher (Chen et al., 2008) and the student's willingness to learn (Palmer, 2005).

23.7 Ownership

The concept of ownership was developed from the Piagetian idea of the "little scientist," providing the student with the chance to take control and ownership of their own learning experience through the provision of tools allowing them to explore topics of interest, and to experiment. Stanton et al. (2003) and Stanton Fraser et al. (2005) reported that data is less abstract when self collected while Brown et al. (2010) found that learners benefited from generating their own knowledge. The literature clearly suggests that dataloggers will support the student in their exploration through enabling them to take control and ownership of their learning. This was shown during the observation investigations where the students reported enjoying the freedom of the dataloggers, and became increasingly adept at using the loggers, seeing them as an extension of themselves rather than a complex tool. This experience based ownership was also found in the Ownership and Automation study whereby those who self collected their data showed a clear preference for their own data in comparison to data collected by the researcher.

During the Ownership and Technology investigation it was noted that the students took great pleasure in recording their learning through taking photographs and were keen to share their pictures with their classmates and to compete with them to have better pictures. It was clear from the effort they made to take photographs and keep their prints that a number of students particularly valued this opportunity.

23.8 Context Diagram

It is clear from the work discussed in this thesis that a number of factors are relevant when considering the impact of hand held technology on learning and motivation. This work has focused upon the role of context, which has been subdivided into contextual media and contextual experience. Alongside these two broad concepts, three related factors have been considered: Seams, Ownership and Centricity. In this next section a context diagram (figure 23.2) is introduced, which displays the overlaps between these concepts. The three concepts are included in the diagram illustrating how the two dimensions of context can overlap and the ways they could support the learner. This research concentrated on three key areas: Centricity, Seams and Ownership. This diagram (figure 23.2) is designed as an aid for explaining how context can be divided into experience and media representations, both of which provide opportunities for engaging and supporting the student in the learning process. The three concepts of Ownership, Centricity and Seams were selected from the literature and have been shown in the studies presented to influence students in terms of achievement and motivation.

Palmer (2005) discussed the importance of the use of hands on activities and the impact that this can have upon motivation. It is suggested that hands on activities can allow students to engage with real world problems. Palmer notes that motivation probably arises due to opportunities to become actively involved, and to collaborate with others. These ideas fit well with the model, which highlights the role of ownership as an important aspect of learning, and suggests how the use of tools such as dataloggers provide opportunities for students to gain control of their learning leading to the suggestion that the resulting sense of ownership can be motivating. For constructivist theoreticians, learning is an active process: it follows therefore, that in order to provide the necessary effort the student must be motivated. Furthermore, the research suggests that this motivation is increased if it is intrinsic. Ergo, a tool that motivates the student to take part in a lesson will be providing the ‘activation

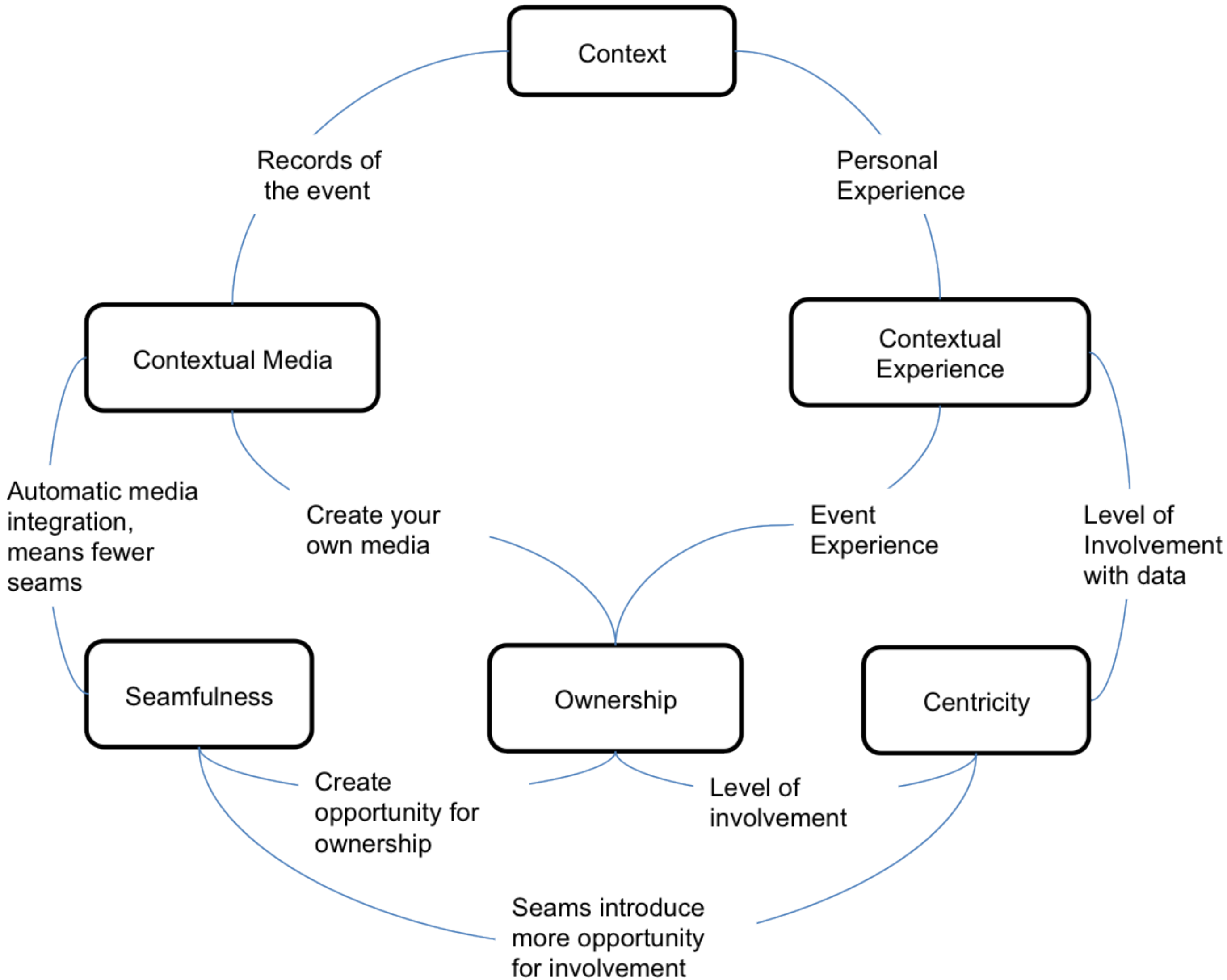


Figure 23.2: Diagram showing how different factors interact with context

energy' for the student to engage with and learn about the scientific topic.

The diagram shows ways in which the concepts support and interact with each other. For instance the level of centricity a student experiences may impact upon their sense of ownership, while the inclusion of seams or disruptions to the process might provide students with increased opportunity to interact with the data and generate a more egocentric experience. This diagram aims to make these connections explicit to emphasise the multiplicity of context. It is acknowledged that this diagram is but one method of representing context and it is likely that other researchers would be able to build upon this diagram to develop new connections and relationships between other factors involved in context. In particular focus could be placed on the role of the teacher and peers for collaboration.

Future work could extend the diagram: for instance, this diagram does not consider the role of collaboration or the relationships between peers and teachers. Allison et al. (2005) produced a list of pedagogical features which would support a successful learning experience, they suggest: collaboration; personalisation; learner-centricity; context-awareness; realism; personal learning profiles; personal special needs; ubiquity; accessibility; and availability. In the literature review it was noted that peers, teachers or tools could support the zone of proximal development. In much the same way, this diagram could be extended to include other concepts. For instance another concept could be attached to Contextual Media entitled "relationships" this would indicate how the way in which the learner experienced the event, and how the interpretations that they made may have been affected by the presence of others. For example, while they may not have had the same level of involvement in collecting the data through working in a team students may still feel a level of collective ownership.

23.9 Reflecting on the Context Diagram

The context diagram was developed to help structure the way in which the investigations in this thesis could contribute to our understanding of context and its impact on student learning and motivation. This second diagram (figure 23.3) indicates how the results of this work relate to the proposed context diagram.

The results suggest that students find the act of generating contextual media to be a motivating experience. Students enjoyed taking photographs and collecting their own data. The photographs acted as good records of the events. However, the students did not appear concerned about ownership of the data; in

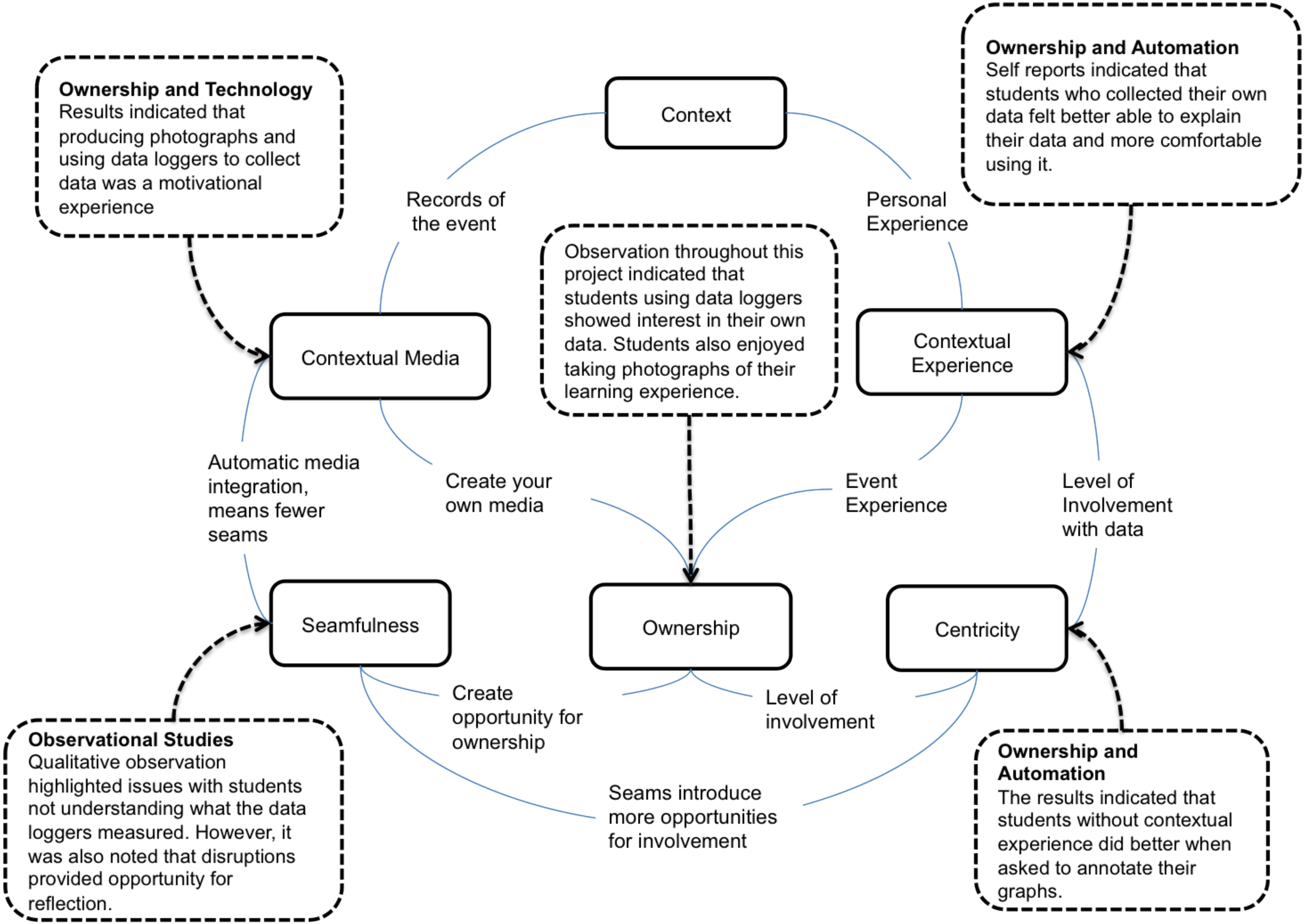


Figure 23.3: Context Diagram with relationship to findings

particular during the observation studies, the students often referred to ‘our’ data as opposed to ‘my’ while in the Ownership and Technology study the students stopped using the name badges, suggesting that they were not concerned about identifying the photographs as their own.

It was noted both in the observation studies, and in the Technology vs Traditional study that teachers’ input is required when technology fails as they can effectively utilise the seam and explain problems to the student. In this work, the experience of seams did not show a connection to ownership but they did allow for students and teachers to collaborate and discuss findings that may have had an affect on the level of centricity.

Interestingly, students with minimal hands on experience during collection did not benefit from increased centricity during presentation. In fact they benefited from automation with students who looked at and annotated preproduced graphs performing better. While this may imply that increased centricity is not required the students who self collected reported that they felt more able to explain their own data. This is an important consideration as students need to feel confident and in control of their learning (O’Neill, 2010).

This diagram is an initial overview of factors explored in this thesis, their relationship to each other and the concept of context. With personalised technology becoming increasingly prevalent in schools it is of vital importance that educationalists consider the impact that these new tools can have upon how students can learn and how this will affect the methods used to teach. In particular, by introducing hand held technology into schools, students are more than ever able to have a personalised and context based experience allowing for the students to increasingly develop their own understanding and construct their learning. Constructivist theory suggests that there is potential for this technology as it provides the students with greater control over their learning, and access to real world data. However, the results of this work suggest that it is important that technology does not become too automated as students will also need to understand the underlying process of their experiments. Furthermore, while dataloggers have been shown to be engaging and motivating for the students the results presented in this thesis have suggested that the impact upon assessment scores is moderated by the time spent with the tools and the role of the teacher.

A review of the context diagram (figure 23.3), in light of this research, suggests that the diagram may need to be evaluated. In particular, more research is needed into ownership and its relationship with control. The current investigations have indicated that students are not too concerned with owning ‘their’ data and contextual media. However, the motivation literature, and the student responses during the Ownership and Automation study suggest that students value context for providing a sense of control, and also indicated a desire for contextual experience. The context diagram could benefit from an extension to consider the role of collaboration. Students are continually interacting with the teacher and their peers, and including these interactions in the diagram would enhance our understanding of how students share experiences and their trust in using data from their peers.

24 Questions raised during the investigations

During the research for this thesis a range of mixed methods studies have been designed and carried out. Exploring the use of hand held technology by school children across a range of settings, including classrooms and field trips. In this section the key issues faced during this research are explored. During these investigations, methodologies have been changed and adapted to accommodate certain characteristics and issues of the investigating environment. In choosing to use a mixed method approach, it has been important to ensure that the research was as controlled as far as possible, but at the same time avoiding distorting the normal learning environment too much. As a researcher it is important to acknowledge that one cannot stand outside of your work and merely observe. By choosing to conduct research, you are inherently changing that which you wish to observe. Work by Danziger (1994) emphasises that we need to recognise the social nature of scientific activity, ensuring that, when attributing cause and effect, the researcher must be aware of their own involvement in shaping the environment within which the experiment occurred. As researchers 'in the wild' it is vitally important that we consider how our own presence may have an impact upon our results.

In addition to this awareness of methodology and validity there are a number of other issues that have been faced during this research. The next section discusses a number of issues which have been highlighted during this researchand attempt to address some of the questions which they raise.

24.1 Are the results replicable?

During the literature review, it was clear that the majority of the research conducted in this area is qualitative in nature and utilises the researchers' understanding and interpretation of the students' experiences. Further research into qualitative approaches led to an understanding of ethnography and the role of video for documenting phenomena to enable repeated reviewing to develop a clear understanding of the processes and underlying themes involved. In order to gain an in-depth understanding of the research area, the first two studies conducted for this thesis were designed to be observational and to use ethnographic techniques of analysis. This allowed the research to build upon the existing body of work, and provided an informed starting point for the design of mixed method experiments.

However, despite the original intentions of recording the student interactions with the dataloggers, conducting this research led to increased involvement in the students' lessons and activities; holding dataloggers, taking measurements, and being drawn into conversation with the students and teachers. As a consequence the video footage taken during the excursions was limited in terms of both its quality and its ability to represent the events and interactions that occurred. Despite this, through using a range of qualitative techniques the analysis is considered to be an accurate representation of the events. Ultimately more was gained through inclusion in the class environment, than acting as an external observer. Indeed, the close links with the students and teachers, gave an informed insight into the education system in general and school trips in particular which were then utilised in designing the later experiments, leading to better informed and more innovative mixed method studies.

These studies, while designed to be replicable, were conducted within a school environment in an effort to maintain ecological validity. As a consequence, while the methodologies could be repeated by researchers, there needs to be an awareness that as this was conducted outside of the laboratory a number of extraneous variables were present which would make it impossible to replicate perfectly.

By conducting research in real life environments the data collected represent something that we know can occur in the classroom. The Observation and Automation experiment was a complex design due to attempts to create a controlled, repeatable experiment while maintaining the appearance of an authentic school trip. Arguably, the results might have been accentuated had they been conducted in the laboratory. However, this may have led to findings that lacked validity in the classroom. By devising experiments within the classroom, this programme of work bridges issues of control and relevance to the real world. The methodologies described here are repeatable and clearly reported to allow future research.

24.2 Has learning been measured?

A key question in this body of research has been how can we measure learning? It is often noted that tests and exams currently fail to provide an adequate platform for students to showcase their learning, knowledge and understanding. In order to provide an insight into "learning" a number of techniques and measures were employed during this research. Initially, learning was explored using assessment tasks derived from curriculum materials. These were extended to provide opportunities for students to explain their answers, allowing an improved understanding of the reasoning employed.

Measures of assessment were supported by motivation questions designed to explore the students' attitudes to these investigations. These questions highlighted opinion changes towards the dataloggers. Questions and answers around how comfortable the students felt with their data led to the design of the confidence measure which was used in the Technology vs Traditional study. The use of the confidence measure provided an insight into questions that had shown no change in response from pre to post. This additional measure proved valuable for measuring the changes in response which otherwise would have been missed. This was of particular importance with regard to multiple choice questions, whereby, through guessing alone, the student could have provided the correct answer. With the addition of the confidence measure it was possible to understand where the student was making an educated guess.

In the final investigation, the student learning was assessed by the teacher. While this was a valuable experience as it increased the validity of the learning scores through using methods already familiar to the class, it made it hard to continue with the confidence measures and study of student misunderstandings. It would be interesting to extend this study and further develop the assessment materials so that they continue to use the existing measures but also build in questions which query how confident the student is in their answer. It is interesting to note that during this investigation, the students often experienced open book exams, where they were allowed to use their textbooks and work books to help them answer the questions. Despite this, the students rarely used the books. Further investigations into students' research skills and their understanding of their own learning may provide an insight into why they failed to utilise all of the resources provided to them. Furthermore this could be explored in relation to the zone of proximal development, and understanding the motivation required for students to propel themselves using tools and peers, rather than the teacher. This again returns to the idea of the student needing to take control of their learning, with the support of the teacher, peers or tools. The curriculum needs to be redeveloped to focus upon students' learning experimental and research skills so that they can find the answer for themselves, rather than simply being given the answer with limited understanding of how to repeat the experiment or investigation. In summary, this research has undoubtedly measured factors which relate to learning, and in the case of the standardised assessments, are recognised as measures of learning. Despite this it is apparent that other factors are at play in the concept of learning, and future research will build upon our understanding of learning and methods for supporting it. Furthermore, it would be advantageous if education and curriculum defined by the government were reexamined so that assessments of learning include value added knowledge and the students' engagement and motivation to further their own understanding. Teaching is not limited to facilitating the passing of assessment tests, but broader, inspiring students to explore their world. To draw on work by Cole (1998) it is important that the research findings and the concept of learning are not reduced too far, and we remain aware of the multiplicity of learning when we try to measure them. Clearly, there are a number of factors at play, and it is as much about measuring them as it is identifying and mediating them to provide an optimum environment for learning.

24.3 Are the results a novelty effect?

A potential flaw in a lot of technology research is the effect of novelty upon the results with improvements in learning potentially being due to an increased, but unsustainable, engagement in the topic due to the novelty of the technology. This has been a risk during this research. However, attempts were made to reduce this factor.

During the Observation and Automation investigation, the 'peer' students[62] were given a mini interactive demonstration, which showcased the dataloggers without allowing direct access. Informal evaluation of this suggests that the students found it to be an engaging experience. Indeed, on feedback forms the researcher who presented the demonstration was listed as the best part of the day, with requests for him to teach the class in future!

A delayed post test was also conducted to provide feedback on the dataloggers. However, due to the start of the new academic year, the group of students which, engaged in the study were now taught by new teachers, and in some cases the students had moved to different classes separate from their peers. This reduced the number of responses. The albeit limited, number of

[62] Those who did not get to use the datalogger

responses revealed that few students could recall details about the day, including whether or not they had had direct experience of the dataloggers. While this is good in that it suggests that the dataloggers were not so novel that the students were still thinking about them, it also suggested that the single intervention was not enough to produce a long term change in the students' understanding and engagement with the science topic.

The Technology vs Traditional study was designed to directly question the idea that learning with technology is necessarily more engaging than traditional methods. Interestingly, the technology showed little novelty effect, with the students showing no increase in motivation. This may have been due to the perceived faults with the datalogger, leading the students to mistrust them. It is interesting to note that all the students were engaged in the activity throughout. Thus it may not have been entirely due to the novelty of the technology, but instead due to increased independence which, the students were given during this investigation enabling them to direct their own learning. It would be interesting to explore this effect further, and see whether students with a sustained level of control over their learning maintain their interest or if after a period of time they would find directing their own learning to be effortful.

Finally, during the Ownership and Technology investigation the factor of novelty was directly investigated through the camera condition. It was hypothesised that if novelty was a factor, then the students would take more photographs at the beginning, but that this would decrease over time. This was shown to be false, with students taking a similar number of photographs across the modules. It is interesting to note that the teacher also used an audience response system during this investigation. Despite the students being familiar with this tool, they still showed increased excitement and engagement when provided with the opportunity to use it. Perhaps, instead of being fearful of a novelty effect, teachers need to utilise it, by employing a range of teaching techniques and tools to keep the students engaged throughout the school year.

24.4 Did using a mixed method approach add value?

The use of a mixed method research design was a novel and innovative method for exploring an area of research that already has clear qualitative findings. By including quantitative techniques, this field is developed further and provides in-depth insights into the interactions between context, technology and learning. However, in order to conduct these experiments they need to be designed with respect to the environment and the needs of the schools and students. It is clear that, to explore the impact of an intervention, it needs to be studied over an extended period of time. It is also important that other confounding factors are reduced, for instance conducting the research within the classroom, working in conjunction with the teachers, and employing experimental methods that are of interest to the student. For instance, experience from the Ownership and Automation investigation led to the redevelopment of the testing material so that it could be used online, reducing the paperwork that the students had to complete. It also forced the students to answer every question.

During this programme of work, and in similar projects[63], the support of the teacher has been vital to the success of an investigation. During the Plug Back Into Science project[64] teachers noted that they did not have the time to learn new technologies, did not have appropriate technological support and lacked motivation (Bevan, Stanton Fraser, Crellin and Martin, 2011). During the investigations conducted for this thesis, those issues were overcome through the direct support of the researcher. By spending time with the teachers and offering technical and motivational support, the teachers used the dataloggers within their teaching.

Clearly, using a hands-on mixed method approach has added value to this field of research by providing data around the impact of technology and context on learning. Paving the way for future research using these techniques, it has also highlighted the importance of working in collaboration with teachers to produce investigations with ecological validity. The insights provided by the mixed methods approaches, and the insights of the quantitative data outweigh the difficulties faced during the design of the tasks and the analysis.

Had this work been purely quantitative, the results would have suffered from being reductionist and non representative of the classroom environment. At the same time had it continued to use a purely qualitative and observational approach as favoured in the literature, the results would not have indicated the clear empirical impact of the dataloggers on student learning. Furthermore, the use of mixed methods led to a direct involvement in the class and close collaboration with the teachers. This experience benefited not only the research in terms of its relevance and validity, but also benefited the teachers by providing them with an opportunity to explore dataloggers in a supportive environment.

[63] Plug Back Into Science

[64] A one -year project funded by an EPSRC Knowledge Transfer Bid, this project explored the current and future role of mobile technologies in promoting hands-on learning in Science teaching.

25 Future Work

As a society we need to understand how best to support new generations by giving them the opportunity to formulate their own understanding based on their experiences of the real world. As Luckin's (2010) work suggests, we should be teaching students to adapt and formulate their own ideas rather than merely teaching them facts and content. This work has used a mixed method approach to generate a deeper understanding of the interactions occurring during the learning process. Future work could take this further by exploring the conditions required to promote effective learning, through further defining learning as a concept built of a multitude of factors such as motivation, engagement and confidence. By understanding the factors involved in learning it may be possible to generate better tests of this, providing students with an opportunity to showcase their skills and learn for the future rather than for the test.

This research has also developed the idea of contextual experience and contextual media. Ideas for future experiments include further exploring the comparison between physical and virtual field trips, in particular when the students in the virtual simulation can direct those in the physical world, building on work by Spicer & Stratford (2001); Evans & Gibbons (2007). Exploring this overlap would provide an insight into what can constitute a contextual experience: for example can it be generated by seeing the phenomenon through the eyes of a peer? The qualitative workbook results suggest that some students held a shared sense of ownership, while others suggested that they may not trust the data of their partner. O'Neill (2010) reports that ownership is empowering, and it would be interesting to explore how a sense of ownership can impact on student motivation, and the relationship between ownership and control. This could be supported by further work into the role of data visualisation and methods for supporting the students in their exploration of the collected data.

It would be interesting to extend the final study, Ownership and Technology, through collecting comparison data from previous years to explore whether the modules have an underlying difference in difficulty that may affect the results. It would also be informative to explore whether different modules would benefit from photographs in different ways. For instance, would the photographs have been more valuable to the students in the light module compared to the sound module?

Future work could also look to collaborate more closely with software developers to design and evaluate tools which can support the learning process, in particular exploring how the language used in the software tools, and the usability of functions, may impact upon the students' motivation to use the technology (software or hardware) and ultimately their motivation for the topic.

The success of these investigations has highlighted that mixed methods research is valuable in the area of mobile and contextual learning. Future work needs to build upon this foundation and continue to develop novel and innovative methodologies for exploring these phenomena. In particular it is crucial that more research is conducted in direct collaboration with the teachers and technicians.

An alternative might be to continue this work in the emerging world of open badges. Open badges are a concept that is built on the idea of each day providing a learning opportunity, that need not be confined to the four walls of an education institute. As Wilson (1993) noted, learning can and should occur everyday. The open badges initiative allows the public to obtain "badges" as certificates of their learning. The badges concept is similar to that of the scouting and guiding badges, which are obtained to show your skill in a particular area. The key difference is that open badges are open to anyone and are virtual, with badges being shown on websites and personal blogs. Anybody can set up a course that leads to an open badge, allowing the world to become a school, with your peers as your teacher. Future work could explore how these alternative qualifications could be compared to existing ones and used as evidence for learning which does not need to be assessed in the traditional manner.

26 Final Points

This thesis set out with the aim of assessing the importance of context and hand held technology for learning for students in secondary school science education. In order to do this, four research questions were derived from a review of the literature, and explored using a range of techniques. A mixed methods approach was adopted in the design of novel studies to provide a new angle on our understanding of assessing learning. While this research has taken a step in the direction of exploring in a more concrete way how these factors really are having an impact on learning research still has some way to go. Researchers need to continue to explore the importance of contextual data during collection and interpretation for student's understanding. In particular, further work needs to be carried out in conjunction with teachers to enable realistic scientific investigations in the classroom. Building upon the work from the final investigation, research could use a longitudinal approach, with the researcher embedded within the classroom. Alternatively, building on work by Laurillard

(2008) teachers should be encouraged to undertake their own research and be provided with opportunities to explore new technologies and innovative tools as aids for their teaching process.

The results found in these investigations corroborate those discussed in the literature review, but are novel in that they explore the area using a quantitative approach. This is positive, as the results found in this programme add to a large body of work, which highlights the importance of using technology and tools to engage and improve learning in science.

Whilst in hindsight there are certain aspects of the investigations that may have benefited from being designed differently, each of the investigations reported in this thesis was designed in collaboration with, and in response to, discussion with teachers and science technicians. While this may have limited the ability to gain fully quantifiable results, it has provided a stepping stone from the tightly measured and controlled laboratory to the real world classroom providing an insight into the role of hand held technology upon real students and teachers.

Finally, it is important to note that since this thesis was started in October 2008, a number of changes have occurred, including but not limited, to an increased prevalence of mobile devices, a change in British Government which has led to a substantial restructuring in the world of education and pedagogy, and finally with the launch of Raspberry Pi and increased popularity of Arduino[65] a new era of computing and technology is being born. ScienceScope are currently completely redesigning their dataloggers and sensor range to produce a product that is relevant now and for the foreseeable future[66]. These changes highlight how quickly work in this field can become sidelined by new technologies, changes of focus or even ideology. It is vitally important that researchers keep asking about the benefits of real world experience for students, and ensure that policy makers are aware of tools which are not only technologically advanced but also show clear benefits to the students' learning and motivation to learn.

[65] cheaply available microprocessing tools which enable the average person to develop their own technological understanding outside of an education environment

[66] See Hennessy (2006) for a discussion on the importance of technology keeping pace with science education and its role in reshaping pedagogy.

Part VIII

References

References

Abergbengtsson, L. (2006). Then you can take half almost: Elementary students learning bar graphs and pie charts in a computer-based context. *The Journal of Mathematical Behavior*, 25(2):116–135.

Abnett, C., Stanton, D., Neale, H., & O'Malley, C. (2001). The effect of multiple input devices on collaboration and gender issues. *Proc. Euro-CSCL'01*, pages 29–36.

Adams, A., Coughlan, T., Rogers, Y., Collins, T., Davies, S., Blake, C., & Lea, J. (2011). Live linking of fieldwork to the laboratory increases students inquiry based reflections. In *CSCL 2011 Proceedings: Volume II Short Papers and Posters*.

Aldridge, J., Fraser, B., & Velayutham, S. (2010). Development and validation of an instrument to measure students motivation and self-regulation in science learning. In *AARE 2010 International Education Research Conference*.

Alibali, M. W. & Nathan, M. J. (2010). Conducting Research in Schools: A Practical Guide. *Journal of Cognition and Development*, 11(4):397–407.

Allison, C., Cerri, S. A., Ritrovato, P., Gaeta, A., & Gaeta, M. (2005). Services, semantics, and standards: Elements of a learning grid infrastructure. *Applied Artificial Intelligence*, 19(9-10):861–879.

Anastopoulou, S., Sharples, M., Ainsworth, S., Crook, C., O'Malley, C., & Wright, M. (2012). Creating personal meaning through technology-supported science inquiry learning across formal and informal settings. *International Journal of Science Education*, 34(2):251–273.

Angeli, C. (2007). Distributed Cognition: A Framework for Understanding the Role of Computers in Classroom Teaching and Learning. *Journal of Research on Technology in Education*, 40(3):271–279.

Ash, D. (2007). *Video Research in the Learning Sciences*, Using video data to capture discontinuous science meaning making in nonschool settings, pages 207–227. Routledge.

Attride-Stirling, J. (2001). Thematic networks: an analytic tool for qualitative research. *Qualitative Research*, 1(3):385–405.

Ayala, G. & Castillo, S. (2008). Towards computational models for mobile learning objects. In *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, pages 153–157. IEEE.

Baggot le Velle, L., Wishart, J., McFarlane, A., & Brawn, R. (2005). Teaching and Learning with ICT within the subject culture of secondary science. In *Network-Based Education*, Rovaniemi, Finland.

Balaam, M., Fitzpatrick, G., Good, J., & Luckin, R. (2010). Exploring affective technologies for the classroom with the subtle stone. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, pages 1623–1632, New York, NY, USA. ACM.

Bamberger, Y. & Tal, T. (2008). Multiple Outcomes of Class Visits to Natural History Museums: The Students' View. *Journal of Science Education and Technology*, 17(3):274–284.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In Pajares, F. & Urdan, T., editors, *Self-efficacy beliefs of adolescents*, pages 07–337. CT: Information Age, Greenwich.

Barkhaus (2003). Is Context-Aware Computing Taking Control away from the User? Three Levels of Interactivity Examined. In Dey, A., editor, *UbiComp*, pages 149–156.

Barton, R. (1998). Why do we ask pupils to plot graphs? *Physics Education*, 33 (6):366–367.

Bell, M., Reeves, S., Brown, B., Sherwood, S., Macmillan, D., Ferguson, J., & Chalmers, M. (2009). Eyespy: Supporting navigation through play. *Technology*.

Belshaw (2011). *Purpos/Ed*. Scholastic Books Ltd, Oxford.

Bencze, J. L. & Bowen, G. M. (2007). Student-teachers Dialectically Developed Motivation for Promoting Student-led Science Projects. *International Journal of Science and Mathematics Education*, 7(1):133–159.

Bevan, C., Fraser, S., D., Crellin, D., & Martin, S. (2011). Plug back into science. *E&T Education*, Autumn:27–29.

Bigge, M. L. & Shermis, S. (1992). *Learning Theories for Teachers*. HarperCollins.

Boticki, I. & So, H. (2010). Quiet captures: a tool for capturing the evidence of seamless learning with mobile devices. *Conference of the Learning Sciences*, 1:500–507.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2):77–101.

British Government (2004). National curriculum guidelines. Online https://www.education.gov.uk/publications/eOrderingDownload/QCA-04-1374.pdf (Retrieved 09.07.13).

Brown, A., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A., & Campione, J. (1993). Distributed expertise in the classroom. In Saloman, G., editor, *Distributed Cognitions: Psychological and Educational Considerations*, pages 188–228. Cambridge University Press.

Brown, E., Borner, D., Sharples, M., Glahn, C., Jong, T., & Specht, M. (2010). *Location based and contextual mobile learning. A STELLAR Small-Scale Study.* Technical report, STELLAR European Network of Excellence in TEL (EU).

Bruner, J. & Weinreich-Haste, H. (1987). *Making sense: the child's construction of the world*. Methuen.

Bunderson, J. S. & Reagans, R. E. (2011). Power, status, and learning in organizations. *Organization Science*, 22(5):1182–1194.

Callanan, M. (2007). *Video research in the learning sciences*, Expanding studies of family conversations about science through video analysis, pages 227–238. Routledge.

Cameron, J., Banko, K. M., & Pierce, W. D. (2001). Pervasive negative effects of rewards on intrinsic motivation: The myth continues. *The Behavior Analyst*, 24(1):1.

Caudill, J. G. (2007). Mobile Computing : Parallel developments. *International Review of Research in Open and Distance Learning*, 8(2):1–13.

Chalmers, M., Dieberger, A., Hook, K., & Rudstrom, A. (2008). Social Navigation and Seamful Design. *Japanese Journal of Cognitive Science, Special Issue on Social Navigation*, 11(3):171–181.

Chen, F. C., Lai, C. H., Yang, J. C., Liang, J. S., & Chan, T.-W. (2008). Evaluating the Effects of Mobile Technology on an Outdoor Experiential Learning. In *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, pages 107–114. IEE.

Choo, S. W. (2005). *Dataloggers for Inquiry- Based Science Learning*. Technical report, Educational Technology Division, Ministry of Education, Singapore.

Cobcroft, R., Towers, S., Smith, J., & Bruns, A. (2006). Mobile Learning in Review: Opportunities and Challenges for Learners, Teachers and Institutions. In *Proceedings Online Learning and Teaching (OLT) Conference*, pages 21–30.

Cole, H. & Stanton, D. (2003). Designing mobile technologies to support co-present collaboration. *Personal and Ubiquitous Computing*, 7(6):365–371.

Cole, M. (1998). *Cultural Psychology: A Once and Future Discipline*. Harvard University Press, 2nd edition.

Cole, M. & Engestrom, Y. (1993). A cultural-historical approach to distributed cognition. In Saloman, G., editor, *Distributed Cognitions: Psychological and Educational Considerations*, pages 1–47. Cambridge University Press.

Cordova, D. I. & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology*, 88(4):715.

Crabtree, A., Benford, S., Tennent, P., Chalmers, M., & Brown, B. (2006). Supporting Ethnographic Studies of Ubiquitous Computing in the Wild. In *DIS '06 Proceedings of the 6th conference on Designing Interactive systems*, pages 60–69.

Crook, C., Harrison, C., Farrington-Flint, L., Tomas, C., & Underwood, J. (2010). *The Impact of Technology: Value-added classroom practice*. Technical report, BECTA.

Danziger, K. (1994). *Constructing the subject: Historical origins of psychological research*. Cambridge Univ Pr.

Davies, N. & Connor, D. (2005). Enriching the UK Curriculum with Real Data. In *IASE and ISI55th Session (Sydney, Australia, 2005)*.

Deaney, R., Hennessy, S., & Ruthven, K. (2006). Teachers strategies for making effective use of datalogging. *Science*, 88(December):103–111.

Deci, E. L., Koestner, R., & Ryan, R. M. (2001). Extrinsic rewards and intrinsic motivation in education: Reconsidered once again. *Review of Educational Research*, 71(1):1–27.

Deng, F., Chen, W., & Chai, C. S. (2011). Constructivist-oriented Data-logging Activities in Chinese Chemistry Classroom : Enhancing Students Conceptual Understanding and Their Metacognition. *Education*, 2:207–221.

Denscombe, M. (2002). *The good research guide: For small-scale social research projects*. Taylor & Francis.

Denzin, N. K. & Lincoln, Y. S. (2005). *The Sage handbook of qualitative research*. Sage Publications, Inc.

Department for Education (2007). *How Science Works Agenda, National Strategies*. Technical report, Department For Education.

Department for Education (2011). *Digital Technology in Schools*. Technical report, Department for Education.

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., Hall, R., Koschmann, T., Lemke, J. L., Sherin, M. G., et al. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The Journal of the Learning Sciences*, 19(1):3–53.

Dewey, J. . (1964). Science as subject matter and as method. In Archambault, R. D., editor, *John Dewey on Education. Chicago.*, pages 182–192. University of Chicago press.

Dicks, B. (2006). Multimodal ethnography. *Qualitative Research*, 6(1):77–96.

Dillenbourg, P. (1999). *Collaborative-learning: Cognitive and Computational Approaches*, What do you mean by collaborative learning? pages 1-19. Oxford: Elsevier.

du Boulay, B., Avramides, K., Luckin, R., Martínez-Mirón, E., Méndez, G., & Carr, A. (2010). Towards systems that care: a conceptual framework based on motivation, metacognition and affect. *International Journal of Artificial Intelligence in Education*, 20(3):197–229.

Duffy, T. M. & Cunningham, D. J. (1996). Constructivism: Implications for the design and the delivery of instruction. In *Handbook for research in Educational Communications and Technology*. New York, Simon and Shuster Macmillan.

Emmison, M. & Smith, P. (2000). *Researching the visual: Images, objects, contexts and interactions in social and cultural inquiry*. Sage Publications Ltd.

Ercikan, K. & Roth, W.-M. (2006). What Good Is Polarizing Research Into Qualitative and Quantitative? *Educational Researcher*, 35(5):14–23.

Erikson, F. (2006). *Complementary Methods in Education Research*, Definition and Analysis of Data from Videotape, pages 177–193. American Educational Research Association.

Evans, C. & Gibbons, N. (2007). The interactivity effect in multimedia learning. *Computers & Education*, 49(4):1147–1160.

Facer, K., Joiner, R., Stanton, D., Reid, J., Hull, R., & Kirk, D. (2004). Savannah: mobile gaming and learning? *Journal of Computer Assisted Learning*, 20(6):399–409.

Fails, J. A. (2007). Mobile collaboration for young children. *Proceedings of the 6th international conference on Interaction design and children - IDC '07*, page 181.

Fearn, F. (2006). Data-loggers in ecological enquiry in school grounds and beyond. *Science*, 87(March):69–74.

Fishman, B., Soloway, E., Krajcik, J., Marx, R., & Blumenfeld, P. (2001). Creating Scalable and Systemic Technology Innovations for Urban Education. *Urban Education*, pages 1–24.

FitzGerald, E. (2012). Analysing video and audio data: existing approaches and new innovations. In *Surface Learning Workshop '12*.

Flanagan, J. C. (1954). The critical incident technique. *Psychological bulletin*, 51(4):327.

Friedler, Y. & McFarlane, A. (1997). Data logging with portable computers: a study of the impact on graphing skills in secondary pupils. *The Journal of Computers in Mathematics and Science Teaching,*, 16(4):527–550.

Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making Sense of Graphs: Critical Factors Influencing Comprehension and Instructional Implications. *Journal for Research in Mathematics Education*, 32(2):124.

Gall, M. & Breeze, N. (2008). Music and eJay: An opportunity for creative collaborations in the classroom. *International Journal of Educational Research*, 47(1):27–40.

Gardner, H. & Hatch, T. (1989). Multiple Intelligences Go to School: Educational Implications of the Theory of Multiple Intelligences. *Educational Research*, 18(8):4–10.

Geertz, C. (1973). The Interpretation of Cultures: Deep Play: Notes on the Balinese Cockfight. In *The Interpretation of Cultures*, pages 412–455. HarperCollins.

Gipps, J. (2002). Data logging and inquiry learning in science. In *Proceedings of the Seventh world conference on computers in education conference on Computers in education: Australian topics-Volume 8*, pages 31–34. Australian Computer Society, Inc.

Graesser, A. C., D'Mello, S. K., Craig, S. D., Witherspoon, A., Sullins, J., McDaniel, B., & Gholson, B. (2008). The relationship between affective states and dialog patterns during interactions with autotutor. *Journal of Interactive Learning Research*, 19(2):293–312.

Habgood, M. & Ainsworth, S. (2011). Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games. *The Journal of the Learning Sciences*, 20(2):169–206.

Hartley, D. (2007). Personalisation: the emerging revised code of education? *Oxford Review of Education*, 33(5):629–642.

Hartnell-Young, E. (2007). Making the Connections: Theory and practice of mobile learning in schools. In *MLearn 2007*, pages 86 – 95.

Healey, M. & Jenkins, A. (2000). Kolb's Experiential Learning Theory and Its Application in Geography in Higher Education. *Journal of Geography*, 99(5):185–195.

Heath, C. & Hindmarsh, J. (2002). Analysing interaction. *Video Ethnography*.

Heath, C., Hindmarsh, J., & Luff, P. (2010). *Video in Qualitative Research*. SAGE.

Heinze, A. (2008). *Blended Learning: An Interpretive Action Research Study*. PhD thesis, University of Salford.

Hennessy, S. (2006). Integrating technology into teaching and learning of school science: a situated perspective on pedagogical issues in research. *Studies in Science Education*, 42:1–48.

Hennessy, S., Wishart, J., Whitelock, D., Deaney, R., Brawn, R., Mcfarlane, A., Ruthven, K., & Winterbottom, M. (2007). Pedagogical approaches for technology-integrated science teaching. *Computers & Education*, 48:137–152.

Herrington, J., Mantei, J., Herrington, A., Olney, I., & Ferry, B. (2008). New technologies, new pedagogies: Mobile technologies and new ways of teaching and learning. In *In Hello! Where are you in the landscape of educational technology? Proceedings ASCILITE, Melbourne 2008*, pages 419–427.

Heym, N. & Hartnell-Young, E. (2008). *How mobile phones help learning in secondary schools*. Technical Report March, Nottingham: Learning Sciences Research Institute, University of Nottingham.

Hillman, D. C., Willis, D. J., & Gunawardena, C. N. (1994). Learner-interface interaction in distance education: An extension of contemporary models and strategies for practitioners. *American Journal of Distance Education*, 8(2):30–42.

Hinrichsen, J. & Jarrett, D. (1999). *Science Inqury for the Classroom: a Literature Review.* Portland: Northwest Regional Educational Laboratory.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 7(2):174–196.

Honebein, P., Duffy, T., & Fishman, B. (1992). Constructivism and the design of learning environments: Context and authentic activities for learning. In Duffy, T., Lowyck, J., & Jonassen, D., editors, *Designing Environments for Constructive Learning*, pages 87–108. Springer-Verlag, Berlin.

Huizenga, J., Admiraal, W., Akkerman, S., & Dam, G. T. (2009). Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game. *Journal of Computer Assisted Learning*, 25(4):332–344.

Hunt, D. (2003). The concept of knowledge and how to measure it. *Journal of intellectual capital*, 4(1):100–113.

Isaacs, T. (2010). Educational assessment in England. *Assessment in Education: Principles, Policy & Practice*, 17(3):315–334.

Jarvela, S., Volet, S., & Jarvenoja, H. (2010). Research on Motivation in Collaborative Learning: Moving Beyond the Cognitive-Situative Divide and Combining Individual and Social Processes. *Educational Psychologist*, 45(1):15–27.

Johnson, D. M., Franklin, T. D., & Wardlow, G. W. (1997). Hands-on activities versus worksheets in reinforcing physical science principles: Effects on student achievement and attitude. *Journal of Agricultural Education*, 38(3):9–17.

Kanjo, E., Benford, S., Paxton, M., Chamberlain, A., Fraser, D. S., Woodgate, D., Crellin, D., & Woolard, A. (2007). MobGeoSen: facilitating personal geosensor data collection and visualization using mobile phones. *Personal and Ubiquitous Computing*, 12(8):599–607.

Knapp, D. & Barrie, E. (2001). Content Evaluation of an Environmental Science Trip. *Science Education*, 10(4):351–357.

Kolb, D. A. (1984). *Experiential Learning: Experience as the source of Learning and Development*. Prentice-Hall.

Krajcik, J., Blumenfeld, P., Marx, R., Bass, K., & Fredricks, J. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences*, 7(3):313–350.

Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education*, 14(1):23–40.

Kravcik, M., Kaibel, A., Specht, M., Terrenghi, L., & Augustin, S. (2004). Mobile Collector for Field Trips. *Educational Technology & Society*, 7:25–33.

Kwon, O. N. (2002). The effect of calculator-based ranger activities on students' graphing ability. *School Science and Mathematics*, 102(2):57–67.

Lai, C., Yang, J., Chen, F., Ho, C., & Chan, T. (2007). Affordances of mobile technologies for experiential learning: the interplay of technology and pedagogical practices. *Journal of Computer Assisted Learning*, 23(4):326–337.

Landis, J. R. & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, pages 159–174.

Laurillard, D. (2008). The pedagogical challenges to collaborative technologies. *International Journal of Computer-Supported Collaborative Learning*, 4(1):5–20.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge Univ Pr.

Law, J. (2004). *After method: Mess in social science research*. Routledge.

LeBaron, J. & Collier, C., editors (2001). *Technology in its place, successful technology infusion in schools*. Jossey Bass.

Lee, W. & Reeve, J. (2012). Teachers' estimates of their students' motivation and engagement: being in synch with students. *Educational Psychology*, 32(6):727–747.

Leech, N. L. & Onwuegbuzie, A. J. (2008). Qualitative data analysis: A compendium of techniques and a framework for selection for school psychology research and beyond. *School Psychology Quarterly*, 23(4):587.

Lepper, M. R. (1988). Motivational considerations in the study of instruction. *Cognition and Instruction*, 5(4):pp. 289–309.

Liu, C. C. (2008). Beyond the Ownership of Handheld Devices: Active Learning with Ubiquitous Learning Minds. *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, pages 11–19.

Lombardi, M. & Oblinger, D. (2007). Authentic learning for the 21st century : An overview. *Learning*, 1:1–7.

Luckin, R. (1998). *'Ecolab' : explorations in the zone of proximal development*. PhD thesis, University of Sussex, Brighton.

Luckin, R. (2006). Understanding Learning Contexts as Ecologies of Resources: From the Zone of Proximal Development to Learner Generated Contexts. In Reeves, T. & Yamashita, S., editors, *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2006*, pages 2195–2202, Chesapeake, VA:. AACE.

Luckin, R. (2008). The learner centric ecology of resources: A framework for using technology to scaffold learning. *Computers & Education*, 50(2):449–462.

Luckin, R. (2010). *Re-Designing Learning Contexts Technology-Rich, Learner-Centred Ecologies*. Routledge, first edition.

Mahoney, J. & Goertz, G. (2006). A tale of two cultures: Contrasting quantitative and qualitative research. *Political Analysis*, 14(3):227–249.

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist*, 59(1):14.

McFarlane, A., Roche, N., & Triggs, P. (2007). *Mobile learning: Research findings Interim Report to BECTA*. Technical report, University of Bristol.

Mee, A. M. (2002). Are students who use data logging in leaving certificate practical work at any disadvantage in drawing graphs manually? Master's thesis, School of Computer Applications Dublin City University.

Metcalf, D., Milrad, M., Cheek, D., Raasch, S., & Hamilton, A. (2008). My sports pulse: Increasing student interest in STEM disciplines through sports themes, games and mobile technologies. In *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, pages 23–30. IEE.

Millar, R. & Osborne, J. F., editors (1998). *Beyond 2000: Science Education for the Future.* King's College London., London.

Milliband, D. (2006). *Personalising Education*, Choice and voice in personalised learning, speech to the DfES, DEMOS, OECD Conference, London, 18 May 2004. OECD.

Mistler-Jackson, M. & Butler Songer, N. (2000). Student Motivation and Internet Technology: Are Students Empowered to Learn Science? *Journal of Research in Science Teaching*, 37(5):459.

Moore, M. (1989). Three types of interaction. *American Journal of Distance Education*, 3 (2):1–6.

Munsterberg, H. (1914). *Psychology: General and Applied.* Appleton.

Murdoch, S. (2007). *IQ The brilliant idea that failed.* John Wiley & Sons.

Naaman, M., Harada, S., Wang, Q., & Garcia-molina, H. (2004). Context Data in Geo-Referenced Digital Photo Collections. In *12th ACM international conference on Multimedia*, New York, NY.

Newton, L. (2000). Data-logging in practical science: research and reality. *International Journal of Science Education*, 22(12):1247–1259.

Newton, L. R. (1999). Data-logging in the science classroom: approaches to innovation. In *Second International Conference of the European Science Education Research Association (ESERA)*, pages 153–160, Kiel Germany.

Ng, P. H. & Yeung, Y. Y. (2000). Implications of Data-logging on A . L . Physics Experiments : A Preliminary Study Role of Practical Activities in A.L. Physics Curriculum. *Asia-Pacific Forum on Science Learning and Teaching*, 1(2):1–14.

Ng, W. & Nicholas, H. (2007). Ubiquitous learning with handheld computers in schools. In *Proceedings of the 6th Annual International Conference on Mobile Learning*, pages 186–198.

Niaz, M. (2006). Can Findings of Qualitative Research in Education be Generalized? *Quality & Quantity*, 41(3):429–445.

O'Malley, C., Vavoula, G., Glew, J. P., Taylor, J., Sharples, M., & Lefrere, P. (2003). *MOBILEARN- Guidelines for Learning/Teaching/Tutoring in a MobileEnvironment.* Technical Report June, Mobilearn project deliverable.

O'Neill, T. B. (2010). Fostering spaces of student ownership in middle school science. *Equity & Excellence in Education*, 43(1):6–20.

Orion, N. & Hofstein, A. (1991). Factors which influence learning ability during a scientific field trip in a natural environment. In *Annual Meeting of the National Association for Research in Science Teaching (Lake Geneva, WI,).*, Lake Geneva, WI.

Osborne, J. & Hennessy, S. (2003). *Report 6: Literature Review in Science Education and the Role of ICT: Promise, Problems and Future Directions.* Technical report, Futurelab, Bristol.

Palmer, D. (2005). A motivational view of constructivist-informed teaching. *International Journal of Science Education*, 27(15):1853–1881.

Paxton, M., Chamberlain, A., & Benford, S. (2007). Sensor-Based Systems for Environmental Education. In *Workshop of Emerging Technologies for Inquiry-Based Learning in Science*.

Pea, R. (2002). Learning science through collaborative visualization over the Internet. In *Proceedings of the Nobel Symposium (NS 120)*, pages 1–14.

Pedretti, E., Mayer-Smith, J., & Woodrow, J. (1998). Technology, text, and talk: Students' perspectives on teaching and learning in a technology-enhanced secondary science classroom. *Science Education*, 82(5):569–589.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational researcher*, pages 5–12.

Pintrich, P. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, 95(4):667.

Pintrich, P. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review*, 16(4):385–407.

Punch, K. & Punch, K. (1998). *Introduction to social research: Quantitative and qualitative approaches*. Sage Publications Ltd.

Quine, W. (1987). *Quiddities: An Intermittently Philosophical Dictionary*. The Belknap Press of Harvard University Press, Cambridge, MA and London.

Randell, C., Price, S., Rogers, Y., Harris, E., & Fitzpatrick, G. (2004). The Ambient Horn: designing a novel audio-based learning experience. *Personal and Ubiquitous Computing*, 8(3-4):177–183.

Rau, P., Gao, Q., & Wu, L. (2008). Using mobile communication technology in high school education: Motivation, pressure, and learning performance. *Computers & Education*, 50(1):1–22.

Rebolledo-Mendez, G., Du Boulay, B., & Luckin, R. (2006). Motivating the learner: an empirical evaluation. In *Intelligent Tutoring Systems*, pages 545–554. Springer.

Resnick, M., Berg, B., & Eisenberg, M. (2000). Beyond Black Boxes: Bringing Transparency and Aesthetics back to Scientific Investigation. *Journal of the Learning Sciences.*, 9(1):7–30.

Robertson, I. (2007). Technology-based learning : Problematising VET students preferences and readiness. In *AVETRA 2007 - 10th Annual Conference. Evolution, revolution or status quo? The new context for VET.*, pages 11–13.

Rogers, L. & Wild, P. (1996). Data-logging: effects on practical science. *Journal of Computer Assisted Learning*, 12(3):130–145.

Rogers, Y. New theoretical approaches for HCI. In *Annual Review of Information Science and Technology*, pages 87–143.

Rogers, Y. (2004). New Theoretical Approaches for Human-Computer Interaction. *Annual Review of Information Science and Technology*, 38:87–143.

Rogers, Y. & Ellis, J. (1994). Distributed cognition: an alternative framework for analysing and explaining collaborative working. *Journal of information technology*, 9:119–119.

Rogers, Y., Price, S., Fitzpatrick, G., Fleck, R., Harris, E., Smith, H., Randell, C., Muller, H., Malley, C. O., Stanton, D., Thompson, M., & Weal, M. (2004). Ambient Wood : Designing New Forms of Digital Augmentation for Learning Outdoors. In *Third International Conference for Interaction Design and Children*, pages 3–10. ACM.

Rogers, Y., Price, S., Harris, E., Phelps, T., Underwood, M., Wilde, D., & Smith, H. (2002). *Learning through digitally-augmented physical experiences : Reflections on the Ambient Wood project*. Technical report, Equator working paper.

Rogers, Y., Price, S., Randell, C., Fraser, D. S., Weal, M., & Fitzpatrick, G. (2005). Ubi-learning integrates indoor and outdoor experiences. *Communications of the ACM*, 48(1):55.

Roschelle, J., Rafanan, K., Estrella, G., Nussbaum, M., & Claro, S. (2010). From handheld collaborative tool to effective classroom module: Embedding CSCL in a broader design framework. *Computers & Education*, 55(3):1018–1026.

Roschelle, J., Tatar, D., Chaudhury, S. R., Patton, C., & Digiano, C. (2007). Ink, improvisation, and interactive engagement: Learning with tablets. *Computers*, 40 (9):42–48.

Rosenbaum, E., Klopfer, E., & Perry, J. (2006). On Location Learning: Authentic Applied Science with Networked Augmented Realities. *Journal of Science Education and Technology*, 16(1):31–45.

Rudmann, C. L. (1994). A Review of the Use and Implementation of Science Field Trips. *School Science and Mathematics*, 94(3):138–41.

Salmi, H. (2003). Science centres as learning laboratories: experiences of heureka, the finnish science centre. *International Journal of Technology Management*, 25(5):460–476.

Saloman, G. (1993). *Distributed cognitions: Psychological and Educational Considerations*. Cambridge University Press.

Scaife, M. (1996). External cognition: how do graphical representations work? *International Journal of Human-Computer Studies*, 45(2):185–213.

Scanlon, E., Blake, C., Twiner, A., Collins, T., Jones, A., & Kerawalla, L. (2011). Collaboration in communities of inquirers: an example from a geography field trip. In *CSCL 2-11 Proceedings: Volume II Short Papers & Posters*.

Segall, R. G. (1989). Thick descriptions: A tool for designing ethnographic interactive videodiscs. *ACM SIGCHI Bulletin*, 21(2):118–122.

Sharples, M. (2009). *Researching Mobile Learning: Frameworks, Tools and Research Designs*, Methods for evaluating mobile learning, pages 17–39. Peter Lang Publishing Group, Oxford.

Sharples, M., Amedillo Sanchez, I., Milrad, M., & Vavoula, G. (2009). *Technology Enhanced Learning: Principles and Products*, Mobile learning: small devices, big issues, pages 233 –249. Springer, Heidelberg, Germany.

Sharples, M., Corlett, D., & Westmancott, O. (2002). The Design and Implementation of a Mobile Learning Resource. *Personal and Ubiquitous Computing*, 6(3):220–234.

Sharples, M., Taylor, J., & Vavoula, G. (2005). Towards a theory of mobile learning. In *Proceedings of mLearn 2005*.

Sharples, M., Taylor, J., & Vavoula, G. (2007). *The Sage Handbook of Elearning Research*, A Theory of Learning for the Mobile Age, pages 221–247. Sage.

Silburn, K. R. (2008). *Teaching secondary science with data loggers: the NSW experience*. PhD thesis, University of Wollongong.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research*, 95(6):323–332.

Sinha, N., Khreisat, L., & Sharma, K. (2008). Learner-Interface Interaction for Technology-Enhanced Active Learning Interaction in Active Learning Implementing the Technology Sample Interaction Session. *Innovate: Journal of Online Education*, 5.

Smith, H., Luckin, R., Fitzpatrick, G., Avramides, K., & Underwood, J. (2005). Technology at work to mediate collaborative scientific enquiry in the field. In *Proceedings of the 2005 conference on Artificial Intelligence in Education: Supporting Learning through Intelligent and Socially Informed Technology*, Amsterdams. IOS Press (ISBN:1-58603-530-4).

Smith, H., Underwood, J., Fitzpatrick, G., Luckin, R., & Fraser, D. (2006). Identifying Tools to Support Schools' Collaborative Teaching and Learning. In *Science and Grid Computing, 2006. e-Science '06. Second IEEE International Conference on*, pages 140–140. IEEE.

Smith, L. (2009). *Fifty Modern Thinkers on Education: From Piaget to the Present*, Jean Piaget, 1896-1980, pages 37–44. Routledge.

Spicer, J. & Stratford, J. (2001). Student perceptions of a virtual field trip to replace a real field trip. *Journal of Computer Assisted Learning*, 17(4):345–354.

Spikol, D. & Milrad, M. (2008). Combining Physical Activities and Mobile Games to Promote Novel Learning Practices. In *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education, 2008*, pages 31–38. IEEE.

Stanton, D., OMalley, C., Fraser, M., Ng, M., & Benford, S. (2003). Situating historical events through mixed reality: Adult-child interactions in the storytent. In *Proc. Computer Support for Collaborative Learning*, pages 293–303.

Stanton Fraser, D., Smith, H., Tallyn, E., Kirk, D., Benford, S., Paxton, M., Price, S., & Fitzpatrick, G. (2005). The SENSE project: a context-inclusive approach to studying environmental science within and across schools. In *Computer Support for Collaborative Learning. Proceedings of the 2005 conference on CSCL*, pages 155–159.

Stears, M. & Gopal, N. (2010). Exploring alternative assessment strategies in science classrooms. *South African Journal of Education*, 30:591–604.

Tangney, B., Weber, S., Hanlon, Pand Knowles, D., Munnelly, J., Salkham, A., Watson, R., & Jennings, K. (2010). MobiMaths: An approach to utilising smartphones in teaching mathematics. In *Mlearn2010 - 9th world conference on mobile and contextual learning*.

Tanner, H. & Jones, S. (2007). Using video-stimulated reflective dialogue to learn from children about their learning with and without ICT. *Technology, Pedagogy and Education*, 16(3):321–335.

Tao, P.-K. & Gunstone, R. (1999). Conceptual change in science through collaborative learning at the computer. *International Journal of Science Education*, 21(1):39–57.

Teodosio, L. & Bender, W. (1993). Salient Video Stills: Content and Context Preserved. In *Proceedings of the first ACM international conference on Multimedia*, Anaheim, California, United States.

Traxler, J. (2007). Defining, Discussing, and Evaluating Mobile Learning: The moving finger writes and having writ.... *International Review of Research in Open and Distance Learning*, 8 (2)(2):12–25.

Traxler, J. & Wishart, J. (2011). *Making mobile learning work : case studies of practice*. Technical report, The Higher Education Academy.

Tuan, H., Chin, C., & Shieh, S. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education*, 27(6):639–654.

Turney, P. (1996). The Identification of Context-Sensitive Features: A Formal Definition of Context for Concept Learning. In *Proceedings of the Workshop on Learning in Context-Sensitive Domains, at the 13th International Conference on Machine Learning (ICML-96)*.

Uzunboylu, H., Cavus, N., & Ercag, E. (2009). Using mobile learning to increase environmental awareness. *Computers & Education*, 52(2):381–389.

Vallerand, R., Pelletier, L., Blais, M., Briere, N., Senecal, C., & Vallieres, E. (1992). The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and psychological measurement*, 52(4):1003–1017.

Vavoula, G., Sharples, M., Scanlon, E., Lonsdale, P., & Jones, A. (2005). *Report on literature on mobile learning, science and collaborative activity.* Technical report, EU Sixth Framework programme priority 2, Information society technology, Network of Excellence Kaleidoscope, (contract NoE IST-507838), project "Mobile learning in informal science settings".

Villavicencio, F. T. & Bernardo, A. B. (2012). Positive academic emotions moderate the relationship between self-regulation and academic achievement. *British Journal of Educational Psychology*.

Von Glasersfeld, E. (1989). Cognition, Construction of Knowledge, and Teaching. *Synthese*, 80(1):121–140.

Vrasidas, C. (2000). Constructivism versus objectivism: Implications for interaction, course design, and evaluation in distance education. *International Journal of Educational Telecommunications*, 6(4):339–362.

Weal, M. J., Michaelides, D. T., Thompson, M. K., & DeRoure, D. C. (2003). The Ambient Wood Journals - Replaying the Experience. In *Proceedings of the fourteenth ACM conference on Hypertext and hypermedia*, volume 44, pages 20–27, New York, NY, USA. ACM.

Weiner, B. (1990). History of motivational research in education. *Journal of Educational Psychology*, 82(4):616.

White, R. W. (1959). Motivation reconsidered: The concept of competence. *Psychological review*, 66(5):297.

Wilson, A. L. (1993). The promise of situated cognition. *New Directions for Adult and Continuing Education*, 1993(57):71–79.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, 17(2):89–100.

Woodgate, D., Fraser, D., Paxton, M., Crellin, D., Woolard, A., & Dillon, T. (2008a). Bringing School Science to Life: Personalization, Contextualization and Reflection of Self-Collected Data. In *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, pages 100–104. IEEE.

Woodgate, D. & Stanton Fraser, D. (2005). *eScience and Education 2005: A Review. JISC Report*. Technical Report October, JISC.

Woodgate, D. & Stanton Fraser, D. (2006). eScience, Science Education and Technology Integration in the Classroom: Some Practical Considerations. In *e-Science'06. Second IEEE International Conference on e-Science and Grid Computing, 2006*.

Woodgate, D., Stanton Fraser, D., Crellin, D., & Gower, A. (2008b). Mobile Learning in Context: School Science Data Collection as Legitimate Peripheral Participation? In Traxler, J., Riordan, B., & Dennett, C., editors, *Proceedings of the MLearn 2008 conference: The Bridge from Text to Context.*

Woodgate, D., Stanton Fraser, D., Gower, A., Glancy, M., Gower, A., Chamberlain, A., Dillon, T., & Crellin, D. (2009). Using Mobile and Pervasive Technologies to Engage Formal and Informal Learners in Scientific Debate. In Goh, T., editor, *Multiplatform E-Learning Systems and Technologies: Mobile Devices for Ubiquitous ICT-Based Education*, pages 196–215. Information Science Reference.

Yen, H.-C., Tuan, H.-L., & Liao, C.-H. (2010). Investigating the Influence of Motivation on Students Conceptual Learning Outcomes in Web-based vs. Classroom-based Science Teaching Contexts. *Research in Science Education*.

Zoldosova, K. & Prokop, P. (2006). Education in the Field Influences Childrens Ideas and Interest toward Science. *Journal of Science Education and Technology*, 15(3-4):304–313.

Zurita, G., Baloian, N., & Baytelman, F. (2008). Supporting Rich Interaction in the Classroom with Mobile Devices. *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education (wmute 2008)*, pages 115–122.

Zurita, G. & Nussbaum, M. (2007). A conceptual framework based on Activity Theory for mobile CSCL. *British Journal of Educational Technology*, 38(2):211–235.

Part IX

Appendix A - Consent Forms

A Longitudinal Observation

Dear Parent / Carer,

I am working with ***** your child's science teacher, and Environmental Science students at ***** School to observe and understand students' use of new technologies for science learning. This research will form part of my PhD, which is funded by Great Western Research in collaboration with the Universities of Bath and Bristol and ScienceScope. During classroom and fieldwork sessions for the upcoming Environmental Science GCSE project, I would like to make video recordings and still photographs of the process, mainly for evaluation and analysis purposes, but also possibly for use in academic presentations and publications.

Please could you complete the form below to indicate whether you are willing to give permission for any images which include your child to be used as described, and return to ****at ***** School. Please be assured that confidentiality and anonymity of your child would be maintained, since we do not under any circumstances issue names or other details of children to anyone outside of this project.

Thank you.

Susanna Martin PhD Research Student Department of Psychology University of Bath	Dr Danaë Stanton Fraser, Senior Lecturer, Department of Psychology, University of Bath (Supervisor)	Dr Dawn Woodgate Research Fellow, Department of Psychology, University of Bath (Supervisor)

If you have any questions or concerns, please feel free to contact Susanna Martin by post or phone via the Department, or by email S.M.Martin@bath.ac.uk

---

Dear Susanna Martin,

Student's name---

Form--------------------------------------- Age------------------------

PARENTS/GUARDIANS:
I consent to my child taking part in this field trip

YES/NO

I consent to video footage and still images of my child being collected and used for academic purposes

YES/NO

STUDENTS:
I consent to taking part in this field trip

YES/NO

I consent to video footage and still images of me being collected and used for academic purposes

YES/NO

PARENT / GUARDIAN NAME: ---

PARENT/GUARDIAN SIGNATURE: ---

STUDENT SIGNATURE:---

DATE: --

Please indicate here if you are not happy with any of the above, or if you have any stipulations (continue overleaf if necessary):

Figure A.1: Consent Form Longitudinal Observation

B Single Event Observation

Dear Parent / Carer,

I am working with ****, your child's science teacher, and Environmental Science students at **** School to observe and understand students' use of new technologies for science learning. This research will form part of my PhD, which is funded by Great Western Research in collaboration with the Universities of Bath and Bristol and ScienceScope. During the students field trip to the Gower, I would like to make video recordings and still photographs of the process, mainly for evaluation and analysis purposes, but also possibly for use in academic presentations and publications.

Please could you complete the form below to indicate whether you are willing to give permission for any images which include your child to be used as described, and return to *** at **** School. Please be assured that confidentiality and anonymity of your child would be maintained, since we do not under any circumstances issue names or other details of children to anyone outside of this project.

Thank you.

Susanna Martin	Dr Danaë Stanton Fraser,	Dr Dawn Woodgate
PhD Research Student	Senior Lecturer,	Research Fellow,
Department of Psychology	Department of Psychology,	Department of Psychology,
University of Bath	University of Bath	University of Bath
	(Supervisor)	(Supervisor)

If you have any questions or concerns, please feel free to contact Susanna Martin by post or phone via the Department, or by email S.M.Martin@bath.ac.uk

---

Dear Susanna Martin,

Student's name--

Form-- Age------------------------

PARENTS/GUARDIANS:
I consent to my child taking part in this field trip

YES/NO

I consent to video footage and still images of my child being collected and used for academic purposes

YES/NO

STUDENTS:
I consent to taking part in this field trip

YES/NO

I consent to video footage and still images of me being collected and used for academic purposes

YES/NO

PARENT / GUARDIAN NAME: --

PARENT/GUARDIAN SIGNATURE: --

STUDENT SIGNATURE:--

DATE: --

Please indicate here if you are not happy with any of the above, or if you have any stipulations (continue overleaf if necessary):

Figure B.1: Consent Form Single Observation

C Ownership and Automation

UNIVERSITY OF BATH

Department of Psychology
Bath BA2 7AY, United Kingdom
Telephone: 01225 384349

Dear Parent / Guardian

My name is Susanna Martin and I am working with [teacher's name], your child's teacher to investigate new ways of improving school students' learning in science I have invited your child to attend a Sound and Research day at the University. The session will consist of three parts. Firstly, the students will be given a talk on sound. Secondly, they will be given the opportunity to take some sound recordings around the University campus in supervised groups, using hand held devices. Finally, they will take part in some learning activities using sound graphs. During the sessions I would like to make video recordings and still photographs of the process, mainly for evaluation and analysis purposes, but also possibly for use in academic presentations and publications. This research will form part of my PhD, which is funded by Great Western Research in collaboration with the Universities of Bath and Bristol and ScienceScope.

Please could you complete the form below to indicate whether you are willing for your child to take part in this event and to give permission for any images which include your child to be used as described, and return to [teacher's name] at [School]. Please be assured that confidentiality and anonymity of your child would be maintained, since we do not under any circumstances issue names or other details of children to anyone outside of this project.

Thank you.

Susanna Martin

Susanna Martin PhD Research Student Department of Psychology University of Bath	Dr Danaë Stanton Fraser, Reader, Department of Psychology, University of Bath (Supervisor)	Dr Dawn Woodgate Research Fellow, Department of Psychology, University of Bath (Supervisor)

If you have any questions or concerns, please feel free to contact Susanna Martin by post or phone via the Department, or by email S.M.Martin@bath.ac.uk

Figure C.1: Consent Form Ownership and Automation

D Technology vs Traditional

Dear Parent / Carer,

I am working with ***, your child's science teacher, we are running a Pulse Rate event at **** School on Thursday 15th July. The students will be given a talk on pulse rate and then given the opportunity to take their own pulse rate recordings using hand held data loggers, these allow the students to measure their pulse rate accurately and instantly. This will be followed up with the students developing their own project ideas and being given the opportunity to work further with pulse rate.

During the lab and fieldwork sessions I would like to make video recordings and still photographs of the process, for evaluation and analysis purposes, which will hopefully be used in academic presentations and publications. This will form part of my PhD, which is funded by Great Western Research in collaboration with the Universities of Bath and Bristol and ScienceScope. The aim of my research is to investigate the effects of hand held data loggers on student's learning and motivation. I do this by working with teachers, students and product designers, by working with a range of people I can feedback my findings effectively and work within appropriate areas of the curriculum, ensuring that students benefit from my studies.

Please could you complete the form below to indicate whether you are willing for your child to take part in this event and to give permission for any images which include your child to be used as described, and return to ****. Please be assured that confidentiality and anonymity of your child would be maintained, since we do not under any circumstances issue names or other details of children to anyone outside of this project.

If you have any questions or concerns, please do not hesitate to contact me, Susanna Martin, by post or phone via the Department, or by email S.M.Martin@bath.ac.uk

Thank you.

Susanna Martin
PhD Research Student
Department of Psychology
University of Bath

Dr Danaë Stanton Fraser,
Reader,
Department of Psychology,
University of Bath
(Supervisor)

Dr Dawn Woodgate
Research Fellow,
Department of Psychology,
University of Bath
(Supervisor)

Figure D.1: Consent Form Technology vs Traditional

E Ownership and Technology

Dear Parent / Carer,

For the remainder of the school year we have invited researchers from Bath University, Ms Susanna Martin and Dr Danaë Stanton Fraser, to work with us on developing our science lessons through the use of technology. The researchers will be observing and taking part in a number of your child's science classes as well as bringing in some newly developed technology. This is an exciting opportunity for our school to help shape future technology and to give feedback on our experiences.

As part of the research process it would be useful for the researchers to be able to video certain lessons to allow other team members to review the lessons. These video tapes would primarily be used for evaluation and analysis purposes, but also possibly for use in academic presentations and publications.

The researchers would also like to use the student's end of module assessment scores and their responses to a motivation questionnaire designed by the researchers, to analyse the effect the technology has upon the students. This data will be completely anonymous.

Please would you complete the form below to indicate whether you are willing to give permission for any images which include your child to be used as described, and return to me. Please also indicate if you are willing to allow access to your child's module assessments. Please be assured that confidentiality and anonymity of your child would be maintained. If you decline to give consent your child will still take part in the class but data will not be collected about your child.

Thank you.

*****

If you have any questions or concerns, please feel free to contact Susanna Martin by post or phone via the Department, or by email S.M.Martin@bath.ac.uk

Susanna Martin
PhD Research Student
Department of Psychology
University of Bath

Dr Danaë Stanton Fraser,
Reader,
Department of Psychology,
University of Bath
(Supervisor)

Further information regarding this research can be provided, please indicate on the form if you would like to know more.

Figure E.1: Consent Form Ownership and Technology

Part X

Appendix B - Experiment Materials

F Ownership and Automation

F.1 Example SAT papers

A number of papers were evaluated for relevant questions, the following is a list of the papers used to inform the pre and post test questions.

- 2003 Paper One
- 2003 Paper Two
- 2004 Paper One
- 2004 Paper Two
- 2005 Paper One
- 2005 Paper Two
- 2006 Paper One
- 2006 Paper Two
- 2007 Paper One
- 2007 Paper Two

F.2 Timetable of Events

Stage	Time	Who	Activities
Session One **09:45-10:45**	20 mins	All Students	Students are placed in pairs/groups and introduced to the concept of sound and the experiment,
	25 Mins	All Students	Complete the pre-test and the hypotheses section of the workbook
	15 Mins	1,3,5,	Students collect data from Pond
		7,9,11	Students collect data from Construction
		13,15,17	Students collect data from field
		2,4,6,8,10,12,14,16,18	Sound in the Lab
		1,3,5,7,9,11,13,15,17	Return Loggers
Break **10:45-11:00**	15 Mins	All Students	Break
Session Two **11:00-12:45**	15 mins	1&2, 3&4, 5&6, 7&8, 9&10, 11&12, 13&14, 15&16, 17&18	Spend Time discussing with pair + observation section of workbook
	45 mins	1, 7, 13	Upload own Data followed by Teacher Data
		2, 8, 14	Upload Teacher Data followed by Partner Data
		3&4, 9&10, 15&16	Draw Graph for Own and Teacher Data
		5&6, 11&12, 17&18	Look at Graphs for Own and Teacher Data.
	45 Mins	All students	Work on Poster
Lunch **12:45-13:30**	45 Mins	All Students	
Session Three **13:30-14:45**	45 Mins	All Students	Students work through the work book and post test
	30 Mins	All Students	Work on Poster
Finish **14:45-15:00**	15 Mins	All Students	Pack up and leave

Figure F.1: Timetable of Events

F.3 Workbook

Name____________________ Number_______________

Age _____________________ Gender_______________

Measuring Sound and Producing Graphs

Sound is part of our natural environment

How we experience a location can be heavily influenced by the sounds that are present at the time. A location that appears scenic and calm can actually be loud from people or from other sounds such as construction work.

Remember!!

There are no right or wrong answers.

Where possible please explain the choices that you make

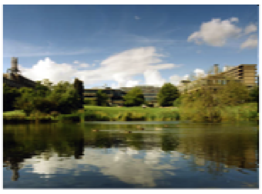
If you need more space or want to explain further please use the back page or ask for paper.

Comparing Sound across Locations

In this task you will be looking at sound recordings from two different locations across the campus.

Location A: Construction Site

Location B: The Pond



Below is a space for you to make predictions about each location.

Consider :

How loud/quiet you think places will be.

What you think the graphs will look like

any other important differences and similarities

My Predictions…

I predict that

____
____
____
____
____

I think this because

____
____
____
____
____
____

Observations

In this section please record any observations that you have for the location you have visited. Remember you're going to talk to the student(s) in your group so consider if you thought it was loud or quiet, were there many people? Was there anything unexpected?

Observations________________________________

If you think of anything else after talking to your partner please jot it down here.

Observations________________________________

Location A

Consider your graph for Location A

At what time was it loudest?
____

How loud was it?____

At what time was it quietest?___________________________________

How quiet was it?____

How loud was it when the recording started?_____________________________

How loud was it when the recording stopped?____________________________

Was the graph what you expected? Explain your answer

____
____
____
____
____
____
____

What observations can you make about the data?

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

Stick your graph here

Location B

Consider your graph for Location B

At what time was it loudest?

____

How loud was it?____

At what time was it quietest?___________________________________

How quiet was it?____

How loud was it when the recording started?_______________________________

How loud was it when the recording stopped?_____________________________

Was the graph what you expected? Explain your answer

____
____
____
____
____
____
____

What observations can you make about the data?

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

Stick your graph here

Any further comments about any of the graphs?

Conclusions

Which location was loudest?____

Which location was quietest?____

Consider your hpredictions, are the results how you expected?

Do you think this was a fair test? Please explain your answer

If you were to do this again what would you change?

What outcomes would you expect from making these changes?

You and Your Graphs

Which set of data did you feel more comfortable working with?

Location A | Location B | No Difference

Please explain your choice

____
____
____
____
____
____
____
____
____
____
____

Which set of data do you feel you can explain better?

Location A | Location B | No Difference

Please explain your choice

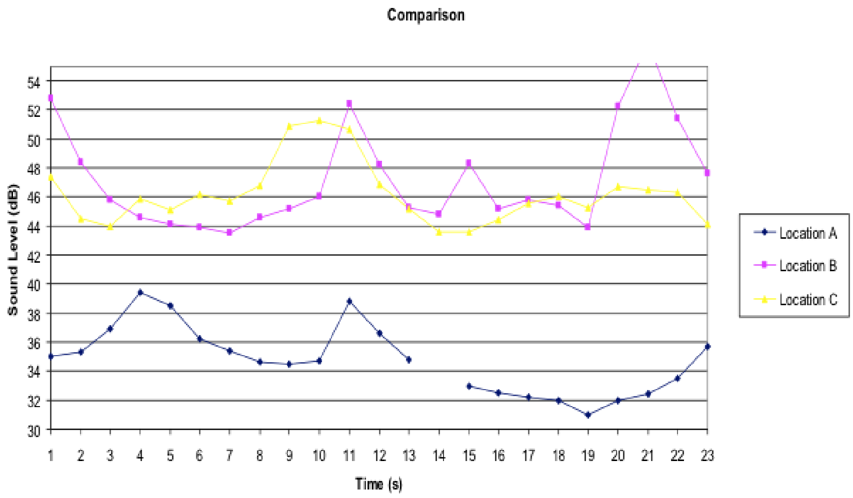
____
____
____
____
____
____
____
____
____
____
____

F.4 Pre/Post Test Example

Exercise Three

- Please answer the following questions to the best of your ability without talking to other people in your class.
- There are no right or wrong answers.
- Where possible please explain the choices that you make
- If you need more space or what to explain further please use the back page or ask for paper.

Question One



a) Which location was the quietest?

Location A Location B Location C

b) What was the sound level at each location when the time was 10s?

Location A ____________
Location B ____________
Location C ____________

c) Data was lost for 14s for location A please consider whether:
   a) The data should go in one place (mark where)
   b) The data could go in a range of places (mark the area)
   c) The data should not be ‘replaced’

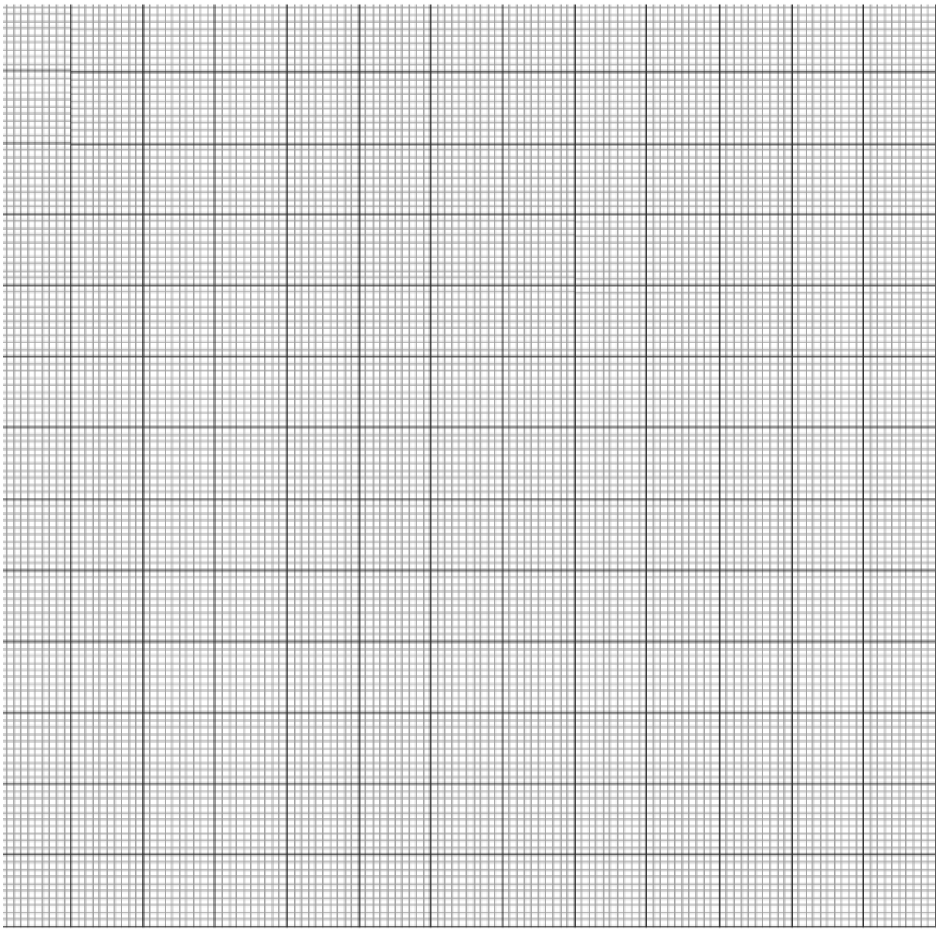
d) If you picked a or b above then please remember to mark on the graph where you think it should be.

e) Please explain your choice for question c

Question Two

Please plot the data points from the table and draw a line of best fit on the graph

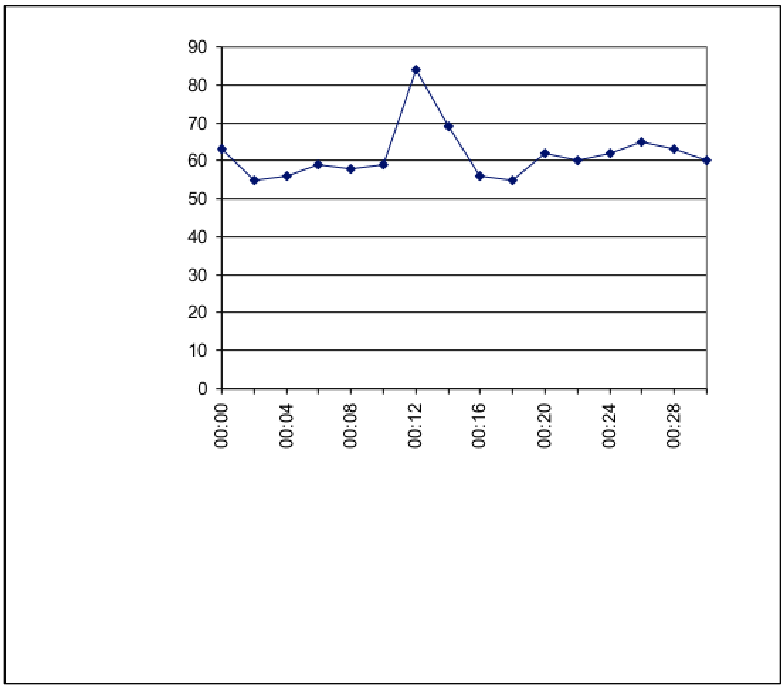
Time (Seconds)	00:00	00:02	00:04	00:06	00:08	00:10	00:12	00:14	00:16	00:18	00:20
Sound (dB)	60	61	62	64	65	66	68	67	69	69	70



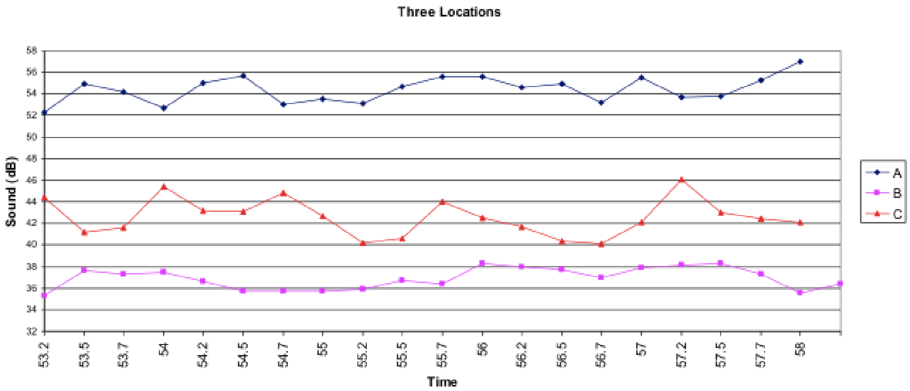
Question Three

Below is a graph showing how sound levels change over time, measured in decibels (dB).
Please label the axis and give the graph an appropriate title.

Title:____
____
____



Question Four



James needs to label his graph with each location but he has forgotten which graph is which.

He visited:

1) The Lab when it was empty

2) The Field

3) The Construction Site

Using your understanding of sound can you work out which graph fits which location best, circle below.

Graph A is location 1 2 3

Graph B is location 1 2 3

Graph C is location 1 2 3

You and Your Graphs

Please answer the following questions on a scale 1 to 5

1-Strongly Agree
2-Agree
3-Neither Agree nor Disagree
4-Disagree
5-Strongly Disagree

Then please explain your reasoning

I like working with data that I have collected 1 2 3 4 5

____
____
____
____

I find it useful to draw a graph by hand 1 2 3 4 5

____
____
____
____

I enjoy using computers to draw graphs 1 2 3 4 5

____
____
____
____

My understanding of a graph is better if I have drawn it myself
1 2 3 4 5

____
____
____
____

My understanding of a graph is better if someone else has drawn it
1 2 3 4 5

____
____
____
____

I think collecting data myself is a waste of time 1 2 3 4 5

____
____
____
____

F.5 Help Sheets

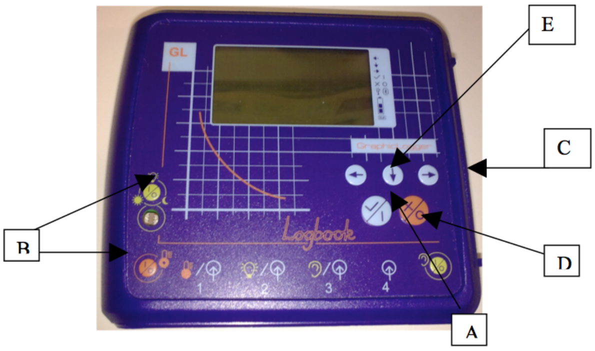
Using a datalogger

DATA COLLECTION

Remember stay quiet while you are recording

Choose an interesting graph to record

Try and think about where you are so you can make notes when you're back in the classroom



1) Switch the logger on using the tick button (A)

2) Press the yellow light and red temperature buttons to toggle between what is shown (B).You only want to see details about the sound level.

3) Press the right arrow to go to live graphs. (C)

4) Then press the tick to start the roll capture (A)

5) Once the graph fills up the whole screen you can choose to record what is on the screen by pressing the tick button (A).

6) You then need to press the cross button (D) Followed by the tick button (A)

7) You can then take further recordings. You can take up to 8 recordings.

8) When you have taken all the recordings you want press the down arrow twice (E)

9) Then press the Right arrow to chose which file

10) To look at a file press the tick

11) Press the cross button (D) to switch off.

Using the Graph Software

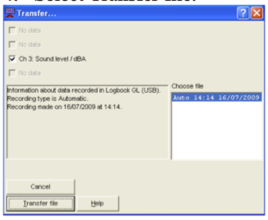
GRAPH PRODUCTION

1. Connect the datalogger to the computer using the USB cable

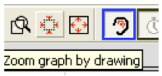
2. Open up DATADISC PT on the desktop

3. Select the FILE menu, then TRANSFER

4. Select Transfer file.



5. You can then play around with the graph, try resizing it using the zoom functions.



6. When you are happy with your graph you can save and print it.

SAVING

1. Choose File, then Save As
2. Press My Computer and then choose the H Drive (Homes)
3. Open the Dos Folder and then the Science and Graph Folder
4. Save your file in today's folder.
5. Name your file "Student __ Location__" with your student number and the location of A or B for the file.

PRINTING

1. Choose File, then Print.
2. You will see a window pop up, deselect the Information box so it looks like the box below.

3. Select OK

G Technology in the Classroom

G.1 Example Exam Papers

Exam Board	Year	Subject	Question Type	Question	Reason
AQA	2006-2008	Biology	ISA B1.2	1	Methodology
			ISA B1/Specimen	1	Methodology
			ISA B1/Fieldwork	1	Methodology
		Physics	ISA P3.3	1	Methodology
				8	Data Handling
				12	Methodology
		Chemistry	ISA C2/Specimen	1	Methodology
OCR	2006	Research Study	Coursework Coversheet		Coursework Require-ments

Table G.1: Sources of information for design of Technology vs Traditional experiment.

G.2 Timetable of Events

Start Time	End Time	Length	Task	Details
09.15	09.20	5 mins	Getting settled	
09:20	09.30	10 mins	Intro to the day	Group the students
09.30	10.00	30 mins	Pre Test	Completed on the computer, paper versions as back up.
10.00	10.25	25 mins	Stage One	Students are given the workbooks
				Students are shown how to calculate their pulse rate (5 mins).
				Students then calculate their pulse rates (10 mins)
				Students report results in workbook (5 mins)
10.25	10.45	20 mins	Stage Two-Planning	Students spend 20 mins planning, discussing and writing up their intentions
10:45	11:05	20 mins	BREAK	
11:05	11:45	40 mins	Stage Two-Doing	Students are given 30 mins to complete their experiment. 10 mins extra for any issues
11:45	12.05	20 mins	Stage Three-Results	Students are provided with additional data, and are given the chance to combine it with their data
12:05	12:35	20 mins	Stage Four-Analysis	Students complete the final section of the work book.
12.35	13.25	50 mins	LUNCH	
13.25	14.15	50 mins	60 Second Scientist	Students are placed into 4 groups. Two groups who data logged, two who pulse rated. (groups of 3 pairs, and 2 pairs)
				Students are given access to Photo Story and digital cameras.
				Encouraged to spend 15 mins planning, 15 mins shooting, and 20 mins putting it together.
14.15	14.45	30 mins	Post Test	Completed on the computer, paper versions as back up.
14.45	14.55	10 mins	Review videos	Watch the four completed videos.
14.55	15.10	15 mins	Debrief and questions	

Figure G.1: Timetable of Events

G.3 Workbook

Name______________________________ Age____________
Team Name_________________________ Male/Female

Investigation into Pulse Rate and Exercise

Everybody needs oxygen, we need it to breathe and we also need it to allow our muscles to work. The heart acts like a pump to push oxygenated blood around the body. You can tell how fast your heart is working by counting the number of beats per minute (BPM). A good measure of heart rate is by feeling your pulse in your wrist.
The average adult heart has a pulse rate of 60-100 BPM. Athletes often have a lower pulse rate sometimes in the range 30-45 BPM.

Stage One-Resting pulse rate
Using the help sheet record your resting pulse rate.
You have 10 minutes to do this, I recommend you try and take your pulse rate more than once.

In the space below please record your pulse rate:

I found my resting pulse rate **by hand/using a data logger** I tested my resting pulse rate ....times and found the following results:

Time One..........................Time Two.........................Time Three....................Time Four......................

On average my resting pulse was......................

On average my partners resting pulse was.................

Use the space below for any calculations/comments that you wish to make.

Stage Two-Thinking about exercise

You are going to have 15 minutes to test the effect of exercise on your pulse rate. There are a number of things to consider when planning your experiment;

- Do you want to repeat your measurements?
- How long will you exercise for?
- What kind of exercise will you do?

Remember you are in a class room so it needs to be sensible, you could consider; push ups, jogging on the spot, sit ups.

In the space below please write a brief section on how you are going to test the effect of exercise on your pulse rate. Include details on the **type of exercise** you will do, **how long you will exercise for** and **whether you will repeat the test**. Please finish the section by **making a prediction** about what will happen.

I am going to test the effect of exercise on pulse rate by ....

I predict that following ....minutes of exercise pulse rate will ....

Stage Three-Reporting the Results

In the space below please record your results, you might find this easiest in a table. Remember to include details of the factors you have changed (type of exercise, how long you have exercised for, how many times you repeated the experiment.) You might want to discuss your results with your partner and consider including their results in your table.

The table below shows the results collected by me and my partner.

Stage Four-Conclusion and Improvements
Please complete the following section and answer the questions to the best of your ability. If you are unsure then put your hand up and ask.

Conclusion:

I tested the effect of exercise on pulse rate by
....
....
....

My results showed
....
....
....
....

If I could do this again I would change
....
....
....
....

Do you think that you have enough data to make a conclusion?
Draw a ring your answer.

Yes/No

Use your data to explain your answer
....
....
....
....

G.4 Pre/Post test Questions

Name__________________________ **Male/Female**
Age____________ **ID Number**_____

Section One
These questions are about an investigation into the lung capacity of four 15 year olds. It was carried out by Lucy. Read Lucy's report, look at the table of data and then answer the questions that follow.

"I wanted to look at whether boys and girls had different lung capacities. I asked two girls and two boys to blow into a spirometer. I predict that boys will have a greater lung capacity than girls; this is because boys are normally bigger than girls so I think they will also have larger lungs. I measured four people at the same time after lunch for three days. Here are my results."

	Lung Capacity (Litre/Minute)			
	Day One	**Day Two**	**Day Three**	**Average**
Girl One	380	400	390	390
Girl Two	400	420	410	410
Boy One	480	500	460	480
Boy Two	520	540	440	500
Girl Total (Average)	***390***	***410***	***400***	***400***
Boy Total (Average)	***500***	***520***	***450***	***490***

Please answer the following questions to the best of your ability. After each question please indicate how confident you are in your answer.

1) Is there any evidence to suggest that Lucy's prediction is correct, and the boys have a greater lung capacity than girls?
   a. Yes/No
   b. Explain your answer.
   ____
   ____
   ____

I am certain that I am correct I think I am correct I am really not sure

2) What was the range of Lung Capacity for the boys?
   a. The range was from.......... to...............

I am certain that I am correct I think I am correct I am really not sure

3) What other factors might affect someone's lung capacity? Tick any factors which you believe apply
   a. Height
   b. Weight
   c. Age
   d. Hair Colour
   e. Amount of exercise
   f. Eye Colour

I am certain that I am correct I think I am correct I am really not sure

4) Lucy tested two boys and two girls. Do you think this is a good number of people to test?
   a. Yes
   b. No she should have tested more
   c. No she should have tested less

I am certain that I am correct I think I am correct I am really not sure

5) Did Lucy carry out a fair test?
   a. Yes/No
   b. Explain your answer.
   ____
   ____
   ____

I am certain that I am correct I think I am correct I am really not sure

Section Two
Your heart continually pumps blood around your body. It is possible to measure how fast this is happening by taking your pulse rate. You can take your pulse rate manually by placing your first two fingers on your risk and counting the number of beats in a minute. Modern technology means we can also take our pulse rate using data loggers. Please answer the questions below to the best of your ability. After each question please indicate how confident you are in your answer.

1) What is the average heart rate for a healthy adult?
   a. 120to 180 beats per minute
   b. 100 to 140 beats per minute
   c. 60 to 100 beats per minute
   d. 20 to 80 beats per minute

I am certain that I am correct I think I am correct I am really not sure

2) Do you think boys and girls will have a different average heart rate?
   a. Yes boys will have a faster heart rate
   b. Yes girls will have a faster heart rate
   c. No there will be no difference between their heart rates

I am certain that I am correct I think I am correct I am really not sure

3) Which do you think will be more accurate for measuring your pulse rate?
   a. By hand
   b. Using a Data Logger

I am certain that I am correct I think I am correct I am really not sure

4) Do you think doing exercise will affect your pulse rate?
   a. No-My pulse rate would stay the same
   b. Yes- My pulse rate would increase
   c. Yes- My pulse rate would decrease

I am certain that I am correct I think I am correct I am really not sure

5) Do you think your pulse rate stays consistent?
   a. Yes, I think if I repeatedly measured my pulse rate it would be the same
   b. No, I think if I repeatedly measured my pulse rate it would have changed
   c. I think it might depend upon the person

I am certain that I am correct I think I am correct I am really not sure

Section Three-Motivation Questions
Please answer the following questions on a scale of 1-5.

1-Strongly Agree
2-Agree
3-Neither Agree nor Disagree
4-Disagree
5-Strongly Disagree

1) I like working with data that I have collected.
1 2 3 4 5

2) I do not find it useful to do an experiment myself.
1 2 3 4 5

3) I enjoy using technology to learn.
1 2 3 4 5

4) My understanding of an idea is better if I can try it out myself.
1 2 3 4 5

5) My understanding of an idea is better if someone tells me about it.
1 2 3 4 5

6) I think collecting data by hand is a waste of time.
1 2 3 4 5

7) I prefer to do something myself rather than use a computer.
1 2 3 4 5

8) Having technology makes my life easier.
1 2 3 4 5

9) I think data collected using special equipment is more accurate.
1 2 3 4 5

G.5 Help Sheets

Using a datalogger

Finding Your Pulse Rate Using A Datalogger

This is a Datalogger with a pulse rate sensor attached.

1. Turn the Datalogger on by pressing the blue button with a tick on (See Diagram 1).

2. Press the three smaller buttons (See Diagram 1) this turns off the sound, light and temperature sensors.

3. Place the pulse sensor on your index finger. (See Diagram 2)

4. Watch how your pulse rate changes on the screen, it can take a while to settle. (See Diagram 3)

5. The average pulse rate is 60-100 beats per minute (bpm).

Sound, light and temperature sensor buttons

On/Off Button

Figure 1-Datalogger Buttons

Figure 2-Pulse Rate Sensor

Your pulse rate, showing beats per minute.

Figure 3-Pulse Rate Display

Pulse by hand

Calculating Your Pulse Rate By Hand

1. Place the tips of your index, second, and third fingers on the palm side of your other wrist, below the base of the thumb.

2. Press lightly with your fingers until you feel the blood pulsing beneath your fingers. You might need to move your fingers around slightly up or down until you feel the pulsing.

3. Use a watch with a second hand, or look at a clock with a second hand.

4. Count the beats you feel for 10 seconds. Multiply this number by six to get your heart rate (pulse) per minute.

5. Calculate your pulse: _______________ x 6 = ________________
(beats in 10 seconds) *(your pulse)*

The average pulse rate is between 60-100 beats per minute (bpm).

Making your 60-Second Movie

Step 1: Preparing your storyboard.

Your storyboard is like a guide to help you decide what you want to say and how you want to say it. It also helps you when you are shooting your film.

- What is your message?
- Who is it for?
- What is the style of your film?

Keep your camera shoots simple - hold your camera steady. Collect a mix of different shoots and angles – close ups and far away.

Step 2: Shooting your film

Using your storyboard as your guide, begin to shoot your film. Think about what images you need to shoot to express your idea. If you need to stage any shoots and need props - make sure you have everything nearby before you start shooting. Think about open shoot and how it can help you set the scene. Take different versions of your image - take your image close up, at a distance, at different angles. Close with a shot which helps to summarise your ideas

Step 3: Edit your film

Make a folder on your desktop and label it – save all the images you have taken on your digital camera into this folder. Go though all your pictures – decide which images you want to use. Label the images you want to use-so that you can easily find them

Create the story flow in Photostory/Powerpoint- arrange your pictures in the order that best tells your story. Think about each image as a 'scene' and what it 'says' about your idea. Add effects to your movie.

Step 4: Save and Submit

- Every time you make a change to your movie save it

Additional Data

Additional Data

If you have had problems collecting your own data, or would like to include extra data into your results then the tables below show some data previously collected.

The students allowed their pulse rate to return to normal before they started the exercise again to repeat the test.

Fifty jumps on the spot							
		Resting Pulse Rate			*Pulse Rate after Exercise*		
Name	***Age***	***Time One***	***Time Two***	***Time Three***	***Time One***	***Time Two***	***Time Three***
Sarah	***15***	86	91	87	110	115	120
Marie	***14***	85	95	92	125	127	130
James	***14***	77	80	83	95	115	123
Tom	***15***	65	68	70	100	107	109

One minute running on the spot							
		Resting Pulse Rate			*Pulse Rate after Exercise*		
Name	***Age***	***Time One***	***Time Two***	***Time Three***	***Time One***	***Time Two***	***Time Three***
Alice	***14***	87	85	91	130	137	135
Kate	***15***	67	70	75	140	124	130
Ben	***14***	85	80	89	110	93	112
Dave	***15***	85	88	90	125	137	129

Thirty star jumps							
		Resting Pulse Rate			*Pulse Rate after Exercise*		
Name	***Age***	***Time One***	***Time Two***	***Time Three***	***Time One***	***Time Two***	***Time Three***
Jenny	***14***	83	80	81	112	120	115
Claire	***15***	77	70	72	130	116	127
Adam	***15***	84	85	87	105	111	98
Matt	***14***	75	80	70	95	113	116

Twenty-five sit ups							
		Resting Pulse Rate			*Pulse Rate after Exercise*		
Name	***Age***	***Time One***	***Time Two***	***Time Three***	***Time One***	***Time Two***	***Time Three***
Emma	***14***	90	92	95	100	103	106
Amy	***15***	63	77	68	99	105	117
Andy	***15***	75	78	72	105	98	115
Dan	***14***	90	93	92	130	125	126

H Ownership and Technology

H.1 Timetable of Events

Module	Intervention	Lesson	Date
Module One - Compounds and Mixtures	No	1	23rd March
		2	28th March
		3	29th March
		4	30th March
		5 - Test	1st April
Module Two - Materials and Recycling	Camera	6	6th April
		7	26th April
		8	27th April
		9	4th May
		10 - Test	9th May
Module Three - Sound	Camera & datalogger	11	10th May
		12	11th May
		13	13th May
		Teacher Away	18th May
		14	23rd May
		15 - Test	24th May
Module Four - Light	No	16	25th May
		Teacher Away	27th May
		17	8th June
		Researcher Away	13th June
		Researcher Away	14th June
		Researcher Away	15th June
		Researcher Away	17th June
		18	22nd June
		19	27th June
		20 - Test	28th June
Module Five - Changes of State	Camera	21	29th June
		22	1st July
		23	6th July
		24 - Test	11th July
Module Six - Forces and Transport	Camera & datalogger	25	12th July
		Sports Day	13th July
		26	15th July
		Teacher Away	20th July

Table H.1: Table showing lessons conducted with regard to date

H.2 Motivation Questionnaire

Name____________________

End of Topic Feedback:
Please tick in the boxes to show how you feel about each statement.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I like working with data that I have collected	☐	☐	☐	☐	☐
I do not find it useful to do an experiment myself	☐	☐	☐	☐	☐
I enjoy using technology to learn	☐	☐	☐	☐	☐
My understanding is better if I can try it out myself	☐	☐	☐	☐	☐
I worked hard in this module	☐	☐	☐	☐	☐
I think collecting data by hand is a waste of time	☐	☐	☐	☐	☐
If I understand the method then I can explain my results better	☐	☐	☐	☐	☐
Having technology makes my life easier	☐	☐	☐	☐	☐
I think data collected using specially designed equipment is more accurate	☐	☐	☐	☐	☐
I would like to do less science	☐	☐	☐	☐	☐
I enjoyed this module	☐	☐	☐	☐	☐
I would like to do more experiments	☐	☐	☐	☐	☐

Figure H.1: Example Motivation Questionnaire

Part XI

Appendix C - Results Tables

I Ownership and Automation

I.1 Accuracy

Question One				
	df	Mean Square	F	Sig.
Collection	1	.467	.151	.700
Presentation	2	3.141	1.014	.374

Question Two				
	df	Mean Square	F	Sig.
Collection	1	.402	.061	.807
Presentation	2	3.063	.463	.633

Question Three				
	df	Mean Square	F	Sig.
Collection	1	1.736	.799	.378
Presentation	2	6.891	3.174	0.55

Question Four				
	df	Mean Square	F	Sig.
Collection	1	2.143	1.811	.188
Presentation	2	.456	.386	.683

Table I.1: Pre Test analysis

		Question One		Question Two		Question Three		Question Four	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Collection	Total	5.68	5.57	6.21	5.3	7.82	7.26	2.39	2.16
	Self	5.58	5.52	6.26	4.82	8.00	7.05	2.15	2.42
	Peer	5.57	5.63	6.15	5.74	7.63	7.47	2.63	1.89
Production	Software	5.57	5.93	5.71	5.38	7.92	7.31	2.5	2.14
	PreProduced	5.25	4.75	6.67	4.92	7.00	6.91	2.5	2.41
	Manual	6.25	6.00	6.33	5.64	8.5	7.60	2.16	1.92

Table I.2: Mean scores pre and post test

I.2 Motivation

			I like working with data that I have collected	I think collecting data by hand is a waste of time	I enjoy using computers to draw a graph by hand
Collection	Self	Z	-2.460*	-1.155	-.413
		Asymp. Sig. (2-tailed)	.014*	.248	.666
	Peer	Z	-.372	-1.319	-.333
		Asymp. Sig. (2-tailed)	.710	.187	.739
Presentation	Software	Z	-.107	.000	-1.190
		Asymp. Sig. (2-tailed)	.915	1.000	.234
	Pre-Produced	Z	-1.081	-2.041*	.000
		Asymp. Sig. (2-tailed)	.279	.041*	1.000
	Manual	Z	-1.342	-1.300	-1.342
		Asymp. Sig. (2-tailed)	.180	.194	.180

*Significant at 0.05 level

Table I.3: Wilcoxon analysis of motivation questions

J Technology vs Traditional

J.1 60 Second Scientist

4 videos were made by adding text to photographs,

Blue Team:

Produced a video which explained their day, they included comedy by inserting a picture of a monster part way through. They also added humour when asking a girl to jump and then saying higher, higher. The blue team used the datalogger in their video.

Yellow Team:

Posited the question 'I wonder what will happen if I exercise'. They produced a more technical video by including short movie clips which repeated. For instance someone running up the stairs multiple times. This also suggested humour as did the wording 'sweaty betty' they concluded 'whoa it's increased' They didn't mention the dataloggers.

Green Team:

Told the story of their research about finding the impact of exercise on bpm. As with the others they used humour, 'he's running, still running' 'Alex is very lazy'.

Red Team:

Produced a 'how to' film, showing how to take a pulse by hand, using a datalogger, they also showed how to increase your bpm with exercise, and used computer tools to combine two images, such as a picture of the body overlaid on a student.

J.2 Accuracy

Paired Samples T Test for combined score from questions two, three and six (graded out of 9).

	Mean Pre	Mean Post	t	df	Sig
Overall	7.05	7.50	-1.193	17	.249
Manual	6.66	7.1	-1.00	8	.347
Datalogger	7.44	7.88	-.710	8	.498

Table J.1: Paired Samples T Test Results

Paired Samples for change in response.

Section	Question	Overall	Manual	datalogging
Section A- Conceptual Knowledge	Question One - asked the students to assess someone else's data interpretation	p= 0.317	p= 0.317	p= 1.00
	Question Two - asked the students to read specific values from the table	p= 0.46	p= 0.782	p= .50
	Question Three - asked the students to select possible factors	p= 1.00	p= 1.00	p= 1.00
	Question Four - asked the students whether four was a valid number of people to test	p= .317	p= 1.00	p= .564
	Question Five - asked the students whether the experiment had been a fair test	p= 0.046*	p=1.00	p=0.564
Section B- Domain Knowledge	Question Six - asked the students to pick s the correct resting heart rate value	P= 0.655	p= .157	p= .564
	Question Seven - asked the students about the effect of gender on pulse rate	p= 0.470	p= .317	p= .785
	Question Eight - asked the students about datalogger accuracy	p= .083	p= .317	p= .157
	Question Nine - asked the students about the effect of exercise	NA**	NA**	NA**
	Question Ten - asked the students about how consistent pulse rate was	p= 0.102	p=.18	p= .317

*Further investigation indicates that four students changed their answer from no to yes: two students from each condition changed their mind. (Z=-2.00,)

**All the students reported the same answer pre and post-test indicating that this question had a ceiling effect

Table J.2: Accuracy results for Technology vs Traditional

J.3 Confidence

Frequencies

Question	Overall			Datalogger			Manual		
	Positive	Negative	None	Positive	Negative	None	Positive	Negative	None
One	2	1	15	1	1	7	1	0	8
Two	4	1	13	2	0	7	2	1	6
Three	2	2	14	1	1	7	1	1	7
Four	3	3	12	2	0	7	1	3	5
Five	1	3	14	0	2	7	1	1	7
Six	10	0	8	5	0	4	5	0	4
Seven	5	2	11	2	1	6	3	1	5
Eight	2	5	11	2	2	5	0	6	3
Nine	17	1	0	0	0	9	0	8	1
Ten	3	4	11	2	1	6	1	3	5
Overall in %	27	12	61	19	19	72	17	27	57

Table J.3: Frequency of changes in confidence

Paired Samples T-Test

	Pre Mean	Post Mean	t	df	sig. (2-tailed
Overall	14.66	14.55	.287	17	.777
Manual*	14.55	14.88	1.00	8	.347
datalogger	14.77	14.22	-.632	8	.545

*Students became more confident at post test

Table J.4: Paired T-Test results for summed confidence scores.

	Datalogger		Manual	
	z	Asymp. Sig. (2-tailed)	z	Asymp. Sig. (2-tailed)
Question One	-1.342	.180	-.447	.655
Question Two	-1.633	.102	-.378	.705
QuestionThree	-1.00	.316	.000	1.00
Question Four	-.577	.564	-2.000	.046*
Question Five	-1.732	.083	-2.236	.025*
Question Six	-1.342	.180	.000	1.00
Question Seven	-2.121	.034*	-2.333	.020*
Question Eight	-1.342	.180	-1.890	.059**
Question Nine	-2.00	.046*	-2.449	.014*
Question Ten	-.816	.414	-1.342	.180

*Significant at 0.05 level
**Nearing significance

Table J.5: Wilcoxon Test Results for pre and post confidence score

J.4 Motivation

		Datalogger		Manual	
		Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
Data Collection	I like working with data that I have collected	-2.126	0.033*	-1.342	.180
	I think collecting data by hand is a waste of time	-1.00	.317	-.632	.527
	I think data collected using special equipment is more accurate	-1.947	.052**	-1.00	.317
Technology	I enjoy using Technology to Learn	.000	1.000	-1.342	.180
	I prefer to do something myself rather than use a computer	-.816	.414	-.541	.589
	Having technology makes my life easier	.000	1.000	-1.00	.317
Hands-On	I do not find it useful to do an experiment myself	-1.807	.071	-1.633	.102
	My understanding of an idea is better if someone tells me about it	.000	1.000	.000	1.000
	If I understand the method then I can explain my results better	-1.508	.132	.000	1.000

*Significant at 0.05 level
**Nearing significance

Table J.6: Wilcoxon analysis of motivation questions

Table J.7: Motivation results for Ownership and Automation

Question	Overall	Manual	datalogging
I like working with data that I have collected	p= .012 (Z=2.157)*	p= 0.033 (Z=2.126)	p= .180
I do not find it useful to do an experiment myself.	p= .018	p= .102	p= .071
I enjoy using technology to learn	p= .739	p= .655	p= .317
My understanding of an idea is better if I can try it out myself	p= 1.00	p= 1.00	p= 1.00
My understanding of an idea is better if someone tells me about it.	p= .739	p= .317	p= .527
I think collecting data by hand is a waste of time.	p= .951	p= .589	p= .414
I prefer to do something myself rather than use a computer	p= .527	p= .317	p= 1.00
Having technology makes my life easier	p= .037 (Z= 2.081)**	p= .317	p= .052
I think data collected using special equipment is more accurate	p= .166	p= 1.00	p= .132
If I understand the method then I can explain my results better	p= .166	p= 1.00	p= .132

*With students becoming more positive at post test.

** Students tended to shift from Strongly Agree to Neither Agree nor Disagree. The datalogging group are nearing significance, indicating that experience with dataloggers has led them to believe that equipment is not always accurate.

Frequencies

Table J.8: Frequencies: I like working with data I have collected

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	0	2	0	1	0	1
Agree	7	10	3	6	4	4
Neither Agree nor Disagree	8	6	4	2	4	4
Disagree	2	0	1	0	1	0
Strongly Disagree	1	0	1	0	0	0

Table J.9: Frequencies: I do not find it useful to do an experiment myself

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	1	0	1	0	0	0
Agree	2	0	1	0	1	0
Neither Agree nor Disagree	4	3	1	1	3	2
Disagree	6	6	4	3	2	3
Strongly Disagree	5	9	2	5	3	4

Table J.10: Frequencies: I enjoy using technology to learn

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	4	4	3	3	1	1
Agree	11	8	4	4	7	4
Neither Agree nor Disagree	3	6	2	2	1	4
Disagree	0	0	0	0	0	0
Strongly Disagree	0	0	0	0	0	0

Table J.11: Frequencies: My understanding of an idea is better if I can try it out myself

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	8	7	4	5	4	2
Agree	6	9	4	4	2	5
Neither Agree nor Disagree	4	2	1	0	3	2
Disagree	0	0	0	0	0	0
Strongly Disagree	0	0	0	0	0	0

Table J.12: Frequencies: My understanding of an idea is better if someone tells me about it

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	3	1	1	0	2	1
Agree	6	8	4	6	2	2
Neither Agree nor Disagree	4	6	2	1	2	5
Disagree	4	2	2	2	2	0
Strongly Disagree	1	1	0	0	1	1

Table J.13: Frequencies: I think collecting data is a waste of time

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	0	1	0	1	0	0
Agree	3	0	1	0	2	0
Neither Agree nor Disagree	5	8	1	3	4	5
Disagree	7	7	6	4	1	3
Strongly Disagree	3	2	1	1	2	1

Table J.14: Frequencies: I prefer to do something myself rather than use a computer

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	2	2	2	2	0	0
Agree	2	3	0	1	2	2
Neither Agree nor Disagree	10	8	5	4	5	4
Disagree	2	3	0	1	2	2
Strongly Disagree	2	2	2	1	0	1

Table J.15: Frequencies: Having technology makes my life easier

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	8	8	3	3	5	5
Agree	6	4	3	3	3	1
Neither Agree nor Disagree	2	4	2	2	0	2
Disagree	2	2	1	1	1	1
Strongly Disagree	0	0	0	0	0	0

Table J.16: Frequencies: I think data collected using special equipment is more accurate

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	8	5	6	3	2	2
Agree	8	6	2	1	6	5
Neither Agree nor Disagree	2	6	1	4	1	2
Disagree	0	1	0	1	0	0
Strongly Disagree	0	0	0	0	0	0

Table J.17: Frequencies: If I understand the method the I can explain my results better

	Overall		datalogger		Manual	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Strongly Agree	8	8	4	3	4	5
Agree	10	5	5	2	5	3
Neither Agree nor Disagree	0	5	0	4	0	1
Disagree	0	0	0	0	0	0
Strongly Disagree	0	0	0	0	0	0

K Ownership and Technology

K.1 Assessment

Grade Translation Matrix

Test Result	Analysis Code
3b	1
3a	2
4c	3
4b	4
4a	5
5c	6
5b	7
5a	8
6c	9
6b	10
6a	11
7c	12
7b	13

Table K.1: Table showing how the student scores were scaled

K.2 Motivation

Motivation Questions	Averages			P
	Typical	Camera	Camera &Datalog	
I like working with data that I have collected.	3.58	3.73	3.78	.273
I do not find it useful to do an experiment myself.	1.85	2.33	2.90	.001*
I enjoy using technology to learn.	4.08	3.53	4.10	.002*
My understanding is better if I can try it out myself.	3.75	3.98	3.88	.442
I worked hard in this module.	3.76	3.8	3.75	.960
I think collecting data by hand is a waste of time.	2.82	2.88	2.85	.802
If I understand the method then I can explain my results better**	4.23	3.8	4.28	.039*
Having technology makes my life easier.**	3.76	4.00	3.98	.599
I think data collected using specially designed equipment is more accurate.	3.75	3.8	3.63	.186
I would like to do less science**	2.38	2.5	2.7	.360
I enjoyed this module.	3.33	3.03	3.18	.438
I would like to do more experiments**	4.55	4.1	4.68	.002*

*Significant Result.

**Greenhouse-Geisser correction employed.

Table K.2: Table of means and within factor ANOVA analysis results for student motivation

Question	Pair	Mean	t	significance
Q2 I **do not** find it useful to do an experiment myself	Typical Camera**	1.85 2.33	-1.81	.087
	Camera Datalog & Camera**	2.33 2.9	-2.71	0.14
	Typical Datalog & Camera**	1.85 2.9	-4.58	.000*
Q3 I enjoy using technology to learn	Typical* Camera	4.08 3.53	3.19	0.005*
	Camera Datalog & Camera**	3.53 4.1	-3.49	.003*
	Typical Datalog & Camera**	4.08 4.1	-.203	.841
Q10 If I understand the method then I can explain my results better	Typical** Camera	4.23 3.8	2.48	.023*
	Camera Datalog & Camera**	3.8 4.28	-2.65	.016*
	Typical Datalog & Camera**	4.23 4.28	-.462	.649
Q12 I would like to do more experiments	Typical** Camera	4.55 4.1	3.60	.002*
	Camera Datalog & Camera**	4.1 4.68	-3.81	.001*
	Typical Datalog & Camera**	4.55 4.68	-1.56	.135

*Significant result
**Greater Mean Score

Table K.3: Table of Paired Samples Scores

K.3 Photograph Statistics

Module	Number of Lesson	Number of Photographs	Relevant	Irrelevant	Faces and Friends
Module Two - Materials and Recycling	4	170	97	39	34
Module Three - Sound	4	177	84	40	53
Module Five - Heat Transfers	3	343	145	59	139
Module Six - Forces and Transport	2	133	79	29	25
Camera (Modules two and five)	7	513	242	98	173
Datalogger with Camera (Modules three and six)	6	310	163	69	78

Table K.4: Details of photographs taken by students

Table L. 1: **GCSE: River: Tape-1 Clip-1**

Time	Person	Statement	Comments
00:00:10	Teacher	right take that reading and then erm (unintelligible)	
00:00:15	Students		Students are talking but in the distance - can't hear them
00:01:00	Teacher	(student's name) take the samples where there (unintelligible)	
00:01:10	Students	you can have it back	
00:01:17	Students		Talking but unintelligible
00:01:19	Teacher	Can I just check with your log book thing, are you doing a new snapshot every time, but it says like one of 252, 2 of	
00:01:23	Students	yeah	
00:01:28	Teacher	2 of 252, 3, 4, etc because those guys went out and back into it and made another file, don't do that, do what you're doing	
00:01:30	Students		Talking but unintelligible
00:01:32	Teacher	yeah	
00:01:44		TAPE END	

Table L. 2: **GCSE: River: Tape-1 Clip-2**

Time	Person	Statement	Comments
00:00:00			short clip at distance of student carrying beaker to the river - not talking
00:00:19		TAPE END	

Table L. 3: **GCSE: River: Tape-1 Clip-3**

Time	Person	Statement	Comments
00:00:03	Teacher	Alright, there, press that down, ok press it again, and then you go back, if you press page on the right there then..	
00:00:23	Teacher and students		Talking but unintelligible
00:00:24	Teacher	health and safety	off camera talking to other students
00:00:28	Student	tell me when you press the button	
00:00:31	Student	it doesn't show the flow for the um, er	
00:00:33	Student	we get all (unintelligible)	
00:00:38	Student	does it have speed on this one? Like on (student's name) one	
00:00:42	Teacher	say what?	
00:00:44	Student	when we had the other one, this has temperature in degrees, and then dB, decibels	
00:00:49	Researcher	is it plugged in?	
00:00:51	Student	yes	
00:01:00	Teacher	it's not actually spinning though	
00:01:02	Other Teacher	Talking but unintelligible	off camera talking to other students
00:01:04	Teacher	turn it around, give it a bit of a twirl	
00:01:06	Student	is there anything tangled in there?	
00:01:07	Teacher	okay guys,	
00:01:12	Teacher	it should identify the device though	
00:01:14	Other Teacher	It might do it on switch on	not sure who he's talking to?
00:01:17	Teacher	yeah, is that turned off now?, right now	
00:01:20	Teacher	save the data and switch it off and on	
00:01:20	Student	the thing about these dataloggers is you switch them off and then on again and they are still connected	talking off camera - not involved on the bank
00:01:25	Other Teacher	it should say, it's got a memory	not sure who he's talking to?
00:01:26	Teacher	They have a memory to save it, that's brilliant isn't it	multiple conversations at this point

Continued on next page

Table L. 3 – *Continued from previous page*

Time	Person	Statement	Comments
00:01:33	Teacher	then just turn it off	
00:01:33	Teacher	is this, er, what they call	unintelligible - I think talking about the scum on the river
00:01:34	Student	primordial soup	
00:01:36	Student	do you not have it the other way around?	
00:01:40	Teacher	what makes them, can you eat them?	not sure who he's talking to?
00:01:52	Other teacher	The data logger has run out of battery	talking but unintelligible
00:01:57	Researcher	Oh right, I've got some more batteries	
00:02:00	Other teacher		Talking but unintelligible
00:02:02	Researcher	haven't they got things on the back of them that you?, I think you just...	
00:02:06	Other Teacher	but it will reset the timer	
00:02:09	Researcher	Oh, will it lose the data? I don't know whether it might lose the data	
00:02:15	Teachers		Talking but unintelligible
00:02:18	Student	we can unscrew it with a coin	
00:02:19	Student	yeah it's got gunk in, so if you can unscrew that	
00:02:23	Researcher	have you got, like a penny, or something?	
00:02:25	Teacher	lefty loosey	
00:02:28	Student	Use this	
00:02:42	Student	I don't know, use a key actually?	
00:02:43	Researcher	just mind you don't lose the white bit	
00:02:43	Student	Woah!	Student nearly drops keys
00:02:44	Researcher	or your keys in the water	
00:02:45	Student		Talking but unintelligible
00:02:49	Teacher	do you want me to hold that for you?	
00:02:51	Researcher	would it be easier if that red bit was kept still	lots of talking over each other here
00:02:53	Teacher	all your work, all your coursework	(talking about USB on the key ring)

Continued on next page

Table L. 3 – *Continued from previous page*

Time	Person	Statement	Comments
00:02:58	Student	too big	
00:03:03	Student	jeez it's tight	
00:03:05	Teacher	maybe you can pull it forward a bit and get out whatever's behind it?	
00:03:14	Researcher	yeah, I think this is what you had last year as well, when it ... , I'll bring it up with the guy that makes them, say they're not sturdy enough.	
00:03:19	Teacher	do you think it affected the rate?	
00:03:23	Researcher	I don't know, maybe the friction, but if it's stopping it from working then it's not a very good piece of equipment	
00:03:26	Teacher	it was still rotating wasn't it	
00:03:28	unclear	yeah but if you,,	not sure if this is two students or teacher and student
00:03:28	unclear	it's whether it slowed it down or not	
00:03:33	Researcher	they can just mention this in their coursework	
00:03:34	Student	shall I just unscrew	
00:03:40	Researcher	what are you doing, screwing up or screwing	
00:03:41	Researcher	If I hold that, and then you...	
00:03:43	Student	are you screwing it in or screwing it out?	
00:03:44	Teacher	screwing it up aren't you, lefty loosey	
00:03:50	Teacher	don't lose the screw	
00:03:55	Student	yeah that'll do	
00:04:02	Researcher	do you want me to hold something?	
00:04:10	Researcher	maybe we could hold the red thing against (...) would that work?	
00:04:14	Other Teacher	Right, this is all the trouble we had last year with this	
00:04:19	Other Teacher	well the ideal thing is, you don't do it over there	Students move out of river
00:04:23	Teacher	What's the problem?	
00:04:26	Student	it was a really thin piece of gunk	
00:04:27	Teacher	basically there's been no improvements in these since last year, because we had this trouble last year, we had two and they both ended up bust	

Continued on next page

Table L. 3 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:04:33	Teacher	you got something in there haven't you	
00:04:36	Teacher	anyone got a pin?	
00:04:49	Student	is it because they were made in Japan?	
00:04:51	Teacher	Japan's actually a very reliable place	
00:05:06	Teacher		Talking but unintelligible
00:05:15		TAPE END	

Table L. 4: **GCSE: River: Tape-1 Clip-4**

Time	Person	Statement	Comments
00:00:03	Student	yeah it's spinning now	
00:00:07	Teacher	it's not very fast is it	
00:00:12	Student		Talking but unintelligible
00:00:19	Student	some people trying to get a loan for 4000 or 4 million	Talking but unintelligible
00:00:21	Teacher	did you take a uni overdraft?	Talking but unintelligible
00:00:26	Student	it went on temp? (Talking but unintelligible)	
00:00:29	Teacher	now are we taking readings, is it now reading?	
00:00:30	Student	yeah	
00:00:31	Teacher	so you've switched it off and switched it on again?	
00:00:33	Student	shall I do it now, take a reading?	
00:00:35	Teacher	yeah, yeah, we're waiting, we're waiting	
00:00:36	Student	we've got to speed up now	
00:00:36	Student	overwrite all the system files, er yeah	
00:00:40	Student		Talking but unintelligible
00:00:41	Researcher	no that's okay that will be a really old one	
00:00:43	Teacher	there's only one or two files on there from today	
00:00:46	Teacher	I mean the thing is gentlemen, if it's gone pear shaped, it's only gone pear shaped on one reading, one site, we can easily come down to that site and it's not as if it's two miles along the river and we've got to hoof it along the river for two hours	
00:00:57		Tape ends	

Table L. 5: **GCSE: River: Tape-1 Clip-5**

Time	Person	Statement	Comments
00:00:04	Teacher	one I'm trying to do is remember where we were last year and take readings in the same place so we can actually build up data over the years on this river, and I think we went in just over this fence here, off down into it there, so we'll try and take a reading just here which is basically at the end of this wood, just there, then we're going to try and take...(student's name) walks his dog around here and he says there's a bridge, so we might take an extra reading at that bridge, and then we're going to go down to the Fosse Way, an old Roman road, it's just there, we're going to take a reading there, and then the footpath will veer away from the river, so what we'll do is we'll walk the footpath back to Brokenborough. So what we're going to do, is possibly two, well a reading here if we get it , might mean just one of you getting into the river, one by the bridge, an extra one from other years, but I think that's no harm, and then what we're going to do is veer away, oh sorry, walk around the river to the Fosse Way, take a reading, and then veer away, and our final will be at Brokenborough, now what's the time? What's the time?	
00:00:52	Other Teacher	five to eleven	
00:00:53	Teacher	five to eleven, so we've got about an hour an half, well about an hour and a quarter if you want (unintelligible)	
00:00:59	Student	why do we go back to the school at lunch?	
00:01:01	Teacher	yeah we're going back to the school at lunchtime yeah, and then you're going to load the data in, this afternoon, assuming we (tape ends)	
00:01:03		Tape Ends	

Table L. 6: **GCSE: River: Tape-1 Clip-6**

Time	Person	Statement	Comments
00:00:02	Teacher	stand on the bank, and see if it's any better there	
00:00:09	Teacher	who has got the other Garmin?	
00:00:14	Teacher	sorry what's the reading?	
00:00:15	Teacher	what's your accuracy?	
00:00:16	Student	It's got 4	
00:00:19	Teacher	oh that's fine	
00:00:23	Teacher	well we're in a very different part of the river so	
00:00:29	Teacher	er, photograph this part of the river	
00:00:30	Teacher	as opposed to damsel flies	
00:00:32	Teacher	yeah you don't want (unintelligible) (student's name) head	
00:00:38	Student		Talking but unintelligible
00:00:44	Student	look it's a heart	
00:00:44	Teacher	how do you get rid of the internal memory?	
00:00:50	Researcher	you only want to delete the ones not from this trip, though don't you?	
00:00:51	Teacher	well I dunno	
00:00:54	Teachers		Talking but unintelligible
00:00:59	Students		Talking but unintelligible
00:01:00	Student	has it run out of battery?	
00:01:01	Student	no, it's fine	
00:01:03	Student	we took a snap shot	
00:01:04	Teacher	you've done it? You've finished, yeah?	
00:01:15	Teacher and students		Talking but unintelligible - teacher is offering sweets around
00:01:22	Student	is this the only reason you've come?	to one of the teachers, about sweets
00:01:24	Teacher	I had no idea he had them	
00:01:33		TAPE END	

Table L. 7: **GCSE: River: Tape-1 Clip-7**

Time	Person	Statement	Comments
00:00:00	?		Talking but unintelligible
00:00:13	Teacher	in fairness the chicken wire would probably hold you alone	Talking about a bridge
00:00:17	Student	there's a dead bird here	
00:00:20	Student	oh! I'll have to take another sample	
00:00:27	Teacher	right Mr (teacher) if you move out the way I can get a decent shot	
00:00:32	Teacher	gentlemen, would it not be easier to ... , would it reach down from the middle of the bridge?	
00:00:34	Student	what bird is it?	
00:00:36	Teacher	yeah I know, but can you?	
00:00:37	Student	well, we'll try	
00:00:38	Teacher	so if you do that, you go off and do that over there okay	
00:00:40	Student		Talking but unintelligible
00:00:45	Student	it says 12 m	
00:00:46	Teacher	well what I'm saying	
00:00:47	Student	satellites	
00:00:49	Teacher	can you shove that in the middle?, someone actually lay down on there, just lay down on the bridge	
00:00:54	Teacher	you alright there?	
00:00:57	Teacher	don't drop them or	Talking but unintelligible
00:01:00	Student	no (student's name) is	
00:01:04	Teacher	that needs to be turned around the other way because the river is coming from behind	
00:01:09	Teacher	I've never really liked them I have to say	
00:01:12	Teacher	in fact you'll be doing an experiment on stinging nettles soon.	
00:01:15	Teacher	you've gotta admire them for their tenacity though	
00:01:21	Student	a friend of mine got stung by one yesterday	
00:01:23	Teacher	right that's good, that's it see	
00:01:24	Student	it's not spinning	
00:01:26	Teacher		Talking but unintelligible

Continued on next page

Table L. 7 – *Continued from previous page*

Time	Person	Statement	Comments
00:01:28	Teacher	well if you don't , try in the middle a bit more, move along	
00:01:34	Teacher	gentlemen, let me just tell you it's not going to collapse, I'm on it as well so if it goes I'll go with you	
00:01:39	Teacher and students		Talking but unintelligible
00:01:41	Teacher	spinning now?	
00:01:43	Teacher	there's two enormous tree trunks under there	
00:01:46	Student	I remember when I was about five	All talking at the same time
00:01:46	Teacher	so that's all it is two tree trunks, and then about 8 planks	All talking at the same time
00:01:47	Other Teacher	you can't get the temperature in, can you? Right we'll just have to leave the temperature, at this point, ok	All talking at the same time
00:01:54	Teacher	right, excellent, done, sorted	
00:01:57	Students		Talking but unintelligible
00:01:59		Tape End	

Table L. 8: **GCSE: River: Tape-1 Clip-8**

Time	Person	Statement	Comments
00:00:01	Students		Talking but unintelligible
00:00:05	Researcher	it get's a bit like that in Bath actually	
00:00:08	Teacher	does it?	
00:00:09	Researcher	yeah there's sirens going all the time	
00:00:10	Teacher	it can't be that dangerous	
00:00:12	Researcher	no I don't think it's dangerous, there just always seems to be sirens around	
00:00:19	Researcher	do you want to take a picture?	
00:00:26	Teacher	it's good, all these electric gadgets and nothing's got dropped in the river yet	
00:00:27	Researcher	don't say that! We'll drop them all in in a minute!	
00:00:30	Other Teacher	Garmin... is it working now?	Off camera
00:00:35	Teacher	gotta take a picture of the site have I?	
00:00:39	Other Teacher	stand here	
00:00:39	Students		Talking but unintelligible
00:00:42	Teacher and Students		Talking but unintelligible
00:00:50	Researcher	that will do I would have thought, it's just to give an idea of what it looked like	
00:00:57	Student	snapshot (...) of 455	
00:01:00	Students		Talking but unintelligible
00:01:13	Student	if we put it in there first	
00:01:15	Student	Woah, 1.4	
00:01:18	Teacher	that's very interesting there	
00:01:20	Teacher	what's happening to the dissolved oxygen here?	
00:01:22	Student	it's going lower and lower	
00:01:24	Teacher	that's because the turbulence is pulling the O2 into the water	
00:01:24	Student	it's going lower and lower as well	
00:01:28	Students		Talking but unintelligible
00:01:40	Students		Talking but unintelligible

Continued on next page

Table L. 8 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:01:54	Teacher		Talking but unintelligible
00:01:56	Students		Talking but unintelligible
00:02:00	Teacher	it's a bit strong ??	Talking but unintelligible
00:02:18	Student	it's 7? (Talking but unintelligible)	
00:02:23	Student	er I don't want to have, shit! Shit I swear I just got wet, er woah, just there, there's a little er...	
00:02:35	Student	wait!	
00:02:38	Students		Talking but unintelligible
00:02:47	Teacher	quite a speed there isn't it!	
00:02:47	Researcher	yeah, I'm avoiding that bit	
00:02:49	Teacher	how do you get round?	
00:02:50	Researcher	I think they went along, kind of through the middle but it's, er	
00:02:52	Teacher	Really?	
00:02:55	Teacher	would you save my life if I, er	
00:02:56	Researcher	no, I'd be too busy saving mine!	
00:03:07	Student	you've got have some on the other side as well	
00:03:10	Students		Talking but unintelligible
00:03:19	Student	should we go further?	
00:03:20	Researcher	I don't know how far you're supposed to go	
00:03:23	Student	woah, look at that turbine, that's flying	
00:03:30	Researcher	that's probably far enough because the others need to come and do all your points as well	
00:03:32	Teacher	yeah you're doing your readings a lot faster than them guys, because they've gotta wait a couple of minutes for each one, you've got the good job	
00:03:35	Student	so what now?	
00:03:47		Tape Ends	

Table L. 9: **GCSE: River: Tape-2 Clip-1**

Time	Person	Statement	Comments
00:00:12	Student	I know, it's a terrible noise isn't it	
00:00:16	Student	hello	Dogs turn up
00:00:25	Passer by	hello, sorry	
00:00:29			Talking but unintelligible
00:00:33	Passer by	come on girls, come on	
00:00:38	Teacher	guys, watch for splashes	
00:00:42	Passer by	I haven't got wellies on so I can't go and get them in	
00:00:48			Talking but unintelligible - Dogs are shaking themselves over people
00:00:50	Passer by	bye!	
00:00:54	Teacher	Right who gave me this (Talking but unintelligible) right here you go	
00:00:58	Teacher	you're looking after your equipment aren't you lads	
00:01:01	Teacher	right this'll be it folks because, um, it's got beware signs on it, beware strong currents, beware sudden drops it would be, um, not advisable for us to go in there	
00:01:10	Teacher	(student's name) look excited	
00:01:12	Teacher	that's fine you're not measureing turbidity are you	
00:01:17	Student	snapshot taken	
00:01:19	Teacher	have you been up there?	
00:01:20	Student	no,	
00:01:21	Teacher	well logically, I would have gone up stream and then down, not in the middle and then up and back down again, scientists yeah? You're looking at the stream down in logical progression never mind it's close enough that I dont think it'll make much difference	
00:01:39	Teacher	There's an argument you should go upstream, as you walk down you're gonna be ...	Talking but unintelligible

Continued on next page

Table L. 9 – *Continued from previous page*

Time	Person	Statement	Comments
00:01:42	Teacher	yeah but we're not measuring anything to do with sediment, you're measuring turbidity of the water	
00:01:53	Students		Talking but unintelligible
00:01:55	Teacher	guys	Talking but unintelligible
00:01:57	Teacher	come on, pull all that rubbish out	
00:01:59	Teacher	Come on let's have some focus please	
00:02:03	Student		Talking but unintelligible
00:02:08	Student	er, wow, shoot I've got water in my (...)	
00:02:10	Teacher	to be honest (student's name) it's your own fault, you've got a place to get in here and it's shallow there, so you've chosen to do that, let's have you going in the proper side shall we?	
00:02:19	Student	don't go in this side you almost...	
00:02:20	Teacher	(student's name) (student's name) (student's name) this side	
00:02:29	Student	it's a shame (student's name) wasn't here	
00:02:34	Teacher	for the 15th time we are not measuring turbidity, it doesn't matter right, it might have an effect on conductivity	
00:02:41	Teacher	There's no point taking a reading yet (student's name) ? Until this gentleman here gets up there with his Garmin	
00:02:46	??	now pull that out and get over there for me	
00:02:52	Teacher	you alright now (teachers name) not dying quite so much?	Talking about hayfever
00:02:53	Teacher	not so much	
00:02:55	?	take the Garmin over	
00:03:01	Teacher	so what are you gonna do with this?	
00:03:02	Researcher	analyse it	
00:03:03	Teacher	and make comments	
00:03:03	Researcher	yeah	
Tape BREAK			
00:03:04	Teacher	it's all fenced off and stuff, dangerous currents	

Continued on next page

Table L. 9 – *Continued from previous page*

Time	Person	Statement	Comments
00:03:23	Teacher	(student's name) , you need to be sensible, I don't want you any further than that	
00:03:35	Teacher		Talking but unintelligible
00:03:47	Teacher	take one here then take the Garmin you want up by there	
00:04:04	Teacher	again ideally it should have gone down the river sequentially	
00:04:06	Researcher	yeah and I think different groups have done it in different orders as well, because they took that side and they took that side	
00:04:12	Teacher	what I'm hoping is there will still be different times and a reading in each place	
00:04:13	Researcher	yeah that's true we should be able to match them up anyway	
00:04:16	Teacher	and to be honest the actual distance is so close together, it's not as if you're miles apart	
00:04:24	Teacher	is it spinning?	
00:04:27	Student	a bit start and stop	
00:04:30	Teacher	does it spin easily in your hand?, if you turn it with your hand is it spinning easily?, right okay then it's the river	
00:04:35	Teacher	don't do it in the reeds	
00:04:41	Teacher	right is that where you got the GPS then? Is that where you're taking the samples	
00:04:48	Students		Talking but unintelligible
00:04:50	Teacher and Students		Talking but unintelligible
00:05:03	Teacher	hi tech arent they, how much were they? Oh that's good	(can't hear a response)
00:05:14	Teacher	okay let's go then folks	
00:05:15	Teacher	when did you do that, was it September?	
00:05:18		TAPE END	

Table L. 10: **GCSE: River: Tape-2 Clip-2**

Time	Person	Statement	Comments
		3 second clip of home	

Table L. 11: **GCSE: River: Tape-2 Clip-3**

Time	Person	Statement	Comments
00:00:02	Teacher and Students		Talking but unintelligible
00:00:04	Teacher	he's also got the pots	
00:00:13	Teacher	right collect the water near the GPS	
00:00:18	Teacher	stay there while he just collects his pots of water	
00:00:21	Teacher	no it's where the water comes from	
00:00:26	Student	I know but you need to be there while he takes the ...	talking but unintelligible
00:00:30	Teacher	and the pH probe needs to come back as well	
00:00:34	Teacher		Talking but unintelligible
00:00:47	Student	do we need to leave the flow meter in for a minute, like with the other samples?	
00:00:50	Student		Talking but unintelligible
00:00:53	Student	no, have it in for about 10 or 20 seconds	
00:00:57	Student		Talking but unintelligible
00:00:59	Student	it says overwrite old file, do I click it?	
00:01:00	Student	yes	
00:01:00	Student	yeah	
00:01:05	Students		Talking but unintelligible
00:01:12	Student	well these are kind of like rapids aren't they	
00:01:17	Student	don't do that you're disturbing the flow walking past us	
00:01:30	Students and Teacher		Talking but unintelligible
00:01:36	Student	one hundred and ninety point eight	
00:01:41	Student	Ooh that's fast isn't it, does that make sense?	
00:01:45	Teacher and Students		Talking but unintelligible
00:01:52	Teacher	Teachers name - dissolved oxygen is that a percentage?	

Continued on next page

Table L. 11 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:01:53	Teacher	yeah yea	
00:01:54	Teacher	they're getting 190 % apparently	
00:01:55	Teacher	for what?	
00:01:56	Teacher	Dissolved oxygen	
00:01:57	Teacher		Talking but unintelligible
00:01:58	Teacher	Is it percent or miligrams per litre?	
00:02:00	Students	Percent	
00:02:03	Teacher		Talking but unintelligible
00:02:06	Teacher	well does 190% make sense?	
00:02:08	Teacher and Students		Talking but unintelligible
00:02:09	Teacher	190% of what?	
00:02:14	Student	by the way there's ...	Talking but unintelligible
00:02:18		TAPE END	

Table L. 12: **GCSE: River: Tape-2 Clip-4**

Time	Person	Statement	Comments
00:00:00	Student		Talking but unintelligible
00:00:09	Teacher	if you're doing the flow meter ...	Talking but unintelligible
00:00:23	Student	we need dissolved oxygen over here and over by the rapids	
00:00:30	Teacher		Talking but unintelligible
00:00:36	Student	there is quite a drop	
00:00:49		TAPE ENDS	

Table L. 13: **GCSE: River: Tape-2 Clip-5**

Time	Person	Statement	Comments
00:00:00	Teachers and Students		Talking but unintelligible
00:00:09	Teacher	(students name), group have abandoned him	
00:00:16	Student	where's (student's name)?	
00:00:19	Student	(student's name) have you sorted it?	
00:00:24	Teachers and Students		Talking but unintelligible
00:00:32		TAPE ENDS	

Table L. 14: **GCSE: River: Tape-2 Clip-6**

Time	Person	Statement	Comments
00:00:00	Teachers and Students		Talking but unintelligible
00:00:17	Student	ah (student's name)'s a pot head	
00:00:20	Students		Talking but unintelligible
00:00:27	Student	don't , ah, ah, how deep does it get?	
00:00:30	Student	where I'm standing, fairly	
00:00:35	Student	I can't go any further than that without getting a welly full	
00:00:40	Teacher	you don't want your photograph taken? No evidence	
00:00:53	Teacher		Talking but unintelligible
00:00:54	Students		Talking but unintelligible
00:01:08	Student	I have to work on the assumption that it has taken a snapshot because if it has it hasn't given me any indication	
00:01:12	Student	are you sure it's plugged in right? Yeah	
00:01:14	Researcher	is it coming up on the screen, is it recording them?	
00:01:18	Student	it just says take snapshot, stop snapshot	
00:01:19	Researcher	right	
00:01:19	Student	which I'm used to	
00:01:20	Researcher	so then what happens if you take one, it just does it?	
00:01:25	Researcher	I thought it was supposed to do something else	
00:01:25	Student	yeah it does normally, snapshot taken, whatever out of 250	
00:01:30	Researcher	that's what I thought, yeah	
00:01:42	Researcher	it's not changing from that screen then is it?	
00:01:43	Student	no	
00:01:44	Researcher	it might be worth going and asking	
00:01:46	Student	(Teachers Name) we might have a data logger that has no readings on it except for the first few	

Continued on next page

Table L. 14 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:01:50	Researcher	when you press keep snapshot it just keeps that screen up, I thought it was supposed to say how many	
00:01:56	Teacher	it should say	
00:02:00	Researcher		Talking but unintelligible
00:02:02	Researcher	it's not doing anything	
00:02:02	Teacher	it's jammed isn't it?	
00:02:05	Teacher	it's not even letting me switch it off, we have a datalogging problem again	
00:02:10	Student		Talking but unintelligible
00:02:10	Teacher	yeah that's okay because that's actually following our track	
00:02:16	Teacher	so, we need to connect to over there	
00:02:19	Researcher	here you go	
00:02:19	Student	cheers	
00:02:22	Researcher	if you hold down the cross will it switch off?	
00:02:22	Student	Can I borrow your	
00:02:31	Teacher	I wonder if, one of them was down to two batteries	
00:02:31		TAPE CUTS	
00:02:34	Students		Talking but unintelligible
00:02:50	Student	fingers crossed	
00:02:56	Students		Talking but unintelligible
00:02:58	Researcher	Is it working?	
00:03:06	Student	oh, water water everywhere and not a drop to drink	
00:03:09	Student	try that and see if it works	
00:03:10	Researcher	it might need switching on and off	
00:03:13	Student	does that, like, delete the stuff that we've done though?	
00:03:15	Researcher	it shouldn't delete it if you get an option to save it	
00:03:20	Researcher	(Teachers name) if we switch it on and off it's not going to lose the data is it?	
00:03:21	Teacher	it will start another log	
00:03:23	Researcher	because it's not recognising it at the minute	
00:03:26	Teacher		Talking but unintelligible

Continued on next page

Table L. 14 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:03:30	Researcher	last week, it won't go over that because there's about 8 logs on there	
00:03:32	Teacher		Talking but unintelligible
00:03:36	Teacher	can you remember how many logs it says it's got on there?	
00:03:38	Student	eight	
00:03:38	Teacher	so it's full we can't afford to cancel that log	
00:03:43	Researcher	so we can't connect the flow meter without switching it on and off	
00:03:47	Teacher	put the flow meter with that one then and see that we don't have the same problem.	
00:03:50	Student		Talking but unintelligible
00:03:50	Teacher	oh no that's alright then, that's okay it never said eight of eight?	
00:03:58	Researcher	and if it does say eight of eight then I would have thought the oldest ones would have been stuff I've been playing about with.	
00:04:01	Teacher	yes I would have thought it would over log the oldest log	
00:04:04	Researcher	turn it off and then back on	
00:04:12	Researcher	there we go, it's come back on now	
00:04:14	Students		Talking but unintelligible
00:04:17	Teacher	how bizarre, it's working again	
00:04:22	Student	there's flies everywhere	
00:04:26	Student	shall we take one from further up?	
00:04:28	Student	we just did	
00:04:28	Student	yeah but with flow	
00:04:35	Researcher	are you gonna reconnect it to that one?	
00:04:35	Teacher		Talking but unintelligible
00:04:43	Teacher	right come on lads we need to move now	
00:04:44		TAPE CUTS	
00:05:03	Student	I just tipped it over myself	
00:05:03	Student	clever	
00:05:04	Researcher	what is it, is this pH?	
00:05:05	Student	yeah	

Continued on next page

Table L. 14 – *Continued from previous page*

Time	Person	Statement	Comments
00:05:06	Researcher	oh it wont do any harm, pH buffer solution, is that dissolved oxygen that one? That'll be potassium chloride then I think	
00:05:15	Student	will it do anything to my skin?	
00:05:16	Researcher	just put your hand in the water, it shouldn't do, but I'm not a chemist so I don't know, oh it was only a tiny bit, do you want me to grab the bottle while you put your watch back on?	
00:05:34		TAPE ENDS	

Table L. 15: **GCSE: River: Tape-2 Clip-7**

Time	Person	Statement	Comments
00:00:02	Teacher	what's that there on the floor?	
00:00:06	Teacher	we've got to start to walk back now	
00:00:10	Teacher		Talking but unintelligible
00:00:25	Teacher	we'll take a sample here and a sample (Talking but unintelligible)	
00:00:32	Teacher	oh if they are now both reading are they now	
00:00:36	Teacher	that got sorted, that's great	
00:00:42	Teacher	leave it another minute before you do your ...	
00:00:43	Researcher	where's the other	
00:00:44	Teacher	it's in my hand	
00:00:50	Researcher	yeah I don't know which one, when you switch it on, that's a demo one	
00:00:52	Teacher	whether it's not a..	
00:00:53	Researcher	how good it is	
00:00:56	Researcher	I mean I don't know what the battery's like on it	
00:00:57	Teacher	the battery needs replacing I expect	
00:01:02	Teacher	come on let's go, it's ten past twelve now	
00:01:09		TAPE ENDS	

Table L. 16: **GCSE: River: Tape-2 Clip-8**

Time	Person	Statement	Comments
00:00:14	Student	decide not to crouch all the way	
00:00:20	Teacher		Talking but unintelligible
00:00:22	Student	I killed them	
00:00:29	Teacher		Talking but unintelligible
00:00:43	Teacher	keep the pot and the stick in the photograph, by all means carry on	
00:00:49	Teacher	the most technical piece of equipment in the entire science world, the pot and the stick, you know, you go to any other school to do your A levels and you won't get a pot on a stick	
00:00:58	Teacher		Talking but unintelligible
00:01:02	Teacher	yes I do, well you know (students name) quite well	
00:01:07	Teacher	now go further up that way	
00:01:15	Student	um, to the side	
00:01:20	Students		Talking but unintelligible
00:01:21	Student	wow	
00:01:21	Student	what?	
00:01:22	Student	that strikes me as being a bit like the quote from (full metal jacket?)	
00:01:24	Student	are not allowed to die without permission	
00:01:27	Teacher	hah, that's about right	
00:01:30	Teacher	if you kill yourself, don't come crying to me	
00:01:37	Teacher	that's actually worth a photograph in it's own right you two	
00:01:43	Student	need to have one of (student's name) in ...	Talking but unintelligible
00:01:45	Student	I've got no more hands to press the button	
00:01:48	Researcher	is it spinning?	
00:01:50	Student	gunk	
00:01:51	Researcher	no it's spinning now	
00:01:55	Student	okay, go	
00:02:03	Student	urgh, got some leakage	
00:02:07	Student	is the water caught underneath (Talking but unintelligible)	

Continued on next page

Table L. 16 – *Continued from previous page*

Time	Person	Statement	Comments
00:02:09		Tape Ends	

Table L. 17: **GCSE: Lesson: Tape-3 Clip-1**

Time	Person	Statement	Comments
00:00:03	Teacher	We need Mr [student's name]...	Talking but unintelligible
00:00:16	Teacher	I've got to remember where I actually put it, data logging 09	
00:00:17	Researcher	Is that the stuff that we did last week	
00:00:18	Teacher	yeah	
00:00:25	Researcher	I'm not sure how good it all is	
00:00:25	Teacher	no well ...	Teacher continues in background
00:00:27	Student		Talking but unintelligible
00:00:33	Student	control.. All the other shortcuts work	
00:00:35	Teacher	you've got all the data it doesn't matter what order it's in because it goes into geographic order	
00:00:42	Researcher		Talking but unintelligible
00:00:52	Teacher	Boys can you open Google Earth for me, can I talk you through this	
00:00:53	Teacher	open Google Earth,	
00:01:00	Teacher and researcher		Talking but unintelligible
00:01:15	Student	woah, I found out that the total size of the x drive is a few terrabytes	
00:01:19	Teacher	how big's a terrabyte?	
00:01:21	Student	it's a thousand gigabytes, so it's a lot	
00:01:27	Teacher	that's what I want to see, is Google Earth turn up	
00:01:33	Teacher and researcher		Talking but unintelligible
00:01:48	Teacher	yes this is lovely online, but what I'm not getting is...	Talking but unintelligible
00:01:57	Student	it's been ages since I last used Google Earth	
00:02:03	Teacher	once you have the side bar, you can keep	Talking but unintelligible
00:02:07	Teacher	you've got the side bar, that's fantastic	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:02:10	Teacher	um if you now, since you're ahead, are you on? Right you're messing around, stop young man now that is the problem with Google Earth as there's no satellite image of that part of South America or wherever it is you are, is it North America? No looks like you're in Africa. I actually found where we went in Uganda on there, I got on and got really confused.	
00:02:26	Teacher	Can you do file, don't do that, don't fly to (...) this is even better, if you do file, open, now you want to go into shared drive, that's X, right I'm going to put the air conditioning off now it's no longer hot in here.	
00:02:45	Teacher	so you should find in there one saying datalogging 2009 you're gonna have to search for it	
00:02:52		right so double click on there	
00:02:54		right click on the first one , that's it	
00:03:00		so all of you go to conductivity data	
00:03:02	Student	which one, QQ or?	
00:03:02	Teacher	it should take control of it, and it's rather like being on, er in space	
00:03:09		as soon as it focusses in you should recognise it	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	Person	Statement	Comments
00:03:12		right now then, on the side bar I'd like to offer you , you opened it and I don't see it, oh there we are... Click on the cross next to that and that's it now you've got more stuff now you can do all sorts of things, you can , you've got a little... now get rid of the sites here that's a good boy, click on the cross next to the conductivity data on the side bar, view side bar and you've got lots of options, you might find it's a good idea to take the calibration data off. So if you click the cross off on the calibration data, the bars disappear and now you can track where you've been a little better as the bars were showing the short cuts we were taking, and now you've got a view of actually what's been done	
00:03:35		let me just show you, unclick the ..., take the calibration data away, I think it is easier to understand the data	
00:03:50		now with the information balloons if you click over an information thing it should give you all the readings that that one took so you see exactly what was done there	
00:04:07		now you can open another file on top of that one which can make life quite fun, so if you click on file open again and choose the next one, and	
00:04:17		which one, flow rate?	
00:04:18		yup flow rate, why not	
00:04:21		now it takes control of you again	
00:04:24		and now you want to get rid of the bars again, so you click on the cross and now you're layering data, you want to have the information balloons, you can take off everything else. Now that is very interesting because somebody didn't start reading till there	
00:04:40	Researcher	I think that's when we had that datalogger broken	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	Person	Statement	Comments
00:04:42	Teacher	ah yeah, okay that's great	
00:04:43		and now when you click on that datalogging one you can click on the info balloon and you should be able to, read the water flow in metres per second. Getting rid of the calibration lines is always a good idea (student's name) because they get in the way	
00:04:56		have you opened a second lot of data?	
00:04:58		you need to get rid of both sets of data so it will be that one now you've got a new set of, er, calibration.	
00:05:03	Student	look look I took that, well me and (student's name) took that, good	
00:05:06	Teacher	that is good	
00:05:10	Teacher	now the slight problem that we have is we're now layering data and we need to think about how you turn this into useful data	
00:05:20	Student		Talking but unintelligible
00:05:22	Teacher	right now we need to download today's data and save it into that file and you can have a look at the whole thing if you pull right back	
00:05:24	Teacher	and I think it's a question for you, what would you want to do next with this information	
00:05:33	Student	Have you uploaded the data from this week?	
00:05:35	Teacher	I haven't yet I was going to show you the process	
00:05:40	Teacher	are you quite sure you haven't got Jdata3d have you all checked the programs, can you start programs for me, yes it should be	
00:05:45	Student	start, program, j data	
00:05:53	Teacher	no it's not there, I need to get them to do that, but that's fine	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:05:58	Teacher	they've got the er datadisc stuff , have you got the data disc stuff? Because MrTeachers name and Researcher downloaded it to datadisc too, so if you minimise Google Earth and, er, open the entire folder, actually open the folder out of my computer, then you actually got Excel files with that data as well. So how do you think is the best way, so when you've done that can you have chat amongst yurselves as four very intelligent young people, can you.. look you've got the conductivity data if you go spread sheet. now that's the conductivity data, that's the data that the thing recorded	
00:06:43	Student	that's the recordings?	
00:06:44	Teacher	that's gone crazy, track data, what's track data, I'm sure you had a much simpler version of that when you first opened it before you started clicking on buttons.	
00:06:55	Student	oh title version? (Talking but unintelligible)	
00:06:56	Teacher	right	
00:07:05	Teacher	11 points GPS...(Talking but unintelligible) the computer must have taken temperature and light level. GPS you don't want the track data do you because you've got 753 points of GPS data	
00:07:19	Teacher	right we need to work out how to do er, what's the next	
00:07:21	Student	merged data is this one here	
00:07:23	Teacher	so what's GPS track data, that we have, that's all those points	
00:07:27	Teacher	wow that's what we want	
00:07:28	Student	I think it's the merge data the one that we want	
00:07:30	Teacher	It's merged data you want with 11 points of data	
00:07:33	Teacher	so why don't you print out the merged data one	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	Person	Statement	Comments
00:07:37	Teacher	I'm going to very quickly load the photographs	
00:07:43	Teacher and researcher		Talking but unintelligible
00:07:47	Student	what's the unit of lx?	
00:07:48	Teacher	Lux	
00:07:49	Student	Lux	
00:08:10	Students		Talking but unintelligible
00:08:16	Teacher	actually while you're all playing for a bit can you all do what (student name's) doing and grab that data	
00:08:20	Teacher	I want to find (lists student's names who aren't in the room)	
00:08:24	Student	(Student Name) might be in maths, ask student services	
00:08:29	Student	do we have the photographic data uploaded?	
00:08:30	Researcher	not uploaded yet, no, because the battery ran out, of um the camera ran out of battery last week so we don't have any	
00:08:35	Students		Students are working individually without talking at this point
00:09:27	Researcher		Talking but unintelligible - off camera with other students
00:09:43	Student	I have a nasty tendency to act silly in front of cameras	
00:09:48	Student	did you just go to print?	
00:09:50	Student	no if you select active sheet, and then print	
00:09:58	Student	just select active sheet, yeah, you probably want to set it to er landscape	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	Person	Statement	Comments
00:10:20	Student	yeah I was once er with my mates erm and he was filming this charity ball thing, just for fun, every time I went past I'd make a face, he was just stood there filming everyone as they went past and the first time I sort of went....like that it was funny.	
00:10:30	Student	at the end, there was me and a friend doing a rendition, a hummed rendition of (..)	
00:10:43	Student	send to printer, that's pretty good	
00:11:07	Student	look, one of us ended in the river here, and another ended on the road, at the end of last week	
00:11:22	Student	at the end of last week we went to that bridge	
00:11:26	Student	so one of us ended in the road	
00:11:40	Student	yeah so we've got the flow for the road here, 0.7 metres per second for flow	
00:11:46	Researcher	is that because of wind or because of GPS?	
00:11:49	Student	the flow actually it's right in the road	
00:11:52	Researcher	remember the GPS can be out by a certain amount as well	
00:11:56	Student	there's two readings, there's one on the road	
00:11:58	Student	whereabouts was it?	
00:11:59	Student	the bridge last Friday, right at the end before we left	
00:12:06	Student	unless Mr (teachers name) walked back to get the mini bus or something	
00:12:07	Researcher		Talking but unintelligible
00:12:43	Researcher	or it might have been on a different thing you've only got two readings on there	
00:12:47	Student	hello how are you, nice of you to show up, where were you?	
00:12:51	Student	Maths	
00:12:55	Students		Talking but unintelligible
00:13:07	Student	so does that show us where we went?	
00:13:08	Student	it does yeah	

Continued on next page

Table L. 17 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:13:12	Students		Talking but unintelligible
00:13:32	Student	I have a feeling all of these tracks have the same data on them	
00:13:38	Researcher	well some of the dataloggers were taking more than one thing weren't they, what have you got, pH and conductivity? Which were done on the same datalogger	
00:13:48	Student	I've also got velocity and light levels	
00:13:53	Students		Talking but unintelligible
00:14:00	Researcher	the dataloggers can take temperature	
00:14:02	Student	I know the pH	
00:14:07	Researcher	the actual loggers, they do temperature and light and they can do sound	
00:14:12		Tape Ends	

Table L. 18: **GCSE: Lesson: Tape-3 Clip-2**

Time	Person	Statement	Comments
00:00:01	Researcher	that's why you get some of those	
00:00:07	Student	look look look ...	Talking but unintelligible
00:00:10	Student	why don't you go there	
00:00:15	Student	oh no, go to my house	
00:00:20	Students		Talking but unintelligible
00:00:26	Student	forget .... Password	Talking but unintelligible
00:00:46	Student	no it's probably ...	Talking but unintelligible
00:00:48	Student	we are learning around ...	Talking but unintelligible
00:01:01	Researcher	they've been looking at the information bubbles	
00:01:02	Teacher	oh good	
00:01:05	Teacher	is that all the data there then?	
00:01:07	Student	no I don't think so	
00:01:11	Teacher	yes but that's ...	Talking but unintelligible
00:01:11	Student	there's no ...	Talking but unintelligible
00:01:14	Teacher	you have got dissolved oxygen on there so you need to upload it	
00:01:15	Student	oh of course	
00:01:17	Student	have a bit of a google around	
00:01:20	Teacher	can you have a look at one of the other....spreadsheets	
00:01:27	Student	these um data (Talking but unintelligible) have the same data	
00:01:30	Researcher	well that's because if they came from the same datalogger	
00:01:36	Researcher	that's pH	
00:01:39	Teacher	yeah the flow is tagged on, do you have the dissolved oxygen on there?	
00:01:41	Teacher	click on there	
00:01:43	Student	I've uploaded all the files	
00:01:45	Researcher	I've got a feeling we couldn't do one last week	
00:01:50	Student	is that the data logger that I was on?	
00:01:55	Student	look that's following everywhere that I went	
00:02:00	Student	is that the one that I was on?	

Continued on next page

Table L. 18 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:02:00	Teacher	I wonder if it's on one of these then	
00:02:04	Student	I mean is that er the data that I kind of	
00:02:19	Teacher	right the point is, what I'd like us to work out is how can we use this data in a useful way because it's great to visualise it now how can we turn that visualisation into something really really useful	
00:02:33	Teacher	what's that? What's most useful to you? would you want to have a graph and look at the visualisation	
00:02:41	Student	..(Talking but unintelligible) and then a graph there, although ...	Talking but unintelligible
00:02:46	Teacher	now that's very interesting can we use Jdata 3d to graph that data?	
00:02:48	Student	you could probably just graph it in Excel	
00:02:50	Teacher	o, you've got it in excel haven't you	
00:02:52	Teacher	right can somebody try to turn that data into a graph for us then	
00:02:55	Student		Talking but unintelligible
00:02:55	Student	it's already there	
00:02:59	Students and Teacher		Talking but unintelligible
00:03:02	Teacher	what sort of graph as well	
00:03:04	Teacher	I'll take the photographs off your pen	
00:03:06		TAPE ENDS	

Table L. 19: **GCSE: Lesson: Tape-4 Clip-1**

Time	Person	Statement	Comments
00:00:00	Student	If we try and condense all of that data into a graph it's not going to work	
00:00:05	Teacher	no	
00:00:10	Student	might as well just	
00:00:11	Teacher	yeah carry on [student name] I think you're thinking in a very	
00:00:13	Student	scientific way	
00:00:14	Teacher	very scientific way yes , it's the whole process of um, I tell you what I know what you're used to now, children, or er young men	
00:00:20	Teacher	what we are trying today is come up with away of making this data a combination of the Google Earth, and the actual written numbers, make sense so that this tells a story and you can interpret the data. does that make sense as a success criteria. does that make sense, all we want is a way of doing it, we can do it later on, but we want the way of doing it.	
00:00:45	Teacher	Can I just, if you tick that bit (unintelligible)... the success criteria is whether we interpret this data and I think you need to find the... oh i'm not sure, yes that's right we need to find the dissolved oxygen	
00:01:00	Student	the best thing would be to put it into several graphs	
00:01:00	Teacher	yes okay	
00:01:01	Student	The first thing would be to put it into a graph, into several graphs for each different thing, I suggest on these Excel files we might as well condense date, time and latitude and longitude to one column, and then it will use them for an x axis and we can use all of these readings for the y axis on about 5 diferent graphs.	
00:01:21	Teacher	okay can you make it happen? As um, er who say's make it so? Picard? (student's name)	
00:01:23	Student	I can do so	

Continued on next page

Table L. 19 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:01:24	Teacher	you can do so good	
00:01:26	Teacher and Students		Talking but unintelligible
00:01:29	Student	I think these were taken ages ago, because even though the school is there, the TVR building which has now been knocked down is still there	
00:01:31	Teacher	oh right let me have a look because I haven't seen this new one at all	
	Student		Talking but unintelligible
00:01:38	Student	that there's been demolished	
00:01:40	Student	the point in action (??)	
00:01:45	Students		Talking but unintelligible
00:01:48	Teacher	so where's the school? Where's the school?	
00:01:55	Teacher	(...) state of carpark?	Talking but unintelligible
00:02:00	Student	no I looked at the lines (??)	
00:02:01	Teacher and Students		Talking but unintelligible
00:02:02	Teacher	yes there it is	
00:02:04	Teacher	so that picture was taken in 2007	
00:02:06	Teacher		Talking but unintelligible
00:02:08	Student		Talking but unintelligible
00:02:10	Teacher	loads of trees (...?)	
00:02:12	Teacher	and er...	
00:02:16	Student	(Teacher's Name) is ...	
00:02:18	Teacher and Students		Talking but unintelligible
00:02:23	Teacher	but still at least that makes it (.....)	
00:02:28	Teacher		Talking but unintelligible
00:02:33	Student	is that still there?	
00:02:35	Teacher	oh the swimming pools been built on there as well	
00:02:36	Student		Talking but unintelligible

Continued on next page

Table L. 19 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:02:37	Teacher	so I'd put this probably at 2006 possibly 2007, they always claim it's right up to date	
00:02:40	Student	but some parts of it is	
00:02:47	Student	the houses up there, yes this is the er	
00:02:52	Teacher	that's a good idea,	
00:02:53	Student	what?	
00:02:56	Teacher	what (student name)'s doing let's see that document again, you've actually got the data next to it	
00:02:59	Teacher and Students		Talking but unintelligible
00:03:00	Teacher	do we need to graph the data or would this be sufficient?	
00:03:07	Teacher	is that too much?	
00:03:14	Teacher	I'm just wondering if we should summarise it	
00:03:22	Teacher	you could put a small bar chart there next to it	
00:03:28	Teacher	You're working on a different way of doing it, so we've got two...we sort of need a third really	
00:03:44	Teacher	um can you actually. Ah, can you actually write, over print it. See the way (student's name) has done it on a word document can you do that on there? can you freeze that?	
00:03:51	Researcher	if you...(„„) then you can copy and paste into a word doucment so it's basically	
00:04:00	Teacher	right who's not working at the moment? Who'd like to see how the data is downloaded	
00:04:03	Student	I would	
00:04:03	Teacher	come on then and er (student's name) what are you doing at the moment	
00:04:06	Student	nothing	
00:04:08	Teacher	come on then if you two come and see how the data's downloaded	
00:04:14	Student	(...) pH....conductivity („) oh and oxygen	
00:04:17	Researcher		Talking but unintelligible

Continued on next page

Table L. 19 – *Continued from previous page*

Time	Person	Statement	Comments
00:04:23	Teacher	that's fine I'll start again to show you, this is the software (...) and if you can do this (...) you will be next week (...)	
00:04:52	Teacher	it will tell you exactly what to do (....) It wants you to connect the Garmin so connect that (....)	
00:04:52	Student		Talking but unintelligible
00:04:55	Teacher	so you connect the Garmin, and you wait for it to give you the next instruction	
00:05:00	Student	where did you get that from??	
00:05:02	Student		Talking but unintelligible
00:05:03	Student	oh yeah	
00:05:04	Student		Talking but unintelligible
00:05:06	Teacher	now that's that file that um (...) (student's name) had. It doesn't record all the time.. So when you were in the minibus it wasn't recording (.....)	
00:05:23	Teacher		Talking but unintelligible
00:05:33	Student	look this is flying???	Talking but unintelligible
00:05:38	Teacher and Students		Talking but unintelligible
00:05:50	Student	I don't know where I am now	
00:05:54	Researcher		Talking but unintelligible
00:05:58	Student	flying over the ocean	
00:06:00	Student		Talking but unintelligible
00:06:25	Teacher and researcher	it's in the box, not the university one, the square	Talking but unintelligible
00:06:30	Teacher	did you see the fox this morning?	
00:06:40	Teacher and researcher		Talking but unintelligible

Continued on next page

Table L. 19 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:06:45	Teacher and Students		Talking but unintelligible
00:06:50	Teacher and researcher	we took the battery out ...	Talking but unintelligible
00:06:51	Teacher	right this is what, no you disconnect the Garmin	
00:06:55	Teacher	and you follow the next instructions, so if you look ...	Talking but unintelligible
00:07:02	Student	if you go the sample ...	Talking but unintelligible
00:07:10	Teacher		Talking but unintelligible
00:07:20	Teacher	no it will download everything (Talking but unintelligible)	
00:07:26	Student		Talking but unintelligible
00:07:35	Teacher		Talking but unintelligible
00:07:44	Student	wow wow look look look (...) did you just see that?	
00:07:49	Student		Talking but unintelligible
00:07:59	Teacher		Talking but unintelligible
00:08:04	Student	I'm going really slowly now	
00:08:15	Teacher and Students		Talking but unintelligible
00:08:16	Student	see I travelled across there?	
00:08:20	Teacher		Talking but unintelligible
00:08:25	Student	See (student's name) that's the sea I travelled across	
00:08:26	Student		Talking but unintelligible
00:08:34	Teacher and Students		Talking but unintelligible
00:08:40	Teacher and researcher	*laughs* analyses the children (discussion with other teacher)	Talking but unintelligible
00:08:51	Teacher	we've got these two look	

Continued on next page

Table L. 19 – *Continued from previous page*

Time	Person	Statement	Comments
00:08:54	Teacher and Students		Talking but unintelligible
00:08:56	Teacher	we have a problem here	
00:08:59	Teacher	are you being sponsored by er? (second teacher)	
00:09:01	Researcher		Talking but unintelligible
00:09:05	Teacher		Talking but unintelligible
00:09:10	Student		Talking but unintelligible
00:09:18	Teacher	what was your? Is your degree in psychology	
00:09:22	Teacher		Talking but unintelligible
00:09:24	Researcher	yeah, my actual psychology degree was very broad	
00:09:27	Teacher		Talking but unintelligible
00:09:28	Teacher	that's the theory	
00:09:32	Researcher		Talking but unintelligible
00:09:34	Teacher	so it was advertised for?	
00:09:42	Teacher and researcher	(discussing phd - Talking but unintelligible)	
00:09:52	Teacher	are you general just hypothesis testing at the moment?	
00:10:00	Researcher	yeah this is just a general (Talking but unintelligible)	
00:10:05	Researcher		Talking but unintelligible
00:10:19	Teacher		Talking but unintelligible
00:10:23	Researcher	yeah I want to look at the learning and motivation	
00:10:25	Teacher	common sense would say it would	
00:10:30	Teacher	that's what makes this so interesting, because as you say it's common sense	
00:10:46	Teacher	what you might think, might not be what you....	Talking but unintelligible
00:10:50	Teacher		Talking but unintelligible

Continued on next page

Table L. 19 – *Continued from previous page*

Time	Person	Statement	Comments
00:10:55	Student		Talking but unintelligible
00:11:00	Teacher	it's because they're digital meters	
00:11:15	Teacher		Talking but unintelligible
00:11:15	Teacher	who's on Google Earth, who's got Google Earth open at the moment?	
00:11:16	Student	I do	
00:11:20	Teacher	(student's name) - do you, show Mr X what sort of datalogging you were doing this morning, show him the results	
00:11:24	Teacher	what we're trying to do is see how. They make these results make sense	
00:11:26	Teacher	so who's going to show me then?	
00:11:26	Teacher	(student's name) is going to show you one way and (student's name) is going to show you another.	
00:11:41	Teacher	well I started (...) and failed to get that data	
00:11:49	Teacher		Talking but unintelligible
00:11:57	Student		Talking but unintelligible
00:12:00	Teacher	because this is an adaptor I haven't disconnected it, so maybe it hasn't recognised	
00:12:10	Teacher and Students	(talking to student about data)	Talking but unintelligible
00:12:17	Student	all these lines show	
00:12:37	Teacher and Students	(talking to student about data)	
00:12:40	Teacher	it's really multiple sensors so this was temp, light and conductivity, that is bizarre oh, wait that's pH	
00:12:47	Student		Talking but unintelligible
00:12:52	Teacher	oh, obviously on this machine I've got	
00:12:55	Teacher and Students	(talking to student about data)	Talking but unintelligible

Continued on next page

Table L. 19 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:13:01	Teacher	er we'd rather go for discrete points than a line graph, yeah do you agree?	
00:13:07	Teacher and Students	(talking to student about data)	Talking but unintelligible
00:13:12	Teacher	right thanks for that	
00:13:13	Teacher	that's not what you came in here for at all, but quite interesting though	
00:13:15	Teacher	no it's not but (talking but unintelligible)	
00:13:22	Teachers	discussing something about science dept	
00:14:00	Teacher	talking to student - I think about the data	Talking but unintelligible
00:14:12		TAPE END	

Table L. 20: **GCSE: Lesson: Tape-4 Clip-2**

Time	Person	Statement	Comments
00:00:02	Teacher and Students		Talking but unintelligible
00:00:15	Researcher	but you can download them again	
00:00:18	Teacher	yes repeat the process	
			camera shows student working on excel, creating a graph
00:00:48	Teacher	is that what you did last week, downloaded it separately	
00:50:00	Researcher	yeah	
00:00:57	Teacher	you want to skip it	
00:00:58	Researcher	it wasn't working either	
00:01:04	Teacher	now if we want to get the other data (....)	
00:01:08	Student	I think there may be something erroneous with the conductivity data	
00:01:09	Researcher	why do you say that?	
00:01:12	Student	because all of these are at 560	
00:01:17			Talking but unintelligible
00:01:19	Researcher	which one of these is conductivity?	
00:01:39	Teacher	so um Susie when it appears (...) probably because we downloaded two (...) at the same	
00:01:46	Teacher	so that's got all the data off there, pH (...) that's all of that one	
00:01:52	Teacher	right so that's the downloaded data, ok um do you want to process (...video ends)	
00:01:57		TAPE END	

Table L. 21: **GCSE: River: Tape-5 Clip-1**

Time	Person	Statement	Comments
			Talking but unintelligible
00:25	Student	oh, be aware there's a [dark ridge dropoff]	
00:30	Student	oh, I found it	
	Student		Talking but unintelligible
00:01:27	Student	the amount of rubbish here	
00:01:30	Student	talks about rubbish? Unintelligible - it's a heart/dart it's a dummy?	more talking unintelligible
00:01:42	Teacher	right we do need to move on sorry to keep hurrying you	
00:01:44	Student	well lets at least get some of this rubbish off here	
00:01:48	Teacher	we could always offer to come back ....[unintelligible]	
00:01:50	Student	well we're here now	
00:01:52			END OF TAPE

Table L. 22: **GCSE: River: Tape-5 Clip-2**

Time	Person	Statement	Comments
00:00:04	Student	what do you want collecting...oh	
00:00:11	Teacher	actually you've done more than necessary	
00:18	Teacher	boys generally speaking [unintelligible..sewers..]	
	Teacher		Talking but unintelligible
00:56	Student	remember I've got the GPS so you need to measure near me	
	Student		Talking but unintelligible
00:01:08	Student	(student's name) do you want to take a sample?	
00:01:15	Student	(student's name) do you want to take a sample?	REPEATS
00:01:19	Student	(Teacher's Name), it's not changing from 80 anywhere	
00:01:23	Teacher		Talking but unintelligible continues in background
00:01:34	Student		Talking but unintelligible
00:01:48	Student	[(student's name)] we need the Garmin	
00:01:54	Teacher		Talking but unintelligible
00:02:03	Student	(student's name) come here, hurry up will yah	
	Teacher and Student		Talking but unintelligible
00:02:25	Student	do you want to do it higher up? Under the bridge	
00:02:35	Student	what are you doing, press the button	
00:02:40	Student	are we going under the bridge?,	
00:02:44	Student	(student's name) we're going under the bridge	
00:02:45	Teacher	no you are not	
00:02:46	Teacher		Talking but unintelligible
	Student		Talking but unintelligible

Continued on next page

Table L. 22 – *Continued from previous page*

Time	Person	Statement	Comments
00:03:02	Student	whatever it is it's dead, look we unearthed a dead cray fish or crab or something	
00:03:06	Student	that's actually a crayfish head	
00:03:07	Teacher		Talking but unintelligible
00:03:22	Teacher	right come on then lads	
00:03:26	Student	someone put red hot chilli peppers on, I can't remember how it goes	
00:03:29	Student		Talking but unintelligible
00:03:30	Teacher		Talking but unintelligible
00:04:18		CAMERA OFF	
00:04:21	Teacher	part of the summer [unintelligible]	
00:04:38	Student	don't forget I've got the GPS	
00:04:51	Student	right then (student's name) I'm ready for when you get back	
00:04:57	Student	43 metres, [(Teacher's name), I've got 43 now 21	
	Teacher and Student		Talking but unintelligible
00:05:02	Researcher	you're quite low down	
00:05:06	Teacher	give the GPS to (student's name) here	
00:05:15	Teacher	there are safer ways of doing this	
00:05:22	Teacher	7 metre accuracy	
00:05:28	Student	five	
00:05:29	Teacher	no It's not been lower than 6 - that's much better than 20 (talking about GPS)	
00:05:30	Teacher and Student		Talking but unintelligible
00:05:45	Teacher	boys..i've just realised..it's athletics next week (unintelligible)	
00:05:58	Student	are we doing [...] in school	
00:05:59	Student	apparently it's inter-house	
00:06:07	Student	why do we have to do this anyway, they said we didn't have to last year, then they dropped the bombshell on us, to do a different kind of (...) the PE department are liars	
00:06:15	Teacher	they just want you to be fit	

Continued on next page

Table L. 22 – *Continued from previous page*

Time	Person	Statement	Comments
00:06:20	Teacher and student		Talking but unintelligible
00:06:26	Teacher	oh well done that's a big [..]	
00:06:27	Student	I've caught a fish	
00:06:36	Teacher	unintelligible (but looking at fish) it's on it's own, it's a got another thing living on it [..] it's become a habitat rather like the tree	
00:06:58	Teacher	come on out under the bridge	
00:06:59	Student		Talking but unintelligible
00:07:00	Student	I want to see it open up, I want to see it open up	Talking about mussels
00:07:02	Teacher	no no it's not fair on the (..)	
00:07:04	Student	What's going on?	
00:07:05	Teacher	I'm not sure those are native, that big	
00:07:07	Student	(Teacher's Name) have you got the Garmin up here	
00:07:09	Teacher	I've got the Garmin [unintelligible]	
00:07:14	Teacher	right unless you want [...] at this rate we can stroll back to school	
00:07:20	Student	oh, I've found another one	
00:07:26	Student	I know a fairly quick route back to school	
00:07:28	Teacher	oh, another one, look at all the (...)	
00:07:32	Student	[Teachers name],[Teachers name]	
00:07:36	Teacher	come out from under the bridge-	
00:07:38	Student		Talking but unintelligible
00:07:40	Teacher	I think we've established that they're living under there	
00:07:44	Teacher	come on out of there	
00:07:44	Student	(Teacher's Name)	
00:07:45	Teacher	yes	
00:07:45	Student	I know a....[video cuts out] END OF VIDEO	

Table L. 23: **GCSE: Lesson: Tape-5 Clip-3**

Time	Person	Statement	Comments
00:00:02	Student	Careful, you're pushing it a bit close to where the unfilmable people are	
00:00:06	Researcher	It's alright if I just point it over there	
00:00:11	Student	you're observing the smart board	
00:00:12	Researcher	yup	
00:00:20	Researcher	unintelligible	
00:00:26	Student	it goes pretty fast doesn't it, I mean relatively fast	Talking about uploading
00:00:31	Student		Talking but unintelligible
00:00:39	Student	Cable?	
00:43	Researcher	Here	
00:44	Student	ah, thank you, helpful psychology students	
00:00:53	Student	I probably shouldn't (..) or I'll (..)	
00:00:58	Student	that's one of the interests (....)	
00:01:02	Students		Talking but unintelligible
00:01:05	STudent	so we'll be A level psychology students, but I'm more likely to be a physics of physical chemistry student when I go to university	
00:01:10	Researcher	you know what you want to do already	
00:01:11	Student	I've got a good idea yeah, it's excellent	
00:01:23	Student		Background talking, unintelligible student talking about format?
00:01:30	Student	actually it looks like discrete points	
			Talking but unintelligible
00:01:32	Researcher	she will be, she's just gone to get her glasses	
00:01:45	Student	do you think we should have done it with discrete or should we have done it with a line graph?	
00:01:47	Researcher and Students		Talking but unintelligible
00:01:48	Student	surely we can re-upload them	

Continued on next page

Table L. 23 – *Continued from previous page*

Time	Person	Statement	Comments
00:01:49	Researcher and Students		
00:01:53	Researcher	Did you pick discrete or continuous?	
00:01:54	Student	I put discrete because they're only, they're not really connected	
00:01:58	Researcher	That's what we did with the other data as well	
00:02:00	Student	Oh good	
00:02:01	Researcher and Students		Talking but unintelligible
00:02:02	Researcher	have you used Jdata 3?	
00:02:03	Student	Not recently	
00:02:04	Student	It's the first time I've used it and (students name) here is the master	
00:02:07	Student	we're skipping photos? I thought we had some photos	
00:02:09	Researcher	They're not uploaded yet, you need to have them already uploaded	
00:02:11	Student	and is this week the only week we've had photos?	
00:02:14	Researcher	no we've had photos taken for every week, we just haven't had them uploaded on the computer at the right time for this	
00:02:16	Student	ah, fair enough	
00:02:21	Researcher	you'll want to name it something you'll remember, connected to what it is	
00:02:23	Student		Talking but unintelligible
00:02:24	Researcher	So is this the flow?, why don't you call it Flow and then the date?	
00:02:27	STudent	Oh, I know the [..] trip	
00:02:28	Researcher	Yeah but you won't know which one it is will you?	
00:02:30	Student	Alright	
00:02:30	Researcher	because when you go back to upload them to Google Earth you're going to need to see which one it is	
00:02:37	Students		Talking but unintelligible

Continued on next page

Table L. 23 – *Continued from previous page*

Time	Person	Statement	Comments
00:02:44	Researcher		Talking but unintelligible
00:02:47	Student	Should be environmental science	Looking to save file
00:02:51	Researcher	It's a log in thing, was it that one? The lbdl one?, I think it was	Navigating the folder options
00:02:56			Talking but unintelligible
00:02:58	Student	Datalog	
00:03:00	Researcher	I think he used it last week, but [..] hasn't used it before	Discussing software use
00:03:06	Researcher	but last week when they did it there was problems with the data loggers so they didn't get any data off	
00:03:10	Students		Talking but unintelligible
00:03:13	Researcher	Those students are looking at last week's, and these are uploading this week's, I think they're gonna rotate because they did the flow meter um [...]	
00:03:20	Researcher and Students		Talking but unintelligible
00:03:23	Researcher	one big group but in kind of pairs of what they're doing	
00:03:31	Students		Talking but unintelligible
00:03:35	Student	exit program, right it's all done	
00:03:35	Researcher	you've done that	
00:03:37	Student	on with the next group then	
00:03:40	Student	careful with your camera	
00:03:41	Researcher	I can blur them out	
00:03:43	Student	you're just aiming at my chest though	
00:03:46		Tape Stop	
00:03:46	Student	there are many more advanced ways of doing it	
00:03:52	Student	Have you only done those two sheets or?	
00:04:00	Student	has everyone else been working on some of those as well? Because we want to present all of our data	

Continued on next page

Table L. 23 – *Continued from previous page*

Time	Person	Statement	Comments
00:04:09	Researcher	is last week's data on the public server now? Because maybe you could do some of last week's?	
00:04:11	Student	we were looking at it	
00:04:14	Researcher	that was the first week's you looked at last week wasn't it?	
00:04:17	Student	I don't think we even have, erm..	
00:04:25	Students	(that tree's still standing) (wow, wow, look)	Talking but unintelligible
00:05:03	?	the folder with the field work	Not sure who asked this
00:05:06	Student	I don't know, Google work?	
00:05:13	Student	Oh, look, look, look	
00:05:24	Student	all sorts of [..] it's so messy	
00:05:25	Student		Talking but unintelligible
00:05:34	Student	do you know which folder the work files are?	
00:05:38	Student	X	
00:05:42	Student	it's x drive, then an odd server name	
00:05:42	Student	oh there we go, look, look, look, it's a (...)	
00:05:46	Student	I was just at the north pole, now I'm at the south	
00:05:50	Students		Talking but unintelligible
00:05:55	Student	we don't have last week's data, we only have ones from the 5th	
00:05:56	Researcher	oh, you've managed to find it?	
00:05:57	Student	I found the folder but we only have the 5th's	
00:05:58	Researcher	erm	
00:05:59	Student	oh, actually, thinking about it I recon (...)	
00:06:06	Researcher	so can you do something with the first week's data? Present it again?	
00:06:10	Student	I might be able to	
00:06:15	Students		Talking but unintelligible
00:06:20	Researcher	because you were doing longitude and latitude points last time weren't you	
00:06:21	Student	it really didn't work, we'll have to come up with (student's name) is probably the best way	

Continued on next page

Table L. 23 – *Continued from previous page*

Time	Person	Statement	Comments
00:06:25	Researcher	right	
00:06:29	Teacher	oh good, okay do you want to enlighten me?	off camera talking to other students
00:06:37	Researcher and Students	oh have you (...)	Talking but unintelligible (not main researcher)
00:06:48	Researcher	I think it will go on into next year	Discussing completion of coursework
00:06:50	Researcher	Oh right, so you haven't got to present it?	
00:06:52	Researcher	no, because they've got kick sampling to do as well, they need to go out of school for that, so they haven't got much time to do this	
00:06:59	Student	problem fetching data	
00:07:00	Student	this is pretty outlying	
00:07:03	Student	is it in the x folder? Called data logging, ah I can't use a computer, look	
00:07:16	Student	hey on the new Google earth you can go underwater	
00:07:20	Student		Talking but unintelligible
00:07:36		TAPE END	

Table L. 24: **A Level:**

Time	Person	Statement	Comments
00:00:00	Teacher	with me and Susie	
00:00:09	Teacher	right folks listen up	
00:00:10	Students		Talking but unintelligible
00:00:14	Teacher	quiet, shut up!	
00:00:19	Teacher	focus folks. Right, now then, the Garmin people, when everybody else comes in the river and starts messing around, that's when I, well Susie, well, Susie and I, will tell you what you're doing okay but for everybody, but can you move forward and let these folk move by, and also you can hear me better? Right, but for everybody the technique of kick sampling is the sort of thing you get tested on and also the thing that Mr (Teacher's name) is going to explain the (...) speed of the Mayfly is something else you get tested on, provided you get Mayflies, so if I can just hand over the pot and stick	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:01:05	Teacher	basically with kick sampling, are you all listening?, are you all talking? Basically whoever stuck that end of this pole in the mud as a walking stick, thanks! Right, basically with kick sampling what you are after are the creatures, you cannot live, you cannot live in the water in the stream because you'll end up in the sea so the creatures that live here are living...can you catch the Morrisons' bag please, can you catch the bag? It's one of ours, great, thanks. Basically the creatures you are after are living in the stones so the technique for getting them is this, you put the head of the net into the stones, into the substrate, you stand upstream you should never be in water over your knees to do this because if you do as soon as you pick the one foot up it gets swept away down steam, and you disturb the substrate with your other foot, hence kick sampling. If you are doing it to assess, to get quantitative data, you'd have to kick for a certain amount of time but what we're interested in today is what species you find and if you find Mayflies. So you kick for approx a minute, or 20 or 30 kicks, just be consistent, all the little critters are now in the bottom of the net, so your mate with the tray, who can be a dry person if you want to be, be a dry person with the tray, fill the tray with water, put water into the tray, now you turn the net inside out into the tray and you want Mayfly, Mayfly have three tails, M, A, Y, three tails , alright so you're looking for the three tailed creatures, and they're waterborn larvae	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:03:37	Teacher	So this, it's the first of four pieces of work you'll have to do, you need to choose one of three statistical tests and the data for this will be... this work will be handed in in September so we'll collect it today and look at it over term, what we have left and then probably the second week in (Talking but unintelligible)	
00:04:08	Teacher	the Mayfly (Talking but unintelligible) and they use these	
00:04:12	Teacher	they're both actually picking up (Talking but unintelligible) if you try to sample in the same water (Talking but unintelligible) you can actually see with this you've got two little electrodes, so do it at the same time and they don't work so get two pots of water, and put the two probes into the water, the sample, the Garmin wil sample where ever it is, so take it where you take the sample. That is working	
00:04:45	Student	it's been on a long time, we turned it on before we left	
00:04:50	Teacher	it is weak, that should be okay	
00:04:54	Student	maybe it's got old batteries in it?	
00:05:00	Teacher	just in case let's keep the sampling in the same place then that Garmin will be within 5 metres of where the samples come from, and on a 2 mile trek, 5 metres will do us nicely	
00:05:12	Teachers and Students		Talking but unintelligible
00:05:16	Teacher	actually funnily enough it's more accurate than that	
00:05:21	Teacher	so that's it, and the other one, yup	
00:05:23	Student	right how do I?	
00:05:28	Teachers and Students		Talking but unintelligible
00:05:32	Teacher	the temperature probe stays with ...	Talking but unintelligible

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:05:32	Student	where's my group	Off camera student not involved in Data Logging
00:05:34	Teacher	that is now all yours	
00:05:40	Student	so that's a temperature probe and, er, a ...	Talking but unintelligible
00:05:48	Researcher	(Talking but unintelligible) just sample here where they are	
00:05:55	Researcher	no the sample and everything is in there, and the Garmin ...	Talking but unintelligible
00:06:00	Teachers and Students		Talking but unintelligible
00:06:09	Teacher	I'm gonna lose that aren't I, I'm gonna lose the liquid out of there	
00:06:11	Researcher	Have we not got another lid?	
00:06:11	Teacher	we need a lid	
00:06:16	Student	we're just trying to say when they start we can start off	
00:06:23	Teacher	right it'll go in my pocket	
00:06:27	Students		Talking but unintelligible
00:06:36	Teacher	now with the boxes, has Susie explained snapshot to you yet, right come down you see it's reading even though you haven't got anything yet, come down, it says start snapshot , press that tick it will record the data, now you don't want to press that tick until it's been in the sample for a count of.....ooh, a bit more than that, twenty? yeah, tick to turn it on, then turn it round, down arrow, down arrow, start snapshot , right, er, down again, start snapshot, now don't press it now until you've got that sampler in the water, and that sampler in the water	
00:07:24	Student	but do you need a little thing?	
00:07:25	Teacher	you don't need a pot, you can do dissolved oxygen straight into the water and you can also put the temperature probe in	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:07:31	Student	and what's this probe here?	
00:07:35	Teacher	the dissolved oxygen needs to have the temperature of the water to calculate the oxygen percentage	
00:07:42	Student		
00:07:43	Teacher	can I just check? Yep you're ...	Talking but unintelligible
00:07:47	Teacher	right okay	
00:07:50	Teacher	let's just go through what these are doing, I agree with (student's name) right the simplest, right what if I put that [talking about Garmin] put that around my neck and I'll stay with you. The simplest, right whoah, the simplest sampler is that one [points at flow meter] because it just turns around, and it gives you a speed	
00:08:12	Student	do I write that?	
00:08:16	Teacher	er, that's the great thing about it	
00:08:17	Teacher	you do not have to write anything down	
00:08:21	Teacher	you're the group that do not have to write	
00:08:23	Student	That's quite fortunate	
00:08:30	Teacher	literally that's a propeller and it will give you metres per second	
00:08:33	Teacher	now this sampler is dissolved oxygen, now I'm not entirely sure how it works	
00:08:36	Student		Talking but unintelligible
00:08:38	Teacher	you don't need to know how it works, and it gives you miligrams per litre of oxygen	
00:08:46	Student	probably the same ways as the oxygen things which clip on your thumb I'd imagine	
00:08:48	Teacher	yeah	Talking but unintelligible
00:08:50	Teacher	and that's just a normal temperature probe	
00:08:53	Student	and all of that's recorded on there?	
00:08:55	Teacher	all of that's recorded in there.	
00:08:58	Student	(Talking but unintelligible) make it start recording	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:09:02	Teacher	all you need, to do is make sure it's been in the water for say, a count of twenty before you press the tick	
00:09:10	Student	I see (Talking but unintelligible) and then it just samples	
00:09:22	Teacher	the pH probe works like a normal pH probe, the conductivity puts a little bolt of electricty, and the higher the conductivity the less the resistance,	
00:09:27	Student	just a little (Talking but unintelligible)	
00:09:30	Student	we've got to be going that way	
00:09:33	Teacher	(Talking but unintelligible) if you hold those two like that	
00:09:38	Student	you've got to be right in the water	
00:09:40	Students		Talking but unintelligible
00:09:47	Student	right ((student's name)) you need to come in as well	
00:09:51	Teacher	(Talking but unintelligible) pots	
00:09:54	Teacher	you could actually have got away without going in the water	
00:10:03	Teacher	it needs to be in the same place as that, so pots in, down, fill, up, sensor in	
00:10:07	Teacher	give them time to settle for a count of at least twenty	
00:10:11	Student	that's twenty can I grab ...	Talking but unintelligible
00:10:12	Teacher	Tick	
00:10:12	Student	That had crossed my mind	
00:10:13	Student		Talking but unintelligible
00:10:18	Teacher	start snapshot, tick, snapshot (Talking but unintelligible) of 250	
00:10:23	Student	can I overwrite oldest file?	
00:10:24	Teacher and Researcher	yup	
00:10:26	Teacher	tick, snapshot taken	
00:10:33	Teacher	right next time, leave the boxes alone now until your next sample	
00:10:39	Student	so are we only doing one here?	
00:10:43	Student	one here and then one further down	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:10:47	Student	(student's name) get these things out of my water	
00:10:51	Students		Talking but unintelligible
00:10:56	Student	Pretty happy with that	
00:11:00	Student	Can we walk down the stream (Teacher's Name)?	
00:11:02	Student	are we walking down stream	
00:11:02	Student	lob it over to me	
00:11:06	Student	well pass it over to me then	
00:11:15	Student	who's got a fish?	
00:11:19	Teachers and Students		Talking but unintelligible
00:11:25	Researcher	it might go to sleep, but just press the tick and it will come back to life	
00:11:29	Student	see (student's name), even you can work it	
00:11:30	Students		Talking but unintelligible
00:12:10	Teacher	you know how to take a reading now	
00:12:15	Student	yeah easy	
00:12:24	Teacher	we'll have to do that as the old fashioned one's not working	
00:12:32	Students		Talking but unintelligible
00:12:41	Student	might as well do it again to get a bit of experience	Lots of students talking, incl kick samplers etc, so it is not clear if these students are datalogging or not
00:12:42	Students		Talking but unintelligible
00:13:14	Student	it was about there	
00:13:17	Student	146 degrees C?	
00:13:20	Student	146? What	
00:13:22	Student	is it 0.4 degrees C?	
00:13:54	Student	temperature probe is not liking this	
00:13:55	Researcher	what's it saying?	
00:13:56	Student	146 degrees C, I wonder if it's not connected properly	
00:14:06	Student	there we go, that's correct	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:14:10	Researcher	I don't know why it goes up when it's not connected properly	
00:14:14	Student	hah, maybe it's just British optimism	
00:14:25	Student	I think I've got the wrong thing dipped in the water	
00:14:28	Researcher	did you see what the temperature was when you took your first snapshot?	
00:14:31	Student	no, I didn't notice it, it tells me 14.6	
00:14:37	Researcher	I'm just wondering if it's worthwhile taking another snapshot over here in a minute	
00:14:41	Student	yeah it just says 14.6, which would make it the same temperature as the ambient air	
00:14:51	Researcher	yeah but If you remember that's got quite cold for a while and then it comes out	
00:14:55	Researcher	(Teacher's Name) the temperature probe wasn't pushed in properly when we took that snapshot, I don't know if you want to do another one, or discount it?	
00:15:00	Teacher	yeah you could do another one	
00:15:15	Student	right okay what's the deal	
00:15:16	Teacher	okay, go back stick everything in,	
00:15:20	Student	I might need a hand there, alright you grab on that, you grab the sensitive valuables	
00:15:22	Student	right and we want all three of these in the water	
00:15:24	Researcher	in the water	
00:15:28	Student	in the water for twenty seconds	
00:15:33	Teacher	except for the expensive valuable part	
00:15:41	Teacher	snapshot taken!, that's brilliant out you come	
00:15:46	Student	my feet are starting to recover now	
00:15:50	Teacher	brilliant	
00:15:55	Teachers and Students		Talking but unintelligible
00:16:13	Student	I can't believe that	Talking but unintelligible
00:16:53	Researcher	you've got to come out and then go around	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:16:58	Student	(Teacher's Name) can I record down here?	
00:17:04	Researcher	I don't think anybody sampled down there	
00:17:27	Student	do you have any idea how deep that is?	
00:17:30	Students		Talking but unintelligible
00:17:42	Teacher	right can we have somebody who's not in the water to carry half the equipment please?	
00:17:45	Student	if you just hold that, I'll pull my shorts up	
00:17:56	Student	right I'll hold that, you hold this	
00:18:00	Student		Talking but unintelligible
00:18:09	Student	you're going in	
00:18:13	Researcher	I think it's quite deep there	
00:18:16	Student	I can't reach there it's too deep	
00:18:17	Student		Talking but unintelligible
00:18:46	Student	right (student's name) we've got to get in the river down here	
00:18:47	Students		Talking but unintelligible
00:19:28	Teacher	deep sided valley with no water at the bottom, when you look at the trees above your head you can see the (Talking but unintelligible), when it goes, it goes about 12 foot deep	
00:19:30	Teacher	did you walk it when you were doing your walk?	
00:19:35	Student	where about's is it?	
00:19:40	Teacher	Bishopston, it's well worth it	
00:19:50	Teacher	no here, there's a Bishopston here	
00:19:55	Teacher	mind you don't drop that oxygen sampler right onto the ground	
00:20:03	Student	okay, now press tick, and that's snapshot four	
00:20:09	Student	how do we know which snapshots are which?	
00:20:13	Researcher	there's a clock in there so that will connect the snapshot with the GPS	
00:20:18	Teacher	It's cool innit	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:20:22	Teacher	so this knows where you were, when you were there, and that knows what the sample was when you were there	
00:20:28	Student	shall we take this out	
00:20:35	Student	okay, so do we need any more readings?	
00:20:37	Teacher	no we don't, not here, unless people want to kick sample	
00:20:44	Student	it's skimming, it's a sport	
00:20:46	Student	Oh, ho, look at that one	
00:20:47	Teacher	no, wait until you get to the sea for skimming	
00:20:50	Student	Can't I just do this one?	
00:20:53	Teacher	(student's name) can you watch your swinging of that oxygen sensor	
00:21:00	Teachers and Students		Talking but unintelligible
00:21:05	Student	oh you dropped it	not clear what Is being talked about here
00:21:12	Students		Talking but unintelligible
00:21:17	Student	she wants to come down stream with us	
00:21:18	Teacher	no we stay together	
00:21:28	Teacher	I'm trying to explain to them Mr (Teacher's name) that if it was us on our own we'd go down there wouldn't we, but we can't, we're a big group	
00:21:46	Students		Talking but unintelligible
00:22:12	Researcher	then about like, where do you put it in the thing? That's something that the people who make this could consider, you could have markings so you'd know how deep you put it	
00:22:29	Researcher	and the fact that you're using it, you're reading off the data shows that that's useful and you are actually ...	Talking but unintelligible
00:22:32	Student	will your PhD dissertation be used to make recommendations to the industry?	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:22:45	Researcher	well the guy that makes these is funding me, so anything I say, I've already said a few problems, and he's going, alright, yeah, we'll fix that, because it's just a small company but they make quite a lot of them	
00:22:57	Students		Talking but unintelligible
00:23:16	Student	Oooh crikey (student's name) you've hit the bottom	
00:23:34	Student	0.7 I recon	This was taking measurements to help the kick samplers who's equipment had broken
00:23:37	Student	Oh right we're moving on, we haven't finished yet	
00:23:40	Students		Talking but unintelligible
00:24:05	Student	it's so fast	
00:24:09	Students		Talking but unintelligible
00:24:14	Student	has it come unplugged?	
00:24:14	Student	it's just not reading	
00:24:21	Student	it's started now	
00:24:22	Student	okay we need to redo our sample then	
00:24:32	Teacher	And you asked somebody to read it off something else, 0.65	
00:24:39	Teacher	0.65 metres per second	Teacher yells to other students who are kick sampling
00:24:40	Students	0.65	lots of students repeat this
00:24:48	Teachers and Students		Talking but unintelligible
00:24:59	Student	getting a bit chilly now	
00:25:01	Teacher	funnily enough my feet are warm	
00:25:04	Student	that's quite impressive	
00:25:07	Student	my little toe, no my big toe in fact is getting numb	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:25:12	Students		Talking but unintelligible
00:25:29	Teacher	take your kick sample so we can get a move on NEW LOCATION	
00:25:47	Teacher	you are not getting in the water here	
00:25:56	Teacher	(student's name) is in the water	
00:25:58	Teacher	get out of the water (student's name)	
00:26:05	Teacher	where's the pot and the stick? Right, where's the other data logging group?	
00:26:08	Student	I've got it	
00:26:08	Teacher	where's the pots?	
00:26:14	Teacher	lets fill with water from the pot on the stick	
00:26:17	Teacher	will you, without falling in, fill the pot	
00:26:21	Researcher	do you need the GPS down there or is it close enough up here?	
00:26:22	Students		Talking but unintelligible
00:27:32	Student	Miss, is the Garmin going to reach up here?	
00:27:35	Teacher	it's the pot, don't you dare! Because the pot has been where I am , it's where the water came from, not where the Garmin came from	
00:27:45	Teacher	right let's see if we can actually get out	
00:27:53	Student	Whoah, oh no!	
00:28:00	Students	laughing	At this point the teacher has lost the pot of water
00:28:07	Teacher	it's broken, the pot and the stick	
00:28:12	Student	that was very expensive, you'll have to buy a new one!	
00:28:23	Teacher	we have lost the pot and the stick (student's name) don't worry about it LOCATION CHANGE	
00:28:50	Teacher	has everybody got the kit that they actually brought down with them?	
00:28:52	Students	yes	
00:28:56	Teacher	has somebody got the, everybody's got the kit that they brought?	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:29:07	Students		Talking but unintelligible
00:29:10	Student	I'll dare you	
00:29:11	Student	I'll fall in	
00:29:11	Student	go on just get in	
00:29:19	Students		Talking but unintelligible
00:29:37	Teacher	now it seems to have shot up?	
00:29:42	Student	can't you make the whole thing waterproof?	
00:29:45	Researcher	well, it could be a recommendation, because they were designed for in class use, er, they're quite robust so just don't drop them in the water!	
00:30:00	Teacher	(researcher) has got you on video saying take your fingers off. . . .	Camera was actually off and doesn't have this supposed comment
		NEW LOCATION	
00:30:06	Teacher	we are moving now into the salt water region of the stream, and those of you who have been walking with me, I've been saying I can't see a strand line, but the strand line is actually behind us, quite high up, can you see the debris just lying here between here and the white clover, that's the strand line for the tide, so we're now moving into the area where it is tidal. Okay we've got one more area we can definitely get	
		NEW LOCATION	
00:30:35	Teacher	yup it's too deep, we'll just do a Garmin sample	
00:30:38	Student	do you want to hold onto this?	
00:30:39	Students		Talking but unintelligible
00:30:59	Teacher	Taken! There we go	
00:31:01	Student	this water looks horrible	
00:31:08	Student	it does it looks like ...	Talking but unintelligible
00:31:08	Teacher	yeah I think there'd have to be an awful lot of that to make a difference	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:31:13	Student	horses can wee a lot at one time	
00:31:14	Teacher	they do, poo, as well	
00:31:17	Teacher	ten poos a day, it's all they do	
00:31:20	Student	they whistle	
00:31:22	Teacher	yes they do whistle	
00:31:28	Student	what's that	
00:31:29	Researcher	if you whistle then they go to the toilet?	
00:31:32	Student	really?	
00:31:32	Researcher	apparently	
00:31:36	Teacher	it doesn't work for birds	
		NEW LOCATION	
00:31:45	Teacher	we're going to have to stay away from the edge, from the salt marsh, head that way and then when we come back here, see where that bloke is, well everybody can definitely get in the water there because it's rocky bottom	
00:31:55	Teacher	because of the ditches they get deeper and deeper and deeper. Right can you stop here for a minute, erm, basically from here on I'm just going to head for the stepping stones because, I'll tell you what I might do, Mr (Teacher's Name) could you go to the stepping stones with everyone else if I took the Garmin people around the edge? and see if I can get another couple of samples, we wont go out of sight will we, we want to kick sample at the stepping stones because the other kids haven't been in the water for ages have they. But, um, while we're here, while we're here, if you look behind you , Oi, biology!,	
		NEW LOCATION	
00:32:38	Researcher	but not anything that's blue	
00:32:40	Teacher	wait, I'll give you a hand in a second	
00:32:41	Teacher	take your snapshot	
00:32:42	Student	I'll go down to the river	
00:32:43	Teacher	got him?	
00:32:44	Student	got it	
00:32:49	Researcher	want to give me those?	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:32:54	Teacher	right don't go in as well (student's name), because I think we're gonna, no don't move! Don't move, stay where you are	
00:33:00	Student	you just don't trust him do you!	
00:33:14	Teachers and Students		Laughing so can't hear what is said
00:33:20	Teacher	the thing is you're now stood where you want to be sampling!	
00:33:23	Student	video, video when he falls over	
00:33:26	Student	we're sampling buddies!	
00:33:29	Teacher	turn it round (student's name), turn the box round	
00:33:34	Student	I'll hold that as well if you want	
00:33:39	Student	right, is this all working	
00:33:43	Student	snapshot, right there we go	
00:33:44	Teacher	now get safely out, equipment first!	
00:33:50	Teacher	boys second because they're, er, ten a penny!	
00:33:55	Student	boys actually aren't though, I'm special	
00:34:05	Teacher	lets go sample, hang on I've got all the equipment , right NEW LOCATION	
00:34:14	Teacher		Talking but unintelligible
00:34:18	Student	no in this part of the river	
00:34:22	Student	we can get in there, we can probably walk along the sand bank,	
00:34:49	Student	who's got the pots?	
00:34:50	Researcher	I've got the pots	
00:34:51	Students		Talking but unintelligible
00:35:09	Teacher	keep your wet shoes on for a bit, because we'll probably all have to get wet feet in a minute	
00:35:16	Student	he's Bear Grylls, I don't think he cares	
00:35:21	Student	mine are getting pretty nasty	
00:35:29	Teacher	right you want to stay dry though don't you? NEW LOCATION	
00:35:41	Teacher	it's quite slow, it's slow past the feet isn't it	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:35:45	Teacher	did you get your sample (student's name)? NEW LOCATION	
00:36:10	Student	er, a pregnant women with, er, ...	Talking but unintelligible
00:36:17	Researcher	does that mean that she died and donated her body? That's quite impressive	
00:36:22	Student	I guess if she died while pregnant	
00:36:27	Students		Talking but unintelligible
		NEW LOCATION	
00:37:15	Teacher		Talking but unintelligible
00:37:30	Student	take one from the other side	
00:37:39	Teacher		Talking but unintelligible
00:37:48	Teacher	if you want to stay dry, cross at the stepping stones but wait for Mr (Teacher's Name) don't move. Alright if you want to keep your feet dry, cross at the stepping stones, this is very slippery, I'd rather you be on the stepping stones	
00:38:07	Teacher	this is horrendously slippery	
00:38:51	Teacher	no, don't be an idiot!	
00:39:14	Teacher	I'm going to go back and cross at the stepping stones NEW LOCATION	
00:39:25	Teacher	and (Researcher Name) is videoing, so come and take over the pots!	
00:39:47	Teacher	right okay	
00:39:49	Student	that'll do	
00:39:51	Teacher	right okay let's go down to the bend NEW LOCATION	
00:40:02	Teacher	the wind is pretty impressive as well	
00:40:05	Student	I like how you're an avid environmentalist but you let that go straight past you	
00:40:07	Teacher	I know, I should have picked it up	
00:40:08	Researcher	we'll catch it up in a minute anyway	
00:40:15	Teacher	there are people, I can't understand them , they do these mountain races ... NEW LOCATION	Talking but unintelligible

Continued on next page

Table L. 24 – *Continued from previous page*

Time	**Person**	**Statement**	**Comments**
00:40:39	Teacher	if I was only coming down for the day I'd never have brought a spare pair	In reference to researcher falling into river
00:40:46	Teachers and Students		Talking but unintelligible
00:41:02	Student	that sounds really good in principle	
		NEW LOCATION	
00:41:34	Teachers and Students		Talking but unintelligible
00:41:39	Student	tell him, he's designed it well	
00:41:40	Researcher	why, what are you saying?	
00:41:47	Student	well you don't have to switch it back on to scroll between screens you can read off all the data and take samples at the same time	
00:41:48	Researcher	oh can you, that's good	
00:41:49	Student	yeah, that's bloody good	
00:41:52	Student	tell him from me	
00:41:53	Researcher	I'll put that in as a quote shall I?	
00:41:57	Teacher		Talking but unintelligible
		NEW LOCATION	
00:42:09	Students		Talking but unintelligible
		NEW LOCATION	
00:42:20	Students		Talking but unintelligible
00:42:24	Student	try this, I'm just sinking	
00:42:38	Student	I'm actually buried	
00:42:46	Student	oh now it's gone to zero	
00:42:49	Teacher	it's got weed around it	
00:43:04	Researcher	it might have weed inside it	
00:43:10	Student	did you break it!	
00:43:10	Teacher	no it got weed in it	
00:43:20	Students		Talking but unintelligible
		NEW LOCATION	
00:43:47	Student	these shoes are gonna smell awful	
00:43:50	Teacher	yeah that's why we leave them in the back porch	
		NEW LOCATION	

Continued on next page

Table L. 24 – *Continued from previous page*

Time	Person	Statement	Comments
00:44:14	Teacher	the tide's coming in, it will be good for your salinity	
00:44:27	Student	it's actually coming in, we're standing here and it's coming in!	
00:44:35	Teacher	Right I think we need to rescue your bag	
00:44:45	Students		Talking but unintelligible
		NEW LOCATION	
00:44:58	Teacher		Talking but unintelligible
00:45:05	Teacher	where did you get the water from, because this is the (Talking but unintelligible), the Garmin will pick it up	
00:45:31	Teacher	warm water is fresh water	
00:45:49	Students		Talking but unintelligible
00:46:00	Student	not a lot of salt in it	
00:46:02	Student	he just put his tongue in it!	
00:46:05	Researcher	very scientific	
		NEW LOCATION	
00:46:12	Students		Talking but unintelligible
00:46:21	Teacher	we've got to get to them before they move off, because the tide is actually approaching them really rapidly	
00:46:38	Student	I was hoping that someone would struggle and need help so I could purposely get in the sea today	
00:46:46	Student	what are we doing tomorrow?	
00:46:47	Teacher	tomorrow we'll go up to a wreck	
00:46:55	TAPE ENDS		