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Will the lights stay on?

Glow and Embedding ICT into Secondary School Curriculum Subjects: A Quantitative and Qualitative Design-based Classroom Study

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WILL THE LIGHTS STAY ON? GLOW AND EMBEDDING ICT INTO SECONDARY SCHOOL CURRICULUM SUBJECTS; A QUANTITATIVE AND QUALITATIVE DESIGN-BASED CLASSROOM STUDY.

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ABSTRACT

A review of recent literature shows that despite huge investment in ICT, few if any have been able to report tangible learning gains from ICT-based teaching as measured by exam results or other quantitative, comparative behavioural measures. In contrast this project is able to report one instance of such gains in a quasi-experiment that allows strong statistical inferences to be established. Four parallel S3 classes were tracked, each working through the same modules forming part of standard grade Biology. Results were tested using summative instruments of assessment using topic-specific questions from past standard grade Biology papers, and an end of year exam. In one of these classes, after two modules taught without it, one module introduced ICT timetabled for one of three lessons each week over one school term, with a mixture of independent and collaborative learning tasks reinforcing the learning objectives for that week. These were delivered using GLOW (the Scottish School's Digital Network) as the platform. Results for the same class with the same pupils and same teacher showed a mean increase of 32.27% marks for the GLOW vs. non-GLOW modules ($p < 0.01$; effect size Cohen's D of >1.0). Comparing this class and teacher to others show that the attainment on the non-GLOW modules was very similar, and significantly less than the best of the four classes, however, on the GLOW module, it was better by 14.69% marks than the mean of the other three classes. Further examination of the results showed that the weaker students benefited as least as much as their more able classmates. Furthermore on the end of year exam, which re-tests all 3 modules in a way comparable to the eventual standard grade exam, the class that had received GLOW based teaching in one module achieved higher average marks even though only one third of the questions were on the topic taught using ICT/GLOW, hinting that a multiplier effect may be operating. The challenges of embedding ICT into subject curricula are discussed, and suggestions for a model of good practice made. This use of ICT could facilitate a partial move away from a predominantly subject based focus in teaching to the more applied approach as

advocated by a Curriculum for Excellence. Phase two of this study will address the issue of sustainability, teacher experience, collect measures of teacher time, effort, and training, and collect classroom observational measures to investigate what detailed changes in the teaching approach were associated with the ICT-based lessons, and which may therefore underlie the learning gains measured.

Keywords **a**ttainment, embedding ICT, quantitative measures, GLOW,

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1.0 INTRODUCTION

1.1 Rationale

GLOW has arrived in many of our schools introduced by a fanfare of superlatives. 'Lighting up learning' and 'When the lights Glow on' being just two used in the promotional material for this new (and somewhat delayed) ICT initiative. This small-scale research project originally set out to examine the challenges involved in introducing and maintaining regular, planned, and pedagogically worthwhile use of ICT as an integral part of the secondary school curricular subjects. Classroom –based research has historically often been undertaken to examine new and innovative educational initiatives and can provide a context of relevance, situation, and direct application of results (Candela et al 2004). However very often research and design proceed in sequential steps without much of an element of synergy between the two and thus appear to have had very little influence upon the classroom practice of Scottish teachers. This is particularly true of developments in ICT which have failed to live up to the transformative expectations envisaged by the researchers, planners and policy-makers driving educational practice. In this project, GLOW was used as the platform for a computer-based ICT programme of learning in the biology standard grade course. As a modular course comprising seven distinct units each assessed by a summative end of topic test, this provides a useful vehicle for the introduction of ICT timetabled for one of three lessons each week over one school term and comprising a mixture of independent and collaborative learning tasks previously prepared by staff and with the aim of reinforcing the learning objectives for the week's lessons. It was hoped that statistical comparisons with other S3 classes following the same topic at the same time might allow for a measure of assessment as to the potential effectiveness of using the GLOW virtual learning environment (VLE) in teaching and learning (based both on quantitative summative assessment comparisons and qualitative measurements of teaching and learning activities) and might give a valuable insight into the challenges of embedding ICT into a subject curriculum. This use of ICT could facilitate a partial move away from a predominantly subject based focus in teaching to the more applied approach as advocated by *a Curriculum for Excellence* (i.e. shifting the focus in teaching and learning away a little from

outcomes to processes; including how the road is to be travelled rather than just the destination to be reached). It was also hoped to be able to design a model of good practice for how to implement and maintain the use of GLOW into everyday use in secondary school subjects by using the experiences gained through this case study on the use of ICT *in* subjects as opposed to ICT *as* a subject.

Windschitl 1998 states that *"Qualitative and interpretive research approaches are valuable in investigating educational phenomena in novel fields"* and as such the approaches to and experiences of embedding ICT into the curriculum during this study may give valuable insights to this challenging problem for others working in this area of educational practice, management, funding, and policy-making.

1.2 The national context to this research study

Increasingly in Scottish schools, the onward march of technological innovation presents a challenge to drive pedagogical change and build capacity in learning styles. More specifically, the pace of development of ICT presents a challenge due to the high expectations of governments and national bodies which have devoted huge resources to the 'computerisation' of our schools. The term ICT encompasses the range of hardware desktop and portable computers, interactive whiteboards, palm-held calculators and computers, data-logging devices, and digital-recording equipment, software applications , generic software, multimedia resources and increasingly, freeware applications such as Podcasting and blogging platforms, VLEs such as Moodle and information systems (both intranet and internet) all of which are now available in schools to a greater or lesser degree depending upon local funding and development priorities. The *Scholar* programme of computer-assisted learning packages for post compulsory education (highers and advanced highers) provides support and tuition both to teachers and learners across the whole of Scotland. The value of ICT in teaching and learning has been the subject of much debate within the education community for some time. Vast amounts of money have underlined and reinforced the commitment of successive UK governments to ICT, not just in schools, but to enhance and facilitate life-long learning. This investment has been justified on a premise that ICT can change the nature of teaching shifting the pedagogy from a

didactic dispensation of knowledge to facilitating knowledge acquisition, improving the focus and quality of teaching and learning and ultimately lead to rising attainment measured by summative assessment (certificate examination results). Initiatives include the National Grid for Learning (NGfL) investment in hardware and software for educational establishments, the establishment of computing as a distinct certificate subject, ICT as a part of undergraduate degrees and initial teacher education (ITE), as well as a raft of training made available as a part of teacher's CPD programmes. The *computers for teachers* scheme in England and Wales has been one of many initiatives designed to encourage the increased use of ICT by teachers in school. Historically, these expensive initiatives (£900 million pounds for the NGfL alone) have come with huge hopes for transformative gains in attainment which have generally not been realised, for many reasons which will be examined during the course of this introduction. The cost of this investment is often justified by evidence from research supposedly supporting improvements in both the quality of teaching and learning and better attainment, year on year. However, this evidence is often contradictory and leans heavily toward the qualitative aspects of ICT use, the quantitative evidence supporting improved attainment being somewhat less obvious. The GLOW virtual learning environment (VLE) is the latest of these national initiatives, currently being rolled out across Scotland, managed by Learning and Teaching Scotland, RM, and partner local education authorities. With a development cost of some £37.5 millions this represents a major investment by the Scottish Government in ICT provision in schools.

1.3 Different perspectives on ICT use.

According to Reynolds et al (2003) perspectives on the use of ICT in schools have generally fallen into one of three categories. *Optimist rhetoric, Pessimist rhetoric and Research evidence.* They state that it is the optimist rhetoric that has driven the UK investment in ICT in recent years. Optimist rhetoric is characterised as being endemic to the educational establishment in the UK. This is a reference to government bodies, such as national departments for education in England and Scotland, and local

education authorities as well as the inspection regimes and non-governmental organisations (NGOs). Such organisations include Learning and Teaching Scotland (LTS), Her Majesty's Inspectorate of Education (HMIE) and the General Teaching Council Scotland (GTCS) in Scotland, and the British Educational Communications and Technology Agency (BECTA), the Office for Standards in Education (OfSTED) and the General Teaching Council (GTC) in England and Wales. Also included are politicians, industrialists, civil servants, the media, and advisory services. Reynolds Treharne and Tripp are of the opinion that much of the research put forward by many of these bodies is methodologically unsafe in suggesting as it does, a link between increased use of ICT and improved standards in schools, and that this has been used by these organisations as justification for the massive investment in ICT that has taken place in the UK in recent years. They argue that many of the so-called 'optimists' claim evidential support for their stance when in fact they are using what amounts to a theoretical approach which is unsupported by good quality quantitative evidence. They report BECTA's use of statistics gathered by OfSTED during primary school inspections to substantiate claims that schools with better ICT resources had better achievement than schools with poor ICT resources as a good example of this so-called optimistic rhetoric highlighting a methodological problem with the cause and effect relationship in the research published by BECTA. Not surprising perhaps as this organisation is after all, in the business of promoting ICT in education, and so Reynolds et al refer to much of this work as "rhetoric couched as research". This optimist-rhetorical view is echoed by Conole (2007) who agrees that technologies are promoted by e-learning policy directives both in the UK and abroad but without the actual changes in pedagogical practice envisaged by the proponents of those policies, a focus on the technology rather than pedagogy which has been characteristic of more recent ICT developments in education despite the improvement in available hardware and high-speed broadband access. This issue will be re-visited later in this introduction.

The opposing view, according to Reynolds et al is the so-called Pessimist-rhetoric. This is often rooted in cultural opposition in principle to the use of computers in any form in schools by organisations which argue that computers de-personalise learning and by the nature of the work involved promote a sedentary lifestyle which is claimed to be unhealthy. Reynolds et al give the example of the Alliance for Childhood in the USA as taking such a stance. Another strand of pessimist rhetoric might perhaps be

the teachers in schools who refuse to use ICT in their classrooms citing the lack of research indicating any concrete benefits to learning, or lack of reliable equipment and quality training. The most recent of the HMIE reports in Scotland on the use of ICT talks about a 'hardcore of staffroom cynics' who refuse to involve the regular use of ICT in their teaching.

The third group in the Reynolds et al paper is the academic research community who have been trying to empirically evaluate the impact of ICT upon teaching and learning over recent years. Their research has consistently refuted the claims of the Optimist-rhetoricians according to Reynolds and his co-researchers who state that their focus is too much on the hardware at the expense of the pedagogy. They highlight the danger of the technology becoming the focus rather than the teaching, and finish by calling on the academic research community to subject the optimist-rhetoric to the same objective examination required by academic research itself.

Which aspects of ICT are used also varies widely, with use of the World Wide Web and word-processing generally being much more frequent than networking using web 2.0 tools and conferencing. Future research needs to address the question of whether this current use of ICT changes pedagogy and promotes new learning practices.

The large body of research on this subject appears to concentrate on a qualitative perspective; on the so-called 'soft' indicators of success with ICT such as motivation, enjoyment, engagement and variety of learning approaches for pupils, and on the issues surrounding increasing use by teachers and the necessary capacity-building in schools to facilitate this increased use but which are difficult to quantify though nevertheless used to justify increased expenditure on ICT. Draper and Nicol (2006) go further. They state that '*the majority of ICT applications to education have declared success because the technology almost always worked, the learners quite liked it, and some learning occurred. They have not been able to show improved learning compared with non-ICT approaches*'. The research on the quantitative aspects of ICT use to raise attainment is harder to find. Harrison et al (2002) did find some evidence of positive impact on attainment due to the use of ICT notably in Science at key stages 3 and 4. Condie and Livingstone (2007) report 'superior' performance in higher and advanced higher examinations from students using the *Scholar* computer-assisted learning programme based on an analysis of performance in collaboration with the SQA. However, these findings should be considered with caution and as

generalist rather than indicating specific gains in attainment due to ICT use, being based on considerations such as the theoretical availability of the *Scholar* materials to all Scottish students rather than actual use. One has to look towards other European countries such as Finland for more of this type of research, particularly the work being done at the Centre for Research on Networked Learning and Knowledge Building, part of the psychology department at the University of Helsinki.

1.4 Teachers' attitudes to ICT

Recent educational initiatives, particularly 'Assessment is for learning' (AiFL) and 'A Curriculum for Excellence'(ACfE), rightly focus attention onto the cross-curricular and holistic transferable skills necessary for success in a 21st century Scotland and the recent reports by Her Majesty's Inspectorate of Education (HMIE) focus on the vital part ICT should play in the realisation of these aims. The most recent in the series of HMIE reports was critical of schools over their adoption of ICT across the curriculum and in particular highlighted the negative effect of a so-called hardcore of 'staffroom critics' on the progress of increased use of ICT. This was also found by Husing and Korte (2007) in their pan-European survey which showed that older teachers with more classroom experience were most resistant to the introduction of ICT. This is significant as teachers have a major impact on the attitude towards learning held by their pupils. Cuban (1986 cited in Postholm 2006) talks about how what he refers to as 'dominant cultural norms' have a neutralising effect on development. This can perhaps explain how the hardcore of staffroom critics referred to by the HMIE report can have so much influence in school subject departments. With respect to teaching and learning one can see how years of experience built up by teachers in developing their classroom practice could be very hard to change, thereby hindering the development of newer pedagogies, particularly when harnessed to a distrust of educational research and publications by quality assurance inspection regimes such as HMIe and from local authority quality improvement officers. Goodson and Mangan (1995, cited in Hennessy et al 2005) discuss the way in which the expected changes fit

with existing subject teaching practices, content and pedagogical paradigms. They term this closeness of fit as 'congruence' and considered teachers to be reluctant to adopt a new way of working which appears to them to be incompatible with their current subject pedagogical approaches or 'antecedent sub-cultures' as they term them (this is very similar to Cuban's idea of the dominant cultural norms that might exist in education). Selwyn (1999) had previously explored this issue of distinct subject cultures finding that computer use was more 'congruent' with some subjects' historical approaches to teaching than others and therefore more likely to be integrated into classroom practice, describing this as "*a sense of ownership by some subjects and an unfamiliarity and suspicion for others".* Cuban agrees that the use of ICT has to mesh with the way a particular teacher actually works in the classroom (the 'why' rather than the 'how'). This is where perhaps the pessimist rhetoric referred to previously comes into play with teachers perceiving extra demands on their time for little or no gain, rather than a recognition that the actual pedagogy might change by a shift away from a didactic dispensation of knowledge to that of a learning facilitator or advisor using more of a scaffolding approach (Wood et al 1976) to student learning in their classrooms. Most teachers will be familiar with the concept put forward by Vygotsky (1968) of the 'zone of proximal development' a part of his socio-constructivist theory of learning. In this, Vygotsky asserts that the difference in knowledge between two or more people can be used to help advance learning. Thus a teacher and more able peers can help a student to complete tasks that they previously could not do without help. Postholm's (2006) study shows how using ICT can help this to happen by mediating and encouraging dialogue between teachers and peers, and just as importantly between peers of different abilities. Classroom based research on how this can result in the same time being spent more effectively by the teacher might be a useful tool to help break through this pessimist rhetoric barrier, particularly as it has been reported that teachers who do use ICT noted that it had resulted in little or no reduction in their workload (Cunningham and Harris 2003). This same report also found that 43% of primary and 35% of secondary school teachers stated that they felt there had been an increase in their workload due from their use of ICT, predominately from loading and maintaining school sites with their materials. Contradictory research by Coles, Richardson and Tuson (2000) however finds the level of motivation of teachers to use ICT to be high, with over 97% of teachers surveyed stating an intention to use ICT in their teaching at some stage in the future.

Whilst this is encouraging, they qualify this optimism by stating that their findings of such intentions do not translate into regular and sustained use of ICT by teachers, the main barriers being lack of training and hardware, both of which appear to be a common theme as barriers to increased use. This research also found that the greater the access to ICT, the more a teacher's use focussed on the pedagogy rather than the technology. Whilst this is encouraging, the ImpaCT2 report four years later indicates that *relatively few teachers are integrating ICT into subject teaching in a way that motivates pupils and enriches learning or stimulates higher level thinking and reasoning*. Does this mean that the teachers who do use ICT are simply paying lip-service to implementing policies from above? Indeed the few teachers who are implementing ICT in the hoped-for and expected transformative model are perhaps those who already possess an innovative pedagogic outlook. Hennessy et al (2005) maintain that this is due to classroom teachers historically having little say in implementing development plans for ICT use within their schools and subjects due to a centralised curriculum and corresponding perceived lack of professional autonomy with regard to teaching and learning. In other words, teachers are just not used to having to make paradigm shifts of such magnitude as has been expected following the advent of ICT. Postholm(2006) also explores the issue of pedagogical change in more depth concluding that good quality training can effect change and importantly help teachers to recognise the specific areas where ICT can be used effectively in their classrooms. This theme of quality of training was another common strand (together with the technology/pedagogy issue) in much of the research and will also be revisited later.

Other research in this area can appear (at first sight anyway) to be somewhat contradictory, particularly with regard to classroom teachers' use of ICT in their work. Husing and Korte (2007) in their survey claim to have found that 96% of UK teachers surveyed reported that they had used ICT in class in the year prior to the survey, however, the earlier ImpaCT2 report (Harrison et al 2002) suggested that roughly 60% of UK teachers made little or no use of computers in their everyday classroom practice, despite the increased focus on ICT in initial teacher training courses since the early nineties. These statistics seem to suggest that in the space of four years, classroom use of ICT by teachers in the UK has risen from 40% to 96% (of teachers surveyed), at face value, an incredible improvement! Unless one pays a

somewhat closer attention to these figures and the amount of ICT use to which they refer.

Attitudes towards the use of ICT also differ amongst teachers of different subjects, with business management teachers having the most positive attitudes, and Maths and Science teachers having the most negative, according to the ImpaCT2 report, however, Husing and Korte, reporting their findings four years later tell a different story, stating that 80% of Maths and Science teachers use ICT amongst the highest of all those subject teachers surveyed. Hennessy et al (2005) also found that Science departments were more positive about the educational benefits of ICT use, whilst Maths departments were the least resistant to its introduction into their classrooms. Perhaps this is due to improvements in technology and a realisation that ICT use allows these subject teachers to introduce simulations of work previously impossible to undertake due to danger or complexity. This also illustrates a change in pedagogy of sorts as the pupils can run the simulations rather than the teacher demonstrating, which is possible due to the gradual improvements over time of both the hardware and software available to teachers, but perhaps more due to teachers realising the possibilities ICT has to offer.

With the spotlight currently on behaviour problems in education it is surprising perhaps that the research on the motivational and engagement qualities of regular ICT use has not appeared to be a factor in increased use of ICT by many teachers. If looking for a way to persuade class teachers to increase their use of ICT then Denning's (1995 cited in Reynolds et al 2003) research which found that 61% of pupils who claimed to 'always' misbehave in class stated that using ICT re-engages them with their learning to the point where they 'don't want to stop' at the lesson's end. This might be a powerful piece of advocacy on behalf of increased ICT use. Further to this, the research discovered that over half of regular truants said that they found lessons involving ICT much more interesting. Surely any means of ameliorating poor and disruptive behaviour in class must be a useful selling point for its uptake by teachers particularly if it also raises the attainment of these particular pupils and of others who presumably will now not have their education affected by the bad behaviour of others. This is a particular favourite topic of the popular press at the time of writing.

Some schools appear to be more successful than others in implementing ICT into their everyday practice. Tearle (2003) carried out a case study of a school where the use of

ICT by almost all staff in all curriculum areas was a regular part of the teaching and learning and noted that the school was characterised by four important and defining features. These were

- Strong leadership and high expectations.
- A positive ethos and collaborative culture which promoted learning.
- Well motivated and caring staff.
- The whole school, not just ICT use, viewed as being 'excellent'.

This study illustrates the importance of leadership by stressing the importance of the ICT coordinator having good interpersonal skills as well as a focus and commitment to the task of implementing and maintaining the school's ICT policies. This can be significant when one considers how the use of ICT can affect the culture and ethos in schools. This is particularly evident in the administration procedures and management structures which may require teachers to adapt or change traditional ways of working to accommodate this into their everyday working lives. An example might be a shift away from daily notices and announcements from paper copies onto a school VLE. Other considerations might be changes in the way teachers collaborate with each other. ICT facilitates an enhanced level of cross-curricular and inter-establishment collaboration and this needs to be managed carefully. Venetky and Davis (2001, cited in Lakkala and Ilomaki 2007) outlined ways in which schools have done this, including shifts from hierarchical management structures to more horizontal ones and the promotion of the staff as a 'professional community' rather than the traditional view of them as a group of employees.

It would seem then that main barriers to increased use of ICT in classrooms by teachers highlighted by the published research appear to be lack of quality training, lack of available hardware and resources allowing sufficient access, and a perceived extra workload for little or no educational benefit. The availability of useful software appears to be less of an issue, perhaps due to an awareness of the ready availability of open-source free resources on the internet which can be readily adapted by teachers after some training Of course, the research does throw up contradictions with regard to these barriers, and it is sometimes difficult to find a way through this. However, much of the research highlighting hardware issues dates back more than five years, during which broadband access and higher specification computers have become the

norm in educational establishments. This leaves the issues of motivation and training, which are still problematic. Cuban's term of 'dominant cultural norms' is significant because the resistance to change by older more experienced teachers highlighted by the HMIe report could have a negative impact on student teachers who will become new entrants to the profession. Also highly relevant are Selwyn's earlier findings about the likelihood that some departments would use ICT more than other departments due to their perceived historical pedagogical approach, thus placing student teachers in a 'lottery' situation with regard to observing the use of ICT in teaching and learning whilst on placement. Is it perhaps a fear of losing control in the classroom as well as pre-existing subject culture that prevents the uptake of ICT by these experienced classroom teachers masked by references to quality of training and relevance to teaching and learning? Jones (2004) reports a lack of confidence by teachers with using technology in the classroom particularly in front of students who may be more skilled than them in using ICT, leading in some cases to feelings of anxiety. This would undoubtedly increase this sense of losing control. And if so, does this influence the quality of the school experience for student teachers on placement? The conclusions of most of the researchers in this section would point unfortunately to this being the reality rather than the exception. The school-level change stimulated by the use of ICT in the management and support structures might well be seen to be adding to this sense of loss of control felt by teachers, although it appears that this is at least addressed by giving teachers a greater feeling of being a part of a group of professionals and adapting the management structures within the school to give them more of a sense of ownership on decision-making. This can also be important in the implementation of ICT into teaching and learning which has been shown to be more successful if the whole school is involved with the decision-making process behind the introduction programme. Teacher anxiety over being replaced by technology or losing their authority in the classroom as the learning process becomes more learner-centered—an acknowledged barrier to ICT adoption—can be alleviated only if teachers have a keen understanding and appreciation of their changing roles in the classroom. All this indicates just how significant school leadership can be in the success or failure of ICT pedagogical initiatives. Baggott La Velle et al (2003) are of the opinion that the production of an evolving body of case-studies relating to experiences with ICT provides evidence and can exist as a vehicle for dissemination

of good practice. This type of research can act as a starting point for such school-wide ethos, leadership and thus pedagogical changes.

1.5 Student teachers

As well as pupils, teachers are also acting as mentors to student teachers. The importance of teachers in training adopting teaching strategies involving the regular planned use of ICT should not be underestimated. If the use of ICT is to be increased then new entrants to the profession must be given the necessary training and the opportunities to use ICT during their courses and placements. Barton and Haydn (2005) surveyed trainee teachers on what helped them to use ICT effectively in their subject teaching. They found that role models (teachers in schools using ICT regularly and effectively) were pivotal in their future practice in this area. The research found that this in-school use was more influential than centrally-run university ICT courses which were viewed as dull and not relevant to school practice. Interestingly, this research also found that trainee teachers' use of 'official' sites such as the National Grid for Learning (NGfL) and the Virtual Teacher Centre (VTC) was very low, if used at all. The reasons cited for this were lack of both awareness and time. This is important as these sites, particularly the NGfL were seen as a key plank of the government's strategy for delivery and building of ICT capacity. This also has significance for the future use of GLOW, in many ways, a platform which builds on the collaborative elements of the NGfL. Will use of the GLOW tools be any better than those within the NGfL? And will the lessons, identified by Barton and Haydn in their research from NGfL be considered with regard to GLOW, especially its use by trainee teachers on placement in Scotland? Another significant barrier to ICT use by trainee teachers was found to be a lack of resources. This again is interesting as the NGfL was envisaged as a 'repository' of resources created by and for the use of, teachers, but which many of the trainee teachers did not find useful. 'Learn' is planned to be a vehicle for exchange of materials by and for teachers using GLOW. Will this fare any better than the NGfL?

The Barton and Haydon research also discovered that the trainee teachers surveyed preferred to use ICT in the classroom rather than have their classes visit special ICT suites. This was also noted by Smeets (2004) who stated that *the presence of a computer room appeared to decrease the amount of skill-based ICT use.* The issues highlighted here tend to be ones of 'disjointed' lessons out of context with the course and whole lessons having to utilise ICT rather than using it in context where appropriate. Given that they found the use of computer suites to be the norm for individual pupil work, and the fact that this is the normal *modus operandum* in Scottish schools which rarely have more than one computer in other classrooms, this may be a discouraging factor in their future use of ICT as fully qualified teachers. Many local authorities and schools across Scotland are investigating the use of 'mini pc's' and wireless hubs as a solution to this perceived problem of access to hardware.

1.6 Implementation of ICT into teaching and learning.

Finger and Russell (2005) identify three stages of ICT implementation in education. These are *skill acquisition,* where ICT skills are learnt and adopted into practice, *enhancement of teaching,* as students become more confident in the integration of ICT into their curricula, and *transformation,* where ICT changes both what and how the students actually learn. They state that this third stage is not a natural step, but is very dependant upon their teachers' views on the world and change (i.e. do their teachers embrace new pedagogies and use them to transform their teaching, or are they limited by a fear or dislike of the emerging technologies). It is this third step which can bring about the transformation of teaching and learning hoped for by funding providers and policy makers. Cox and Webb in their 2004 review of the research evidence relating to ICT pedagogy felt that the introduction of ICT into schools over the past twenty years has had very little effect upon the ways in which teachers actually teach their classes. They are of the opinion that this is because teachers hold the view (perhaps due to their experiences with computer assisted learning at university) that ICT is more suited to independent working by students which they feel has been discouraged

by the drive to raise attainment. However, other research, particularly that from Norway (discussed elsewhere in this introduction) and Finland (Lakkala et al 2001, Ilomäki, Lakkala, and Lehtinen 2004) contradicts their findings, demonstrating a pedagogical shift from didactic knowledge dispensation to learning facilitation. Thus we find ourselves with a rather delicious paradox, particularly here in Scotland. On the one hand, the inspection regime is currently pushing the adoption of ICT into teaching and learning as an important part of *A Curriculum for Excellence* and on the other hand, teachers are very mindful of the annual SQA results review and corresponding constant pressure to drive through a packed curriculum to improve results. More alarmingly perhaps, is the report of ImpaCT2 (BECTa 2004), a major English study which indicates that even when they do involve ICT into lessons, 'relatively few teachers are integrating ICT into subject teaching in a way that motivates pupils and enriches learning or stimulates higher-level thinking and reasoning'. The all too familiar scenario of pupils making up endless Power Point presentations using textbook notes and 'scattergun' google searches springs depressingly to mind here. Teachers who do use ICT tend to use it to complement existing forms of teaching and learning rather than to change existing pedagogical practice. The bridging of the gap between what is perceived as school learning and the real world is more often than not neglected. This is unfortunate as good use of ICT can contextualise learning by situating it in the 'real' world through use of media such as film/video, periodicals, animations and web-cams of places of interest being studied. Cuthell(2005) likens the necessary process involved in driving forward change in working practice necessary to transform teaching and learning by using ICT as 'steering a supertanker'. By using this analogy, he suggests that before changes in direction can be effected in schools, a considerable amount of forward planning needs to occur. This analogy perhaps alludes to the difficulty in getting some teachers to change their existing ways of working. The Norwegian experience shows that these difficulties can be overcome when teachers have access to high quality in-service training which focuses on pedagogy rather than technology. This was supported by the findings of Tondeur *et al* (2007) who stressed the importance of flexible and school-based training coupled with continuing support and follow-up activities to reinforce this initial training. In other words, quality training concerned with the application of ICT to classroom teaching is necessary to ensure that the 'supertanker' is able to change direction.

Marc Prensky (2001), writing on the subject of ever advancing technology uses the term *digital natives* to describe the children of today who have been brought up surrounded by such devices as mobile phones, computers, games consoles, instant messaging and web cams. He argues that learners who grow up in this age assimilate it into their everyday understanding and assign a place in their world to this technology. He further argues that their cognitive development is influenced by this lifestyle in ways such as the ability to multi-task, a preference for graphics and games over serious work, and being used to receiving information at high speed and in a disorganised fashion (such as hypertext). Prensky asserts that this will have serious implications for education now and in the future. Certainly with regard to pupils sensing a 'digital divide' between them and their less adept (in the use of technology) teachers, having shorter concentration spans, and making the link between school work and the world they inhabit. He goes on to describe how the school curriculum must be changed to suit these characteristics of the 'digital natives'. He points in particular to the ability of game designers to engage and motivate and asks how we might harness this creativity so as to enhance the learning environment in schools and the curriculum content in the 'Playstation Age' If we consider that our classroom learners will have sent and received over 200,000 text-messages, instant messages and e-mails by the time they leave school, perhaps this digital literacy needs to be recognised in teachers' use of technology to influence their classroom pedagogies in order to meet this ever increasing pace of development in the world. This concept of digitally native young people is perhaps illustrated by the findings of Condie and Livingstone (2007) with regard to the use of the *Scholar* programme of computer-assisted learning by students and teachers. They found that fifty-six percent of students registered used the on-line materials for up to two hours per week. In contrast to this, few teachers reported making use of the on-line student progress monitoring tools available to them. Furthermore, there was a limited awareness by teachers of the level of home use of *Scholar* by their students. As few as twenty-five percent of teachers reported using the on-line materials in class and much of this limited use was simply of the animations of concepts that are available. Condie and Livingstone suggest that this failure of teachers to use the on-line monitoring tools to build upon the students' independent learning is an opportunity missed. Certainly ICT can be used to bridge the gap between independent and classroom learning, and these findings perhaps illustrate Prensky's concepts of students as *digital natives* and

teachers as *digital immigrants* rather too well (the term *digital immigrant* is used by Prensky to describe someone, usually and adult, who has not been brought up in the digital age, but has tried to adopt the digital technologies into his/her working and social life. Digital immigrants often leave 'traces' such as printing off e-mails and on-line documents which identifies them as 'immigrants'). Interestingly, they also report that fifty-six percent of teachers interviewed discount the possible effect of the use of *Scholar* on a reported superior SQA examination performance by the whole student cohort over the two years of their analysis. Condie and Livingstone suggest that this lack of recognition of the possible impact of the on-line tools on learning was due to the teachers being unaware of the level of independent use by students and that the impact of *Scholar* on results might be greater if teachers could use it to engage students in the learning process. This might be a useful way to encourage teachers to take advantage of the Prensky digital native theory to enhance teaching and learning using ICT to raise attainment. Might this be one way to effect an increase in the use of ICT by teachers, particularly if it can indeed be shown to impact upon student attainment evidenced by the examination results which are so important to subject department effectiveness measurement each year? *Scholar* is an established part of higher and advanced higher teaching in most schools and is familiar to teachers. Training on the available tools to show teachers how they might be used more effectively to support teaching and learning might provide a useful way of opening up the minds of teachers to the possibilities of other ICT- mediated pedagogies in their subjects. The goal of the optimist rhetoric and educational design communities of achieving widespread technologically enhanced learning environments is still some way in the distance.

1.7 Technology vs. pedagogy.

Researchers have long tried to investigate the reasons behind this low take up of computer use by teachers. The work by Postholm referred to in section 1.3 touches on this reluctance. Jones (2004) cites a lack of confidence in using technology as a significant determining factor in teachers' use of ICT. Steve Draper and David Nicol (2006) were of the opinion that the centralisation of computer training for undergraduates and a requirement for them to undergo this instruction removed many barriers to and resulted in increased use of ICT in university teaching. They concluded that as barriers are removed and life is made easier for teachers by this provision of ICT training for them, adoption of new pedagogical approaches will take root much quicker. In other words, teachers must be convinced of the benefits of computer assisted learning and the use of ICT and recognise a benefit to them personally before they are willing to adopt this new way of delivering their courses to pupils. Draper and Nicol also felt that teachers are more likely to adopt new approaches if they are able to talk with colleagues who have successfully instigated the same changes in respect of their own teaching. Research has shown that when pedagogical changes are effected there can be quantitative improvements in attainment outcomes. Mazur's (2001) work on "Peer Instruction" is an example of innovation driven primarily by a pedagogical idea, rather than by technology, that has achieved large improvements in attainment outcomes measures, and subsequently been adopted by other institutions. Another example of this approach might be 'Assessment is for learning' (AiFL) in Scottish schools following the work of Paul Black and Dylan Wiliam on formative assessment to raise attainment (1997). This peer instruction method reported upon by Mazur effected a pedagogical change introducing time for discussion between students in Physics classes, worked into lesson plans based around structured "Concept Tests" designed to assess understanding of the concepts discussed. Crouch and Mazur (2001) have reported on their experience (since 1991) with this approach, demonstrating that it lead to large gains in attainment compared to the pedagogy employed with those same Physics classes in the years prior to the study. The change in and use of the pedagogy rather than the instrument of delivery itself is the important factor here. This last point throws up interesting questions related to this particular research project: can any gains in attainment be attributed to the regular element of ICT embedded into the course delivery, or might any such gains be due to

a change in the pedagogy? And is it the use of ICT itself which might cause this change in pedagogy or does the pedagogy change to accommodate the ICT input? In other words, how could cause and effect be established? Sutherland et al (2003) certainly felt that *there is a tendency to think of ICT as so 'new' that its use will be accompanied by 'new' pedagogies that will somehow transform teaching and learning.* They further state that this created a 'utopian' vision on the part of policy-makers and practitioners which resulted in some basic tenets of the teaching and learning processes central to all learning whether delivered by ICT or not, being ignored.

Research by Cox et al (1999) found that perceived ease of use and usefulness were important factors influencing the uptake of ICT by classroom teachers. This would seem to fit well with Mazur's conclusions about the need to demonstrate quantitative improvement in order to effect pedagogical change, however, other research has focussed upon the different perceptions of the value of ICT and that of the teachers who have to implement the policies that come with such high expectations (pessimist rhetoric). Shulman (1987 cited in Almas and Krumsvik 2007) talks about how pedagogy and subject knowledge are often viewed entirely separately, and states that this has been a problem with education for decades. One can certainly see this at times in secondary schools in Scotland, with teachers defining themselves as subject specialists rather than teachers. Almas and Krumsvik certainly feel that there should be more of a 'symbiotic' relationship between the two echoing Shulman (1987) who asserts that it is at this 'intersection of knowledge and pedagogy' where the really important part of a teacher's work exists. It is here at this junction between the teacher's knowledge and the way that this knowledge is imparted to pupils that the use of ICT needs to be integrated to improve the way the two are joined up. Tondeur et al (2007) report similar problems in Flanders, Belgium finding that teachers focus mainly on the development of technical ICT skills whereas the curriculum focuses on the integration of ICT as an aid to teaching and learning. The importance of this pedagogy has been researched by Smeets (2004) in a study which looked at the specifics of the teaching process using ICT whether its use contributed to what Smeets termed 'Powerful learning environments' where computers were used by pupils to access learning activities which were contextual and authentic (related to the real world) and involved active participation (open-ended tasks) rather than a simple transmission of facts (closed tasks). Smeets characterises these powerful learning

environments in four ways involving rich contexts and authentic tasks, stimulation of active and independent learning, collaborative learning stimulated, and a curriculum adaptation to take into account the needs of different individual pupils, or differentiation. Smeets found that computers, whilst they might be used for remedial-type learning for poorly performing pupils were rarely used to stimulate the learning of more able and gifted pupils. These are often the ones who, unchallenged by their work, become bored and disengaged by school based learning.

Overall, the Smeets study found that ICT when used in this way was effective in raising attainment. This is significant as it appears to underline the conclusions of much of the research cited in this review so far about the importance of quality training for teachers which focuses on pedagogical rather than technical issues. These powerful learning environments seem to lend themselves to ICT very well, if the teacher can relate the computer based resources to the four Smeets characteristics. Thus it can be seen how important this aspect of teacher-training really is, as without the knowledge of how to author or find resources tailored to the teacher's specific subject, ICT might end up being used simply for the transmission of factual information in the same way that a pupil might be asked to study a book. In this case, there is no real transformation of pedagogy by using ICT and the arguments against its use due to there being no perceived pedagogical advantage can be brought to bear.

Baggott La Velle *et al* (2007) discuss what they call the *democratisation of knowledge domains* by the use of science experiment simulation software. They explain this term as widening access to aspects of science education which might have been problematic for many students previously with regard to the teaching of critical thinking. Simulations allow instant manipulation of experimental conditions and subsequent data collection which is often not possible in a laboratory experimental situation. This ease of use encourages 'what if?' type questions from pupils. The researchers found a motivating effect from the use of ICT here particularly with regard to interaction between pupils and stimulating discussions, fostering peer-assisted learning. They state that this encourages such characteristics as negotiation skills, estimation and examination of alternative concepts and interpretive skills, and that this leads to enhanced social and scientific abilities. GLOW might be ideally placed to exploit this idea of powerful learning environments with open-ended rather than closed tasks provided teachers are able to exploit its applications by designing lessons with activities based on these criteria, as this appears to be critical in the use

of ICT to raise attainment. The focus moves firmly away from the technology and comes to rest on the pedagogical approach, and in particular how to address the challenge of managing the changes in working practices that appear to be necessary to facilitate this refocusing of approach.

1.8 Experiences from other countries.

Other countries have their own approaches to the challenge of integrating ICT into classroom practice. The Norwegian government has legislated for this by making the use of ICT in every subject mandatory in every mandatory school level. There appears to be a consensus between all parties in Norway about the importance and priority of digital literacy, something that the research cited so far in this discussion has shown is lacking in the UK, although it is important to qualify this apparent Norwegian consensus. Almas and Krumsvik (2007) found that there was an historical bias towards ICT rhetoric and ideology rather than the practice; however consensus was reached on the need to address this and legislation was enacted to progress these aims. Research by the same authors illustrated the importance of anchoring ICT in subject curricula, assessment, and everyday practice for it to become a normal and regular part of teaching and learning in schools. They discuss teacher's previous levels of technophobia with regard to computers and found that when this technophobia is reduced teachers take a leading role in ICT implementation in schools. This would appear to be at odds with the emphasis on pedagogy rather than technology in the training programmes; however their experience was that it only took limited instruction for this fear of the technology to be overcome and once this had happened, the teachers became more enthusiastic about adopting new pedagogies involving the use of ICT. It is significant that it took government legislation for this change in approach to happen, and according to Almas and Krumsvik teachers can no longer define themselves and their roles 'without ICT and digital literacy'. This is a major shift in attitude but the Norwegian experiences highlight the importance of involving ICT and digital literacy in all aspects of teacher training, in-service provision and professional development, and, just as importantly, stresses the need for the training

to have a pedagogical rather than a technical focus in order to capture teachers' attention. This has important implications for us here in the Scotland. Will it take legislation along the lines of the Norwegian model to effect change here in our schools? We already have the standard for full registration, a baseline set of standards for measuring teachers' competence to do their jobs, and these contain criteria for the use of ICT in teaching. These basic ICT skills are supposed to be a starting point for teachers who are then expected to build upon them, increasing their pedagogic-didactic skills as a part of their professional development as well as focussing on the metacognitive aspects such as how the use of ICT can add value or where this is limited, and of its impact on individual pupil's learning strategies both in the classroom and at home. Hennessy et al (2005) certainly conclude that a minimal statutory requirement for using ICT in the UK is one contributory factor to the poor uptake of ICT in teaching and learning. The regional government of Flanders, a part of Belgium has followed a similar route to that of the Norwegians, by defining a framework of ICT competencies which teachers are supposed to use in their subject teaching (Tondeur, Van Brak and Valcke 2007)

The Digital Education Enhancement project (DEEP) funded by the UK government department for international development looked at how ICT could improve teacher education and thus enhance teaching and learning in the Republic of South Africa and Egypt. This project, carried out in primary schools in these countries, found that the introduction of ICT (primarily laptops and hand-held devices) had a positive effect on teaching and learning in a number of ways, such as increased pupil attendance, curriculum development and improved classroom practice and learning activities. Interestingly, and perhaps in contrast to the UK, they found that some of the most significant development in effective practice was developed by teachers who had little or no previous experience in using ICT for teaching. The training for teachers was delivered in short curriculum-focussed mini development projects involving using both hardware and software to develop new teaching and learning strategies. The teachers worked in pairs on these projects. The research found that all participating teachers took forward the introduction of these new developments involving ICT into their lessons. The importance here seems to be the 'hands on' approach, coupled with peer to peer interaction and shared learning, as well as a specifically curricular focus, based on the teaching of literacy, numeracy and science. Again, the theme of pedagogy rather than technology seems to be the key to success in persuading

teachers to adopt ICT into what develops into successful classroom practice. This issue of training seems to be common across Europe. Husing and Korte (2006) carried out a survey of Heads and classroom teachers from 27 European nations found that the majority of teachers not using ICT in their work stated that this was because they saw no pedagogical benefits. In Spain, Germany, Sweden, Iceland, Hungary, France and Finland substantial minorities of teachers expressed the view that there was not much of a pedagogical advantage to using computers in the classroom. This is surprising, particularly in the countries which could be said to be technologically advanced with regard to ICT such as Finland and Iceland. The report states that these teachers tend to be those who have more years teaching experience, rather than younger teachers who hold less scepticism about the value of ICT in teaching. This is particularly true in Germany where 48% of respondents to this survey felt that computers were not of much use in the classroom. Perhaps the fact that average teaching experience of classroom teachers is stated by the report to be 23 years is significant as they would have trained as teachers before ICT use in schools became so commonplace and widespread. This is perhaps an area where research into the quantitative benefits of ICT in schools with regard to raising attainment might be useful, together with whether the pedagogically focussed ICT in-service training discussed previously might work in tandem to influence this group of older teachers in the European countries surveyed. The motivation of such teachers to change such long-held methods of working and effect shifts in their pedagogical approaches is something that certainly needs to be addressed if progress is to be made. It is difficult to see what else might persuade them to change other than hard evidence and good training, other than issues of access, which is becoming less of a problem as countries provide schools with broadband access and the numbers of available computers per pupil ratios are being improved year on year. Greece, for example has moved from a position of one computer per 1300 pupils to a 1 to 35 ratio in under 2 years (UK DFE briefing paper 2006). Concerted action by the European Union has had the effect of shifting attention in many countries away from issues of hardware and connectivity towards those of how to develop ICT as a pedagogic tool by the use of e-learning services and improved educational software as well as the need for more effective inter-agency partnerships (European Commission e-learning action plan 2001). This of course, sits well with all the evidence and concurrent themes from the literature so far reviewed about the need for a focus on pedagogy rather than technology. This is

an important distinction when thinking about the concept of the knowledge economy. If one looks at the work going on in countries who are still at the development stage with regard to this knowledge development, such as the former eastern European and Soviet satellite nations, the problems they face are not only to address the shift in pedagogy necessary to embed ICT into classroom practice, but also issues of capacity building in infrastructure and connectivity. This problem is recognised, for example, in Latvia, where Kangro and Kangro (2004) looked at the issues of integration of ICT in education. Older USSR-produced computers are being replaced together with network infrastructure and software at the same time as addressing the necessary pedagogical shift for successful use of ICT in the classroom. The Latvian government have recognised that this has to proceed in tandem for any lasting gains to be realised and have instituted national level programmes of work to address the technological issues as well as the teacher-training needed in both the use of the technology but also on the integration of ICT into the teaching and learning processes in schools, at the stages of both initial teacher education and existing classroom practitioners.

Again, the common themes from abroad appear to be the need to cause a motivation to change existing ways of working coupled with good quality and well-designed training at both initial teacher training and in-service levels. On this latter point, the issue of training, the research from abroad as well as the UK all agrees on the importance of this being focussed on pedagogical issues. Certainly, with regard to the former the Norwegian experience is that it is legislation which provides the necessary motivation; however this is an approach which has not been copied elsewhere as yet. It remains to be seen whether the expectations of transformation of teaching and learning and attainment improvements in these other countries (as well as in Scotland with GLOW) are quantifiable enough to persuade these other national governments that the Norwegian legislative approach is unnecessary. It is to these expectations of transformation that I now turn.

1.9 Expectations of transformation.

The general consensus of research opinion is therefore that ICT has not had the transformative and energising effect on the school curriculum that was envisaged by its supporters. This is a problem which is not exclusive to Scotland. Klovstad et al (2005 cited in Almas and Krumsvik 2007) alluded to the ambitious ICT visions of policy-makers in Norway and actual use in Norwegian secondary schools. This 'expectation gap' was eventually legislated for in Norway, recognising the importance the government there placed on realising the transformation of teaching and learning using ICT. In the UK, however, the problem still remains. Perhaps this is because the focus has been on the 'end' (attainment), rather than the 'means' (pedagogy). Certainly any transformative effects of ICT in education have been as a result of increased use of the internet but educationalists have struggled to harness its effects in a way that has been truly transformative on raising attainment. It has been somehow just expected that providing the broadband connections and hardware to facilitate internet use (and I include educational software in this) is enough to raise attainment in itself. This is clearly not enough. What is needed is a pedagogical approach that harnesses the potential transformative power of ICT in a way which will involve pupils in peer-assessment and instruction, in collaboration, in encouraging independent learning, and in improving problem–solving and thinking skills. In other words, a coherent and pedagogically sound approach to focussing the use of ICT as the means rather than the end. An ICT-based system of delivery which includes all of the important pedagogical strategies (AiFL, collaboration, differentiated teaching, and independent, responsible, and personal learning) as well as directed use of the internet and common to all subjects and schools may well be the route to crossing the barriers to ICT use. GLOW might be such a breakthrough, and is well placed in Scottish schools at the moment to provide a suitable 'test-bed' for this research project. Of course, this leads to a wider question. Lack of uptake of ICT into regular planned classroom teaching and learning appears to be mainly due to lack of funding for equipment and most importantly, staff training and development, as well as teachers not being convinced of the possible enhancements to the teaching and learning. This review of existing research can be placed in two time contexts: firstly, older research

tends to highlight technological issues as being predominant factors in limiting the use of ICT. Lack of reliable and plentiful computers and broadband connections as well as appropriate software, resources and technological competence are all specified. Latterly though, the more recent research points more towards the culture in schools themselves and points to leadership and ethos, attitudes and perception of usefulness, and pedagogically-focussed training. Tearle (2003) analysing the situation five years ago states

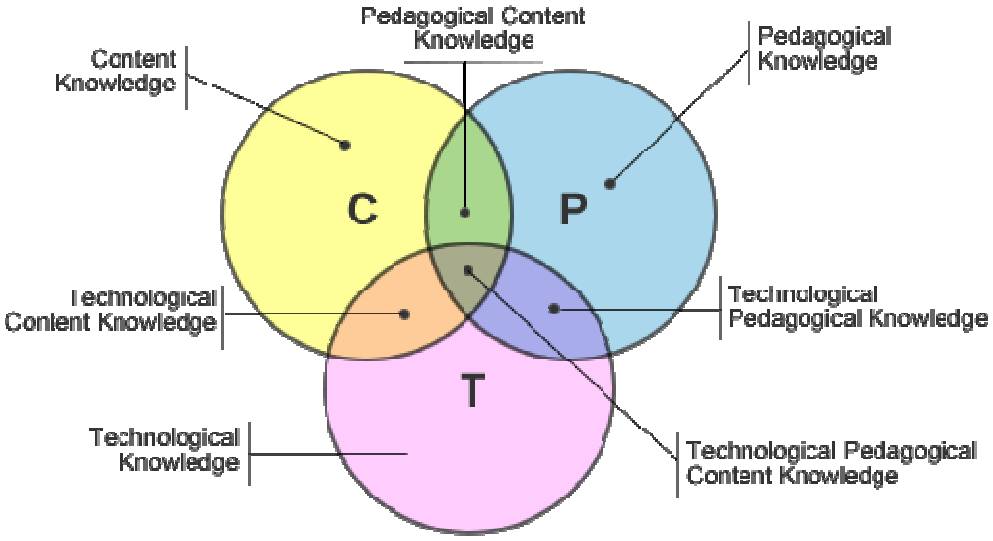
"*What emerges then is not an argument as to whether equipment, support or training is the more important, but much broader debate about mindsets, assumptions, beliefs and values of individuals and organisations. This does not mean that there are no practical actions and material needs, far from it. It almost certainly means however that piecemeal approaches which address discrete elements which are perceived to impact on increasing ICT use, will at best have limited outcomes".*

This analysis is still true today, even more so than in 2003 and with local authority 'efficiency' savings biting into teachers' time forcing them to make sometimes difficult choices about how to use valuable development time. Will GLOW be just another expensive project set up to fail by this multitude of negatives? Or will it prove to be the most effective weapon yet in the battle to cement ICT as an integral part of the teaching and learning in most secondary school subjects by winning the hearts and minds of school managers and teachers, and the debate referred to by Tearle in the quote from her research paper above. Perhaps one of the keys to unlocking the complex system of locks barring widespread use of ICT in the classroom outlined and discussed in this introduction and literary review is evidence that such regular planned use has a positive effect upon the teaching and learning taking place within secondary school subjects. I include the so-called 'soft' indicators of positive impact such as improved motivation, engagement and interest with the subject material, improvement in the quality of the interactions between teacher/pupil and pupil/pupil as well as more concrete indicators of success such as a rise in attainment demonstrated to be attributable to this use of ICT, specifically the GLOW platform and tools. If teachers can be persuaded that shifts in pedagogy such as that of shifting from mainly didactic learning to peer assessment (AiFL) are worthwhile as in the example shown by Mazur's work, what will it take to convince them of the benefits of integrating ICT into their teaching and learning environments? Is it proof of raising attainment that

will convince them, or are other factors such as ease of access to hardware and useful appropriate software as well as quality and availability of pedagogically-focused training involved? Is the lack of convincing quantitative evidence relevant to Scottish schools a determinant? Interestingly, Draper and Nicol (2006) conclude that, at least in higher education, transformation by ICT has only been achieved by "focussing on ends rather than means: on what exactly we want to achieve" as they put it, further stating that " the substantial examples of large measurable benefits have occurred only when this was done". Perhaps this is a good approach to foster in schools, and indeed a focus on outcomes is now one of two key outcomes in HMIE's ten dimensions of excellence, a part of '*How good is our school (5)*' (the 'outcomes' here being the four capacities of ACfE) If we focus on national priorities in education, and specifically raising attainment which is important to teachers and schools, then a proven means of achieving this end might well garner credibility and adoption by those very same teachers and schools (without the need for legislation to enforce this as has happened in Norway for example). Could regular planned use of ICT within all subjects be one way of achieving this particular outcome, and indeed, the key dimension above from HMIE? It is hoped that this research project might go some way towards answering some of these questions.

At this point, it is worthwhile to consider a slightly different approach to these challenges faced by our schools, as developed by Mishra and Koehler (2007). This looks at the way the teaching profession has evolved over the years and builds on Shulman's earlier work on Pedagogical Content Knowledge which examined the interaction between content or subject knowledge and the pedagogies involved in delivering courses in these subjects (1987, cited in Mishra and Koehler 2007) by adding in the latest area of development in education, namely ICT. What Mishra and Koehler argue in their paper is that it is in the overlap between the various areas of a teacher's set of competencies where teaching and learning really advances. Their praxis is that for teachers to adopt ICT into their practice successfully there has to be a development of a complex situated form of knowledge known as Technological Pedagogical Content Knowledge (TPCK). This paradigm involves the roles of and interplay between three essential knowledge sets; content, pedagogy and technology and that consideration of this model can inform the debate on technological integration into teaching and learning on three different levels. These are the theoretical, the pedagogical and the methodological. In other words, how can the

theory that ICT can transform teaching and learning be translated into modified pedagogies, and how can these new pedagogies be introduced into the classroom? The basis of this work is that content knowledge (the 'what' of teaching) has been historically important for teachers. More recently, universities involved in teacher training have emphasised pedagogical knowledge (the 'how' of teaching) as equally if not more important. The overlap between these two is the 'craft' of teaching; where subject expertise and how to transmit this to pupils come together. Mishra and Koehler add a third dimension to this which is technological knowledge. The rapid evolution of ICT makes it almost a certainty that technology in the classroom is here to stay. As others before them, they argue that to date the issues surrounding the progress towards technologically enhanced learning environments has been dominated by issues of technology rather than pedagogy and that it is this that is the major factor in preventing and dissuading teachers from making the changes necessary to their classroom practice for the successful adoption of ICT into teaching and learning. Their model situates the progress towards the integration of technology firmly within pedagogical and content-based contexts. This can be illustrated by their diagram explaining this paradigm which is reproduced below.



Technological Pedagogical Content Knowledge (TPCK)

(From Mishra and Koehler 2007)

The real development of knowledge, they argue, will take place in the overlap between the three elements of their TPCK model. Thus, Mishra and Koehler bring us back to the interaction between the technology and pedagogy rather than an emphasis on one or the other, a polarisation which has become apparent through the literature considered so far. They are in effect, arguing that to ignore the contribution the technology makes to the pedagogy is to ignore a vital component of the knowledge construction process which takes place within a lesson. The challenge is to find a way of motivating teachers to invest their time in developing focussed technological skills which enhance their content and pedagogical knowledge and which will enable them to better situate and contextualise the teaching and learning in their classrooms.

Developing educational theories about how to manage this pedagogical change are difficult to develop as by necessity they have to deal with complex situations involving the interaction between the many different factors which exist in every classroom environment such as teachers, non-teaching staff, disturbances, behaviour, pupils, politics, design and curricular goals, and that as all these factors differ from school to school it is difficult to establish cause and effect using conventional research methodologies. The *design-based* model of research is the way forward according to Mishra and Koehler as it allows for these situational complexities to be considered as well as focusing on the introduction and examination of classroom interventions but allowing for an element of evolution with regard to exact pedagogical goals. The school classroom provides a rich authentic setting for this type of research first proposed by Ann Brown working in California in 1992.

This small-scale classroom-based case study sets out to investigate the effect, if any, of introducing regular planned use of ICT within the S3 Biology standard grade curriculum measured both quantitatively and qualitatively. The aim of this project is two-fold; Firstly to try to measure any gains in attainment achieved by the experimental group of pupils working with the GLOW-VLE being used to deliver ICT-based Biology content, and to assess the probability that any such gains which occur are due in some way to this regular planned use of ICT or to a change in pedagogy mediated by this use of ICT, and secondly, to try and examine the experience of introducing regular planned use of GLOW/ICT into a secondary school

subject curriculum with the goal being to devise a model of 'good practice' which can be adopted by faculties and other schools.

2.0 METHOD

2.1 Design

A design-based research methodology was used for this study. This is an approach which has gained in popularity recently after first being put forward by Ann Brown (1992) and which involves and advances the principle of carrying out experimental design, research and adapting existing practice at the same time. The rationale behind this approach is that there is an explicit and synergistic relationship between these three characteristics, with researchers managing the actual research processes as well as collaborating with participants to continually refine the design process through systematic interventions to facilitate design improvements and thereby advance both theoretical as well as the pragmatic aims affecting practice, in this case, learning and teaching. The researcher assumes the functions of both the designer and researcher and so can draw on procedures and methods from both disciplines to arrive at a methodology involving some of the features of both. As this was a rather wide-ranging study particularly with reference to its aims, one of which was to try and devise refinements to existing classroom practice leading to a possible model of good practice on integrating ICT into subject teaching, the principles of the design-based approach appeared to be a 'good fit' with the aims of this particular project.

A within-participants design was employed in this study as the intervention class were exposed to both conditions whereas the other classes only had access to one of these condition (no ICT). There were two conditions involved in this study, being teaching with and without the involvement of ICT. The independent variable was the teaching of one-third of the coursework using ICT with the GLOW platform being used for this purpose. The intervention class had a period of teaching without ICT before the application of the independent variable during the study period, whilst the other groups had no input from GLOW/ICT into the teaching they received. The dependent variable in this study was the pupils' academic attainment measured at the end of the

period of the study for all the groups involved. This was measured by the use of standardised summative assessment tests consisting of two papers, one at ‘general’ level and one at ‘credit’ level and both consisting of equally weighted problem solving and knowledge and understanding type questions, mirroring the SQA standard grade examination format.. All the groups sat all papers and cross-marking took place to ensure accuracy, consistency and eliminate possible experimenter bias. The learning outcomes on which the assessment instruments were based were the same for each group and had been taught before by all the teachers involved, apart from one who was a probationer teacher in the first year of practical experience.

2.2 Participants

The school in which this study was carried out is an integrated community secondary school in an inner city area of the west-central belt in Scotland. The school serves a catchment area with a diverse socio-economic mix of communities. Whilst there are 'pockets' of affluence, these are outnumbered by areas of extreme deprivation, long-term sickness and unemployment. This is evidenced by the free school meal figure of 25.2%; nearly double that of the national average. The numbers of young people leaving school with qualifications of SCQF level 5 (standard grade credit, higher, and advanced higher) are significantly lower than the national average, as are the 'staying on' rates for pupils after age 16. Despite this, the school has an enviable record of success with helping young people into further education, training and employment, exceeding national averages.

The seventy-two participants involved in this study were all pupils in their third year in this particular secondary school. They were divided into four classes on a random basis at the start of their S3 year during the annual timetabling process, having selected Biology as an option choice at the end of their S2 year. The pupils had no choice or input over which class they were allocated to. The four teachers involved also had no input into this process. An examination of the summative assessment taken by each of the four classes prior to the start of their S3 year was undertaken with the aim of establishing an academic ‘profile’ for each of the classes. This was done to try to ensure that the results analysis would be comparing ‘like for like’.

From this it was possible to produce a mean overall score for each class. This analysis is shown in table 2.21 overleaf.

Table 2.21 Academic 'profile' for each of the S3 Biology classes in the study using S2 science exam score means

CLASS	**S2 EXAM MEAN SCORE (Academic Profile)**
1	61.23
2	64
3	64.53
Intervention group	62.21

As can be seen from Table 2.21, there were very small differences between each of the S3 classes in terms of academic ability as assessed by the academic profiles calculated as previously described. The range is only 3.3 points with a Standard Deviation (SD) of only 1.54 between the means for the four classes. Such a low SD is an indication of how similar these classes are to each other in academic ability.

2.3 Materials

An ICT suite was made available for use in this case study by the school involved. This was timetabled for use by the study group on the same day and time each week for the period of the study. The GLOW virtual learning environment (VLE) had been available to the school for the previous four months as part of an authority-wide roll-out programme to selected schools. The pupils had been given time to become familiar with how to use the various elements of the VLE and given a set of instructions to be followed each time they logged on to the system to allow them to become used to accessing their lesson materials through the VLE.
The teaching and learning materials and content were loaded into the GLOW VLE prior to each lesson as a part of the normal lesson planning process undertaken by

teachers for each class being taught. These materials were either created or sourced and adapted from open-source software or the internet by the experimenter for use in each ICT-based lesson and based on the learning outcomes listed in the arrangements document for the Scottish Qualifications Authority (SQA) standard grade Biology course topic being delivered at the time (for this study, the 'Biosphere' topic). Materials used for classes taught without the input of ICT were of the traditional classroom variety such as text-books, worksheets, experimental/practical work, didactic lectures and note-taking. Although there were small variations from teacher to teacher, these resources were mostly produced by the Biology department for use by all classes, and the text-books used were the same for each class.

The issue of consent as a part of the design was considered using both SERA and BPS guidelines. As there was no possibility of any harm being done to any of the participants and as this study was carried out using the S3 pupil cohort studying biology (a situation which occurs every academic year in the school) and taking an SQA course as normal, it was considered that no such consent was required as the ICT input to the pedagogy whilst formalised for one of the study classes, is nevertheless, an input expected by HMIE in all secondary school subjects.

2.4 Procedure

Each pupil in the intervention class which was to have the ICT input spent two lessons being familiarised with the GLOW VLE and practising using its various applications. They then worked on this system for the period of the study topic with the ICT input into the teaching involving a variety of different modes of delivery including animations and simulations, on-line worksheets and quizzes giving instant feedback, video clips and weblinks directing pupils to on-line materials appropriate to the course outcomes, worksheets and data-handling exercises involving graphing and spreadsheets designed to be loaded onto the pupils' individual VLE whiteboards, and opportunities for on-line collaboration via discussion boards and instant messaging built into the GLOW VLE. These resources and lesson plans were designed and written by the intervention class teacher following normal lesson planning routines,

the only difference being that the resources were computer-based rather than paper or demonstration materials and artefacts as in a non-ICT taught class. Pupils were able to see each other's work and comment on their progress and the quality of their work as well as collaborating on the various exercises and seeking help from peers as well as their teacher. At the start of each ICT-based lesson, pupils would follow a regular procedure involving them logging on to the system where they would find a notice containing the learning objectives for that particular lesson, together with a set of instructions outlining the procedures and activities to be completed in order to achieve the stated learning outcomes for the lesson (examples are included in this report as appendices 2 and 3). They would then go to a specific area (a 'GLOW group') which had been set up to contain all the resources and web links necessary for the lesson tasks. The pupils had been shown how to follow this procedure each time they worked in the ICT suite and so were familiar with the structure of an ICT-based lesson. Each pupil's work and task progress was monitored by the teacher using the VLE in the same way that the pupils could look at each other's work. Instant messaging could be used if necessary to keep pupils on task and for individual pupils to request help, either from their teacher or their peers. Activities were of increasing complexity so that more able pupils could be challenged academically and each pupil was able to proceed at their own appropriate pace based on their own perceived self-efficacy. Each lesson was rounded off with a plenary session to establish each pupil's achievement of the stated learning objectives for the day, either on line through the VLE or as a class group with directed questioning. Pupils in this study class were regularly reminded that they were able to access the GLOW VLE from outside the school and that all the materials were available to them in this way for homework and revision.

The summative assessment results from this topic taught with the ICT input were recorded and a mean score calculated (comprising the four percentage marks from the two papers, general and credit, sat by each pupil) for the intervention class and the other classes which did not receive the ICT input. These mean scores were then compared with the previous 'academic profiles' calculated for each class. Two weeks after this assessment, the S3 cohort sat an end of year biology exam covering all the work covered during the course of the year, comprising two modules taught before the study period and the one module taught as a part of the study. The results from this examination were also considered during the subsequent statistical analysis in order to

give a picture of any underlying effects on learning the use of ICT might have had on the pupil's revision process for this examination.

3.0 RESULTS

The data collected is presented in this part of the report; however detailed analysis and discussion of the data follows in section 4.

An 'academic profile' for each class was first established as previously detailed using the S2 science examination score means.

Summative assessment data was collected for each of the four classes. This was comprised of test score means for each of the three topics assessed and the third year (S3) biology examination. This is shown in table 3.1 below.

Table 3.1 Mean scores for all summative assessment instruments

Topics/classes:	1	2	3	Intervention group
1: Investigating cells	47.58	41.57	59.63	60.98
2: Animal survival	55.73	59.16	67.53	59.89
3: Biosphere	61.17	62.01	76.35	**81.20**
End of year exam	52.31	59.82	63.54	**71.25**

The summative assessment percentage mean score for each class after being taught topic 3 was then recorded and each compared with the class academic profile for any change in mean attainment levels. These statistics are given in Table 3.2

Table 3.2 Class mean scores (%) for topic 3 and any improvement over the class academic profiles

CLASS	ACADEMIC PROFILE	TOPIC 3 MEAN SCORE	DIFFERENCE BETWEEN TOPIC 3 AND ACADEMIC PROFILE MEANS	DIFFERENCE (AS % OF ACADEMIC PROFILE)
1	61.23	61.17	(-0.06)	-0.10
2	64.00	62.13	(-2.91)	-4.55
3	64.53	76.35	+ 11.82	18.31
Intervention group	62.21	81.20	+ 18.99	30.53

As can be seen from Table 3.2, groups 1 and 2 show small differences between the academic profiles and the topic 3 assessments. Group 3 shows a somewhat larger improvement whilst the intervention group after being taught with the ICT input delivered via the GLOW VLE show by far the largest improvement of some 30.53% based on their class academic profile.

Further analysis of theses statistics, examining the mean scores for the individual topics taught immediately before and after the study are shown in Table 3.3

Table 3.3 Differences between the means for topics 2 and 3

CLASS	TOPIC 2 MEAN SCORE	TOPIC 3 MEAN SCORE	DIFFERENCE BETWEEN TOPICS 2 AND 3	DIFFERENCE BETWEEN TOPICS 2 & 3 (AS % OF TOPIC 2 SCORE)
1	55.73	61.17	+5.44	9.76
2	59.16	62.01	+2.85	4.82
3	67.53	76.35	+8.82	9.04
Intervention group	59.56	81.20	+21.64	36.33

These results again indicate that by far the largest improvement in attainment was again that shown by the intervention group of 36.33% expressed as a percentage of their topic 2 mean score (taught without the ICT input). Groups 1 and 3 also show fairly large percentage increases expressed on the same basis, of 9.76 and 9.04 respectively. This however cannot be considered significant when compared to the gains achieved by the intervention group.

The results do appear to suggest that embedding ICT into the Biology curriculum has a significant impact on pupil attainment; however, closer examination of the results is necessary if we are to understand the nature of this rise in attainment. Before the analysis and discussion of these results in section 4, it would perhaps be useful to summarise the data collected during this study.

For the intervention group which benefited from ICT input as a planned part of the teaching of the standard grade Biology course, the results are set out in table 3.4 below in a comparison with the rest of the S3 cohort.

Table 3.4 Changes in attainment over topics 1, 2, and 3; intervention group against the remainder of the S3 cohort (classes 1, 2, and 3)

	TOPIC 1+2 (BEFORE ICT)	TOPIC 3 (AFTER ICT)	PERCENTAGE CHANGE IN ATTAINMENT
INTERVENTION GROUP	60.44	81.20	+34.35
OTHER CLASSES (MEAN)	55.20	66.51	+20.49

This summary is based on the summative assessment mean scores using the percentage marks from topic 3 (sat by pupils after their work using ICT), and shows an improvement in attainment achieved by the intervention group in their assessments

after a period of teaching involving them spending one third of their biology class time working on materials delivered via the GLOW VLE (as previously described in section 2.0). This summary shows that there has been a rise in attainment of 34.35% achieved by the intervention group when compared to their performance prior to this study. This compares with an attainment gain of 20.49% achieved by the rest of the S3 cohort, a difference of 13.86% marks.

The S3 examination consisted of material drawn from all three topics covered during the year, GLOW was only used to deliver material from the third of these topics. When the scores for this examination are added to the S3 topic test results there is still a marked increase in attainment (nearly double, in fact) shown by the intervention group when compared with the rest of the S3 cohort. These results are shown in table 3.5 below.

Table 3.5 Changes in attainment over topics 1, 2, 3, and including S3 examination results.

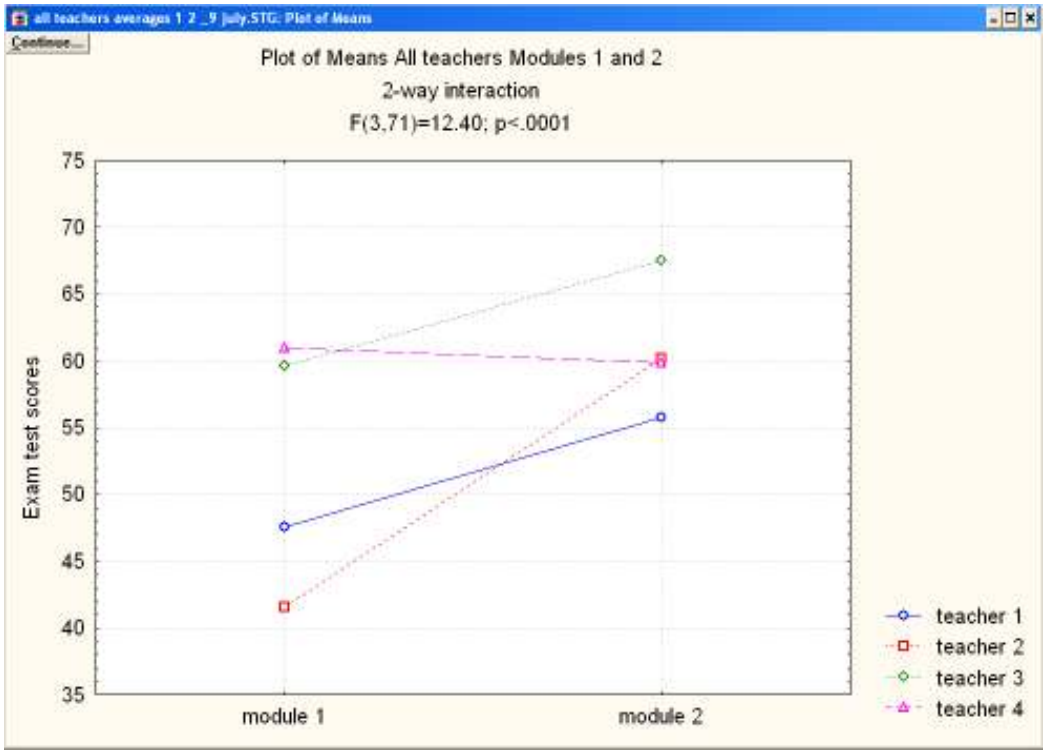
	TOPIC 1+2 (BEFORE ICT)	TOPIC 3+S3 EXAM(AFTER ICT)	PERCENTAGE CHANGE IN ATTAINMENT
INTERVENTION GROUP	60.44	76.23	+26.13
OTHER GROUPS (MEAN)	55.20	62.53	+13.28

This poses questions about the impact that using ICT in this way has had on attitudes and motivation towards, and transformation of styles of learning by the pupils involved in the intervention group. There does appear to be some sort of multiplier effect taking place here involving the learning, memory, and recall abilities of the intervention group.

4.0 ANALYSIS AND DISCUSSION OF RESULTS

The research hypothesis examined in this study was that embedding ICT in the secondary subject curricula would result in an increase in attainment, demonstrated by summative assessment (of course the null hypothesis was that there would be no increase in attainment resulting from this use of ICT). The results so far provide evidence that this is indeed the case with large attainment gains achieved by the intervention group when compared to both this group's scores before and after the study and in comparison to the other classes in the S3 cohort. What is not clear, however, is the exact nature of these gains. Although it was the use of ICT/GLOW which was the independent variable in this study, it is not simply a case of attributing the attainment gains to this use. There could be both direct and indirect effects on attainment stemming from the use of ICT/GLOW acting on pupil attainment for this group of pupils in this study.

Table 2.21 uses previously collected data with the aim of trying to provide a means of comparing the different classes with regard to their overall academic ability with respect to Science. When one considers the academic profile for each class in table 2.21 the standard deviation figure of 1.54 is very low, probably confirming that the random allocation of pupils to each class during the timetabling exercise prior to the start of the academic year has indeed produced classes of genuine mixed ability and that this study is comparing like with like. When the class mean scores for topics 1 and 2 (as set out in table 3.1) are compared there do appear to be some differences when the percentage marks are examined. However statistical analysis does not establish these differences as significant and the differences in marks can perhaps be attributed to small-scale random effects (lack of revision or effort by certain students for example). When this information is presented in a graph, a slight general improvement for the whole S3 cohort can be seen and this perhaps indicates that at the start of the course, students have to *learn how to learn* about biology (or any new subject) and get used to the demands of the subject perhaps working in new or different ways than previously encountered, and this possibility is illustrated by the slight overall improvement between topics 1 and 2, although it should be stressed again that the differences between individual classes within each topic are not significant statistically.



(Teacher's 1, 2, and 3 are of course classes 1, 2 and 3. Teacher 4 is the intervention class)

Turning now to the improvement in attainment shown after assessment of topic 3, it should be stated that despite the larger attainment gains achieved by the study group, the exact nature of the effect the use of ICT is contributing to this is unclear. Is the ICT responsible for the improvements in performance, does the use of ICT change the way a teacher works in the classroom, or is there a transactional relationship between these two, or indeed between multiple factors at work here? Certainly, the pupils are concentrating on their work for much more of the lesson with the usual 'settling down' at the start and lack of concentration towards the end of the lesson which normally happen not being so apparent in the lessons using the GLOW VLE. Does this improved concentration for the whole of the lesson rather than just for perhaps two thirds mean that it is this 'added' time's worth of concentration which is responsible, in whole or part, for the rise in attainment? For all of these reasons, it is probably too much of a simplification to attribute the rise in attainment set out in tables 3.4 and 3.5 purely to the use of ICT alone, although there can be no ignoring the fact that this improvement in attainment followed a period of time using the

GLOW VLE to deliver ICT-based content. It certainly appears to be due to a combination of factors, however these must have been stimulated or kick-started by the use of ICT and so it is probably safe to (rather generally) attribute the gains in attainment to this. To try to address some of these issues, a classroom coding exercise could be devised with the aim of attempting to record the different activities of a teacher in lessons using the GLOW VLE and in lessons where ICT is not used. This coding exercise could also compare the activities of the different teachers of the groups that make up the S3 biology cohort. A similar coding exercise could be devised to record the different types of teacher/pupil and pupil/pupil interactions. This would perhaps give a more detailed analysis of any changes which might be taking place with regard to the classroom pedagogy and if these are due in whole or part, to the use of ICT and the GLOW VLE. The coding may throw some light on the *quality* of the interactions between pupils and teachers and amongst the pupils themselves and provide useful information on the level of peer-assisted learning which might be taking place in different classroom settings. The quality of the interactions between teacher and pupil is also potentially significant as well the peer-assisted learning (which has developed significantly and visibly throughout the course of this study as the pupils use the VLE and instant messaging components of GLOW to comment on each other's work and to seek advice and assistance from their classmates) as both of these might possibly be indicative of a deeper level of thinking and problem-solving skills being developed through more efficient and enhanced transfer of knowledge from short-term working memory to long-term memory perhaps due to *elaborative rehearsal* (a term used to describe the way in which information is extensively processed by activating different aspects of its meaning and linking it to other associated artefacts or memories). The use of different media (including video, simulations, on-line articles and papers and audio podcasts) within GLOW to contextualise and situate learning into the 'real' world certainly builds on this concept and indeed this might be one reason why the improvement in attainment was maintained even in an assessment instrument containing a majority of material not delivered using any level of ICT input. Is this potential improvement in thinking skills and problem-solving due to deeper learning and is it transferable from one topic to another? Research by Maguire et al (1997) has investigated the potential plasticity of the hippocampus, an area of the brain associated with memory. They looked at the brains of London taxi drivers using imaging techniques and found that this area was

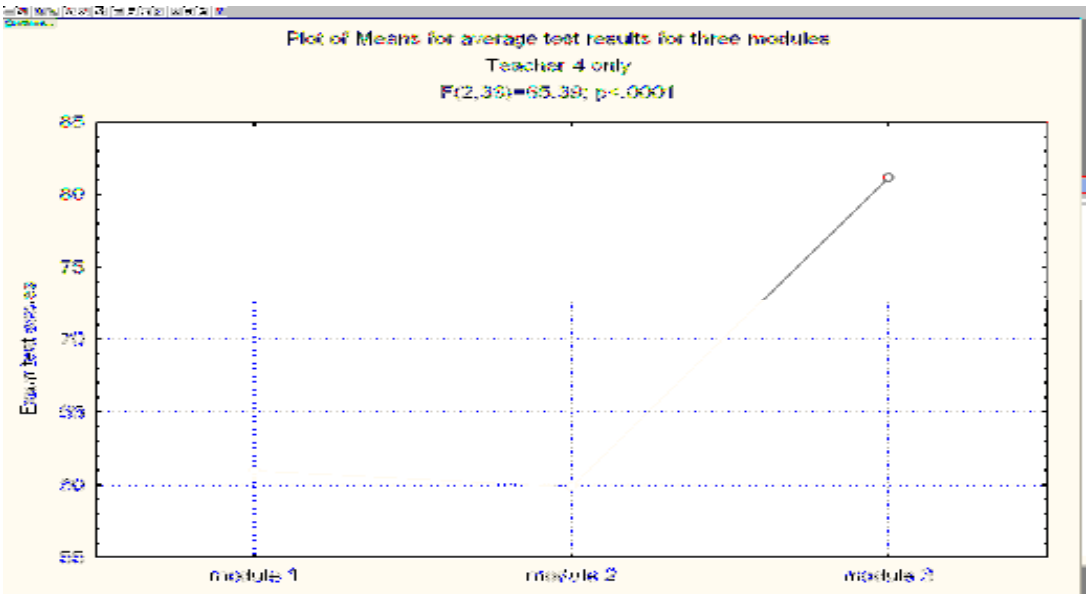
significantly enlarged, which they felt was due to them having to learn street names and routes (involving them using mental representations of the routes taken from one place to another – contextualised situational learning). Perhaps a similar plasticity, or increase in the number of neural connections is taking place in the brains of the students in the intervention group who were exposed to contextualised situational learning through using the GLOW VLE? (Brain plasticity can be defined as the ability to undergo structural and procedural adaptations to accommodate new and complex learning experiences).

The next phase of this study, which will last until June 2009 will involve the construction and extensive classroom use of the proposed coding mechanisms. It is hoped that this will allow us to be more specific about the nature of any changes in pedagogy and/or learning which appear to be behind this large improvement in attainment, particularly as the underlying ontological assumption has perhaps been that it would be a direct effect of the ICT input which might be responsible for any change in attainment.

Tables 3.2 and 3.3 in the results section show the differences in attainment between the academic profiles and topic 3 for the classes (3.2) and the differences in attainment between topics 2 and 3 (before and after the use of ICT with the study group-table 3.3). These show large percentage increases in attainment of 30.53 and 36.33 respectively for the intervention group. Whilst these very big attainment rises appear at face value to demonstrate the effectiveness of the use of ICT to raise attainment, they should be treated with caution for several reasons. Certainly, the largest rise was seen when only comparing one topic with another. There might be differences in the complexity of the subject material which are difficult to quantify and which might account for such large improvements, as well as a possible 'novelty' effect from learning about biology in a new and different way (the issue of sustainability is certainly relevant here, and will be addressed in the second phase of this study). One would normally expect there to be an improvement over the first three topics taught as the pupils learn how to learn about biology, and this is indeed born out by the results and this can be seen by examining the data which shows that the percentage improvement drops when the topic 3 results are compared with the academic profile (table 3.2) rather than just the results from topic 2 (table 3.3). What is significant about this is the *size* of the increase shown by the intervention group. Of

course, a more accurate picture of long term rises in attainment would be possible if the remaining units in the biology course, as well as the standard grade preliminary and final examination results are used in the statistical analysis. This would certainly allow for any such 'novelty' effect which might have been initially present to be minimised. It is planned to record this data during the next phase of this study which, as previously stated, is now to run until June 2009.

Whilst the percentage increases are illustrative of some effect happening, it is necessary to validate this by using statistical tests to calculate the probability of the attainment gains being due to the independent variable rather than any extraneous variables or random factors and for the size of any effect of the independent variable, in this case, ICT/GLOW on the dependent variable (attainment) to be considered. Some explanation of p and *d* statistics is perhaps necessary at this point. The *p* value indicates the probability of the independent variable being responsible for any changes. In this study, the changes that were being measured were of course to do with pupil attainment. The closer the *p* value of a data set is to zero and less than 0.05 the more likely it is (statistically) that any change in the dependent variable is due to the independent variable in a study or experiment. In this case the independent variable was the regular planned ICT input delivered using the GLOW VLE. A graph showing the test score means for topics 1, 2, and 3 for the intervention group, followed by a table of *p* values for the comparisons between the three topics in respect of the intervention group (teacher 4) are shown below;



P values for each of the 3 topics against each other

TOPICS/MEAN	{1} 60.97500	{2} 59.88750	{3} 81.20000
1 {1}		.874841	.000000 *
2 {2}	.874841		.000000 *
3 {3}	.000000 *	.000000 *	

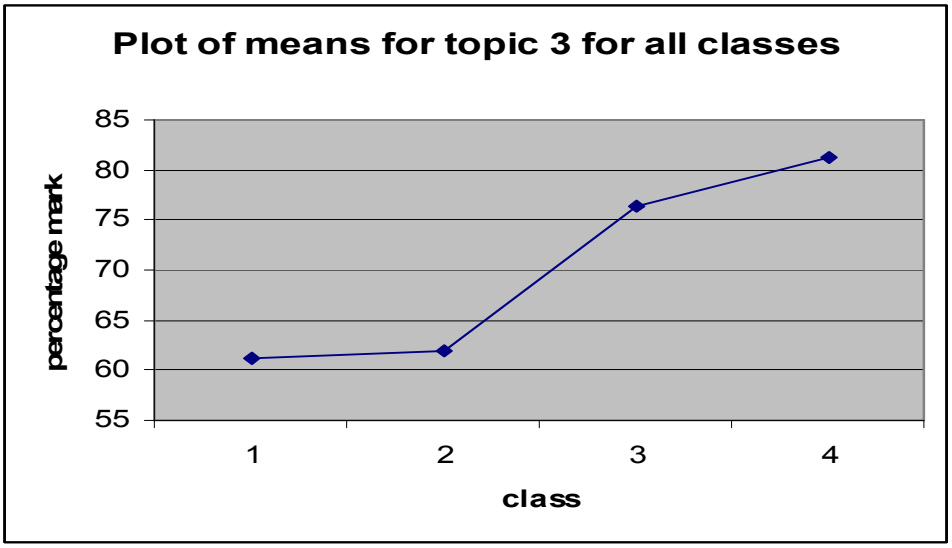
From the above table of *p* values above, it can be clearly seen that when the mean score for topic 3 is compared with the mean scores for topics 1 and 2, the differences have *p* values of < 0.05 and are therefore statistically significant (these are indicated by an * next to the values above) and therefore this appears to be fairly conclusive with regard to the effect the use of ICT can have on attainment, however, the same problems resurface here that were considered earlier in this section when the percentage increases in summative assessment results were considered. These are in effect, the possibility of a change in pedagogy caused by the use of ICT or the actual direct and indirect effects of ICT itself on the pupil's learning, concentration and learning and the nature of the relationship between these factors being unclear, and it is hoped to go some way towards addressing these issues by the proposed coding exercises and classroom observations over the coming months as this research project continues.

The effect size (*d* value) is a statistical measure representing the probable size of the effect the independent variable is having on the dependent variable; in this study, how much of an effect might the use of ICT actually be having on attainment. An effect size in excess of 0.8 is considered to be statistically significant as a large effect size (in excess of 0.4 would be considered as a medium size effect). When calculated for the intervention group using the data for topics 2 and 3, the effect size is >1.0, which on this basis can be considered statistically significant. Yet again, this when taken with both the percentage gain in attainment and the *p* value for the study group is evidence for the significant impact upon attainment of the embedded use of ICT/GLOW in teaching and learning, even though as previously stressed, the exact nature of this effect still needs more clarification.

A further issue of interest here might be the level of commitment shown by individual teachers having an effect on the attainment as both the amount of time

spent preparing resources for use through the GLOW VLE as well as the quality of these resources might well be a factor contributing to any rise in attainment. As with the other factors which might have affected the overall attainment, this is difficult to measure in a short study such as this and is worthy of further investigation, perhaps through the use of 'activity diaries' kept by teaching staff adopting the use of ICT into their classroom practice. This would certainly merit a separate study in the future if the pace of adoption of the GLOW VLE becomes more widespread in schools. Certainly, the planning and preparation for each of the lessons in this study which were delivered using the GLOW VLE took no longer than the author's conventional lesson planning process and indeed results in a longer term time saving as the resources, once prepared and loaded into GLOW are then available for classes taking the same course during subsequent sessions and years. Time constraints were highlighted in section 1.0 of this study report as a major issue for teachers considering adopting ICT into more regular classroom practice. Perhaps this long-term time saving might be a persuasive factor with regard to this eventual change in classroom practice.

Interestingly, group 3 also show an improvement between the academic profile and topic 3 of 18.31 percent (as shown in table 3.2). Without classroom coding, the reasons for this particular set of results are unclear. It maybe that the experience of the teacher working with this particular group is a factor, and indeed teacher experience when examined in the context of this study is an area that can yield some useful information. The following graph plots the topic 3 mean scores for each class.



(Class 4 is the intervention group on the graph). If the data for each class is compared against each other to examine the statistical significance of any differences between them, a series of *p* values can be produced. These are set out below.

Teacher Differences on topic 3

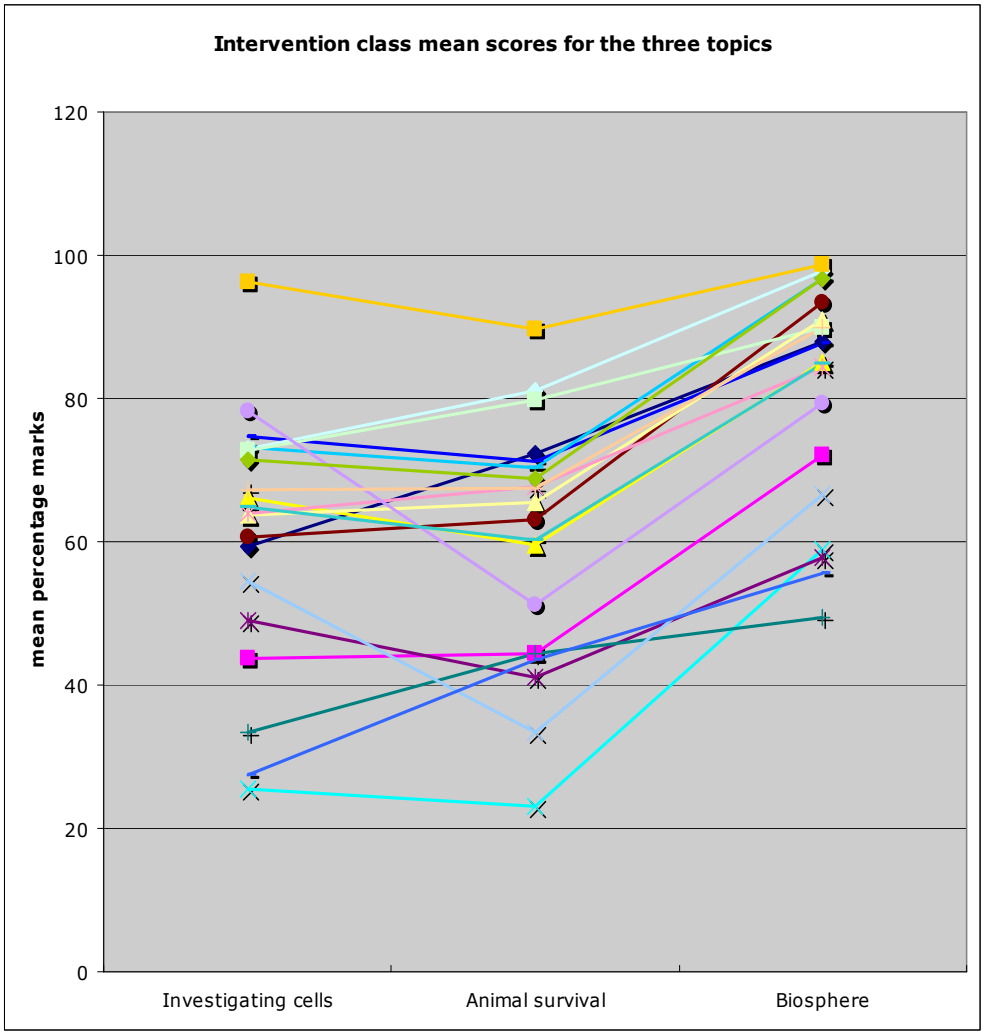
		{1}	{2}	{3}	{4
CLASS/MEAN		61.16667	62.01471	76.34722	81.20000
1	{1}		.998774	.034660*	.001750*
2	{2}	.998774		.056739	.003558*
3	{3}	.034660*	.056739		.805766
4	{4}	.001750*	.003558*	.805766	

(The significant *p* values are indicated * in the table)

When the results of classes 1 and 3 are compared the *p* value is < 0.05 which is significant and this is very nearly the case when comparing class 2 and 3 (0.056766 is only just outside the significance range). When one considers that class 3 was taught by a teacher with over thirty years experience whilst classes 1 and 2 were taught by teachers at the start of their careers (< 2 years experience) then perhaps a significant difference between class 3 and the others is to be expected and this is certainly supported by previous research literature on teacher experience and attainment (i.e. Rhodes and Beneicke 2002, Wiliam 2006). What is surprising however is that this significance is also evident when one compares the means of classes 1 and 2 with the intervention group (class 4 on the graph and table) with *p* values for both comparisons being .001750 and .003558 respectively (the intervention group was taught by a teacher with just 4 years experience). This would seem to suggest that the use of ICT/GLOW in this way can go some way towards compensating for lack of teaching experience. If this were indeed the case then using ICT within subject teaching might be an extremely cost effective way of raising attainment when compared to other recognised ways of achieving this such as reducing class sizes (which is very expensive in terms of both staffing and physical resources year on year) and improving teacher subject knowledge (which is difficult to maintain year on year and expensive) particularly as it is a one-off investment in terms of teacher time and training rather than a yearly cost. Of course, the factors mentioned previously such as

teacher motivation and the amount of time spent preparing materials for an ICT/GLOW lesson need to be considered, although this time factor is in many cases a one-off investment as the resources and lesson plans are available to be used again in subsequent years and indeed could actually result in time savings in subsequent years. This aspect of ICT use needs further investigation. Interestingly, a statistical significance was not noted when considering the S3 examination scores for all four classes by using *p values* in the same way.

One final piece of analysis concerns the spread of the attainment gains across abilities in the intervention class. This can be seen by plotting the mean assessment scores for each pupil in this class for each of the three topics. This data is displayed in the graph below. Each of the coloured lines represents an individual pupil's mean scores.



The graph clearly shows the improved attainment for every pupil from topic 2 to topic 3. The lower performing pupils can be seen to achieve attainment gains as well as the more able pupils and in fact the biggest gains are from the pupils who have performed less well on the first two topics. This would hint at there being a larger effect of using ICT/GLOW on the attainment of lower and middle ability pupils. This is highly significant for many schools, and perhaps echoes the findings of the Dylan Wiliam/Paul Black *Inside the Black Box* (1997) study on the effects of formative assessment being greater on these same two groups of pupils. As the use of GLOW in the ways described in this study uses much of the formative and peer assessment methodology, particularly with the sharing of learning objectives, criteria for success, collaborative work and feedback, then the results displayed on the above graph perhaps come as no surprise.

4.1 Reflexive analysis

As with any design-based research, it is important to consider all other possible sources of error which might have affected the outcome of this study and this type of reflexive analysis is important for the next phase which will involve classroom observation and coding and analysis of long term changes in attainment (if any). The controls put in place such as cross-marking and the use of standardised assessment instruments as well as the random allocation of pupils to classes go much of the way towards eliminating the chance of any possible experimenter bias. However the only way to guarantee this from a purely scientific methodological point of view would be for other staff to be involved in this study, particularly those using GLOW/ICT in the same way and to the same degree as the author (also the study group teacher during this research project). This has not been possible at this point in time in the school involved in this particular study, which is one reason why the design-based approach was used. However, in order to go some way towards alleviating the scientific tradition type of methodological concerns, the proposed coding exercise will examine and compare the classroom efforts and activities of two teachers (study group teacher and one other) during unannounced classroom observation visits to take place over the coming months. However it cannot possibly eliminate with all certainty any

possibility of experimenter bias methodologically speaking and so this does remain a design flaw with respect to this particular study (particularly if one considers the scientific research tradition). The author has an interest and a GTCS-certified and recognised level of expertise in using ICT to enhance teaching and learning and it was these interests and skills which initially lead to this study taking place. However the point of the study was to examine whether or not using ICT in a particular way could have an impact upon pupil attainment both quantitatively and qualitatively and whilst there is evidence for these qualitative indicators (such as motivation, enjoyment, and increased engagement with learning) it was a specific aim of this study to try and measure any *quantitative* effect of embedding ICT into a secondary school subject curriculum. This was to see if it was worthwhile to invest the time and resources in the initial set up, resourcing, and on-going maintenance of the chosen ICT delivery platform (in this case, the GLOW VLE) and the attainment gains recorded by the study group certainly point towards strong initial evidence to support this, provided they are treated with caution and the results from the next phase of the study confirm this level of attainment gain can be maintained. The design-based methodology does challenge the assumption that research is somehow less valid if it is thought to be affected by outside influences which in this case could be said to be the teacher also being the researcher and designer of the study. It should also be noted that as a classroom-based study the ecological validity of this research is high, a particularly important consideration when attempting to generalise the results to the national school population. Pupils are undertaking normal tasks, albeit that the ICT input is more formalised that is usual in a science subject, but these activities are ones that the pupils would not find unusual or extreme. The school is perhaps typical and representative of Scottish inner-city comprehensives and so the findings of this study can be safely generalised, certainly to the total inner city school pupil population across the country (subject to subject considerations highlighted at the start of the next section). In inner city schools such as this one which do fall below national averages for attainment measured at standard grade and higher, any means of raising attainment particularly for the middle and lower performing groups of pupils might be highly significant, particularly in the order of the 28.46 percent increase demonstrated by this study, and certainly merits further investigation. That is what the second phase of this project will aim to investigate by tracking the progress of this particular pupil cohort up to and including their standard grade examinations in May/June 2009.

4.2 Design rationale for ICT/GLOW lesson planning.

An explanation of the thinking underlying the lesson plan format used is useful to inform consideration of both the quantitative and qualitative evidence from the first phase of this study. The main considerations are set out below.

- Regular use of ICT/GLOW allows eventual embedding into the subject curriculum.

- The ICT/GLOW lessons were designed to complement and reinforce classroom learning. This is the rationale behind using ICT for one lesson out of three per week.

- Computer-based lessons allowed for learning to be situated and contextualised. Theory and fact covered in class and practical lessons was reinforced by using real-life examples through multi-media, simulations and animations.

- Collaborative work and peer-assisted learning are strong contributory factors to and provide multiple opportunities for formative and peer assessment.

- Lesson activities completed using ICT/GLOW as outlined, being enquiry based, allow pupils to develop their problem-solving skills. This aspect of the curriculum (which contributes half of the available marks in the standard grade examination) is considered historically to be difficult to teach.

- The lesson activities also involve the pupils in many different styles of learning (linguistic, logical-mathematical, visual-spatial, bodily-kinesthetic, musical, interpersonal and intrapersonal – Gardner 1983). This maximizes the opportunity of every pupil in the class to achieve useful, deep learning.

- Lessons are structured so that there is a list of planned activities which increases in complexity. The learning objectives are covered by the first two or three activities and the increasing complexity of further activities ensures that the more able pupils are challenged and kept motivated.

- Cross-curricular themes are developed, as well as core mathematical and literacy skills through activities such as data interpretation, use of spreadsheet functions, and text analysis and interpretation.

5.0 QUALITATIVE INDICATORS

This report has so far concentrated on the quantitative aspects of raising attainment by embedding ICT into a secondary school subject. The design has been geared to that end; to allow any measure of attainment gain to be quantified. The use of an iterative, design-based research process allows a certain degree of freedom to adapt and refine the methodology and design of a study and indeed this is what has happened here. This study has latterly developed a somewhat dynamic process of refining the research questions, analysis, and methods, leading to changes in interpretation or further questions with regards to the data analysis. The original intention was to try to put together a model of good practice for others looking to increase their use of ICT/GLOW, but it is a matter of debate as to how much use such a model would be whilst other questions as to the nature of the ICT/GLOW mediated pedagogical shift or impact upon attainment has been subjected to further investigation. There is also an issue over the generalisation of the findings from this study involving pupils studying Biology to other subjects taught in secondary schools, all of which have their own particular ethos, although, having said this it is the author's opinion based on personal and professional experience that the model used in this biology-based study could be adapted without major alteration to most other curriculum areas, with the possible exceptions of PE and Creative and Aesthetic subjects. The proposed classroom coding exercises previously described are being developed and it is planned to implement these into random and unscheduled classroom observations over the coming months. However it is possible to consider some evidence as to the qualitative effects of using ICT although it should be noted that this qualitative type of analysis and interpretation is in the hermeneutic tradition and therefore firstly, subjective, drawn from interpretation of events which might be different for another researcher or observer, and secondly, anecdotal, based on professional discussion and observations by visitors who have observed the study class working on the GLOW VLE. Perhaps the most common of these observations was that levels of engagement with the learning were much more evident than with many conventionally taught classes. This has been evidenced by the speed at which pupils log-on to their computers and commence work, and also that they seem able to remain focused and concentrating right up to the plenary sessions which take place in the last five minutes of each lesson. This is

perhaps in marked difference to non-ICT based classes where there is a definite 'settling down' period of time at the start of each lesson, as well as 'delaying' tactics by some pupils who use pencil-sharpening, removing coats and opening bags, fetching books and jotters and other such activities as a way of delaying the start of any meaningful work. This can last for anything up to ten minutes in each lesson. Equally, towards the end of lessons, there is a waning of concentration and effort and very often an increase in conversation unrelated to the subject matter or poorer behaviour. Again, this can be for the last ten or fifteen minutes of a lesson. Taken in total, this amounts to perhaps as much as twenty minutes of each lesson where no productive activity takes place. This time can be extended, particularly at the end of the school day or just before lunchtime, and fits in well with estimates of children's concentration spans at about thirty minutes. This amounts to a considerable amount of 'teaching' time lost over a term or academic year. Of course, it poses the question as to whether the improvement in attainment shown by pupils in this study is actually due to increased time spent concentrating on subject materials rather than any direct effect of the ICT input, as this could still be attributed, albeit indirectly, to the use of ICT in the classroom. Other comments from casual observers allude to the quality of the learning which appears to be taking place. This has been evidenced by the answers pupils give to directed questioning being of a noticeably higher level, indicating enhanced thought processing and critical analysis skills are being developed. Pupils are beginning to make links to and from work done in other subjects. The pupils themselves have commented on how the material they cover using ICT/GLOW seems to 'stick in their minds' much better and they have less trouble recalling it during assessments. The pupils also commented, via an anonymous survey completed on-line, that they 'enjoyed' using ICT every week in biology lessons and that it allowed the teacher to spend more time with classmates who needed more help, or that they felt more able to ask for help from their friends. This last point is quite significant as it confirms both other casual observations and the researcher's own perhaps subjective view that the usual differentiation of classroom materials according to ability is made much easier through the use of ICT/GLOW. Indeed, what has started to happen is not so much differentiation but individualised learning with each pupil getting appropriate levels of one-to-one time from the class teacher. Further investigation of all of these points will be made possible using the classroom observation coding mechanisms over the coming months. Thematic analysis of the transcripts of teacher-pupil and

pupil-pupil interactions will enable these qualitative measures to be examined in much greater and perhaps provide empirical data. This apparent improvement in retained knowledge and deep thinking skills might be due to the increased time the teacher spends on one-to-one teaching with individuals, greater levels of effective peer-assisted learning, increased concentration and engagement on and with set tasks or a transactional relationship between all of these factors. It is hoped that coded observations will throw much more light on these qualitative aspects of the classroom activity and how they might be impacting on the quantitative measurements of improved attainment. Perhaps, just as importantly, they will allow a more accurate assessment of the sustainability of these quantitative improvements. Detailed analysis of the different components of the assessment instruments (knowledge and understanding as well as problem-solving) might also point to just which aspects of pupils' academic performance are being improved the most. Is it more efficient encoding of information into long-term memory, or is it the development of improved levels of thinking, reasoning, and critical analysis skills which are behind the improvements in attainment? Traditionally it has been recognised that it is much harder to teach problem-solving skills than knowledge and understanding. If this way of using ICT can drive up attainment in this particular area of a pupil's academic workload, then it may well be of major significance to future studies and direction of pedagogical development and policy.

Another important area which will be measured during the next phase of this study is the effect using ICT/GLOW might be having on the pupils' social skills. There has been a noticeable change in the pupil-pupil interactions, perhaps because collaboration is made easier by using a VLE to which everyone in the class has access. Is this use of ICT enhancing their communication skills and does any increased level of inter-pupil communication and collaboration have a qualitative focus academically or is it solely socially based? Is this collaboration, communication, and peer-assisted learning which is taking place driving up attainment when compared to the activity in a conventional classroom environment? There also appears to be a motivating effect for more challenging or disengaged pupils. Behaviour issues involving these pupils have been noticeable by their absence during the study group ICT/GLOW sessions. Again, it is hoped that classroom observation coding may throw some more light on these developments.

6.0 TOWARDS A MODEL OF GOOD PRACTICE IN ADOPTION OF ICT/GLOW INTO REGUALR CLASSROOM USE BY TEACHERS.

The evidence so far gives strong grounds for suggesting that something important was achieved in one class, but contributes little to what exactly was important in this. This question of cause and effect will be investigated in phase two of this study. However, it is useful to examine the factors which contributed to the success of this intervention in raising attainment. A staged process of change and adoption worked well during this study. The main features of this process which seem to the author to have been important are set out below. This is not meant to be a closed list, but a starting point for consideration which will by its nature, evolve to suit the needs of specific subject areas and locations (it is assumed that any teacher wishing to embed ICT/GLOW into their teaching and learning will be proficient with the software and systems being used).

- A supportive presence from a leading member of the school management team was essential to facilitate any organisational and logistical changes necessary to move the adoption of ICT forward. Faculty heads and principal teachers were also involved in the planning and organisational processes.

- All staff in the department concerned who were involved understood and were involved with what was happening.

- Staff involved had a personal motivation to raise attainment and a positive attitude to the possibilities which might arise from increased use of ICT. They were prepared to invest time initially in setting up the systems and resources which were to be used regularly each week.

- The classes using ICT were carefully selected to be of genuine mixed ability. This was considered important in order that the full benefits from increased peer-assisted learning could be established as a regular occurrence in classes.

- The day and time of the ICT-delivered lessons needs was established and arranged in advance, preferably in the same location each week. This consistency was important for the smooth running of the classes. The pupils benefited from knowing where and what they would be doing each week and were therefore mostly in the right frame of mind when they arrived at the lesson. This also reduced the organisational workload.

- Two or three lessons needed to be set aside to establish basic organisation and routine. Pupils needed to be logged-on to which ever system was being used, set up passwords, access group/class pages, and be shown how to navigate their way around their on-line environment. They were shown examples of the types of tasks they would be expected to complete as well as the different kinds of resources they would be using, and were given plenty of opportunity to practice using all applications associated with the VLE (with GLOW, three lessons were found to be necessary to complete this familiarisation work).

- Pupils were shown how to upload or submit resources they found for evaluation. An important factor behind successful use of ICT was the pupils taking responsibility and ownership of their learning experience. A big part of this was developing the skills necessary to source and evaluate materials for use by other classmates.

- Pupils were absolutely clear what was expected of them from each lesson. A set of clearly defined learning outcomes was provided via their pupil homepage, which was then used as they proceeded through the tasks set for the day. This was then used as a lesson plenary session towards the end of the class to check learning outcomes for each lesson. A task list was provided for each lesson which told the pupils how to work through the materials to achieve the learning objectives. Pupils would then work at a pace appropriate for them, monitored by staff.

- Initial lessons involved fairly simple tasks and pupil workload was carefully managed to ensure each student managed to complete a programme of useful

work matched to clearly defined learning objectives. As pupils gained confidence and experience, the pace and complexity was changed to suit the needs of individuals. Work set was then of increasing complexity to challenge more able pupils to allow them the opportunity to make faster progress.

- Pupils were given regular opportunities to comment on and evaluate the quality of their learning experience using ICT/GLOW. These evaluations were invaluable in adapting the lesson plans and materials throughout this study. These evaluations took the form of on-line anonymous surveys (using www.surveymonkey.com) which allowed pupils the freedom to be open and honest about their experiences.

- Pupil virtual 'whiteboards' provided regular opportunities for pupils to collaborate with each other or to view the work of classmates. Instant messaging was useful for asking questions of each other and keeping a level of 'classroom banter' going. Teachers were able to check each pupil's progress by looking for their individual whiteboards in their drop-down menu list. This gave access to the whole class's work from the teacher's computer terminal and enabled help to be targeted very quickly to where it was needed.

- The author checked with pupils that they were able to access their pages from outside the school. This was useful for revision and homework which was often loaded onto the system (GLOW can be particularly good for this as the GLOW group's form a very effective resource bank for pupils to access at will). A wider range of resources can be loaded onto GLOW group pages than is possible by giving pupils text-books to take home.

7.0 CONCLUSION

This research study has raised important issues of cause and effect during the process of measuring attainment gains following the introduction and regular planned use of ICT/GLOW in one Biology class. The study addressed the issue of embedding ICT into secondary subject curricula from both quantitative and qualitative viewpoints and the limitations of starting with such a wide-ranging set of intentions in such a short space of time is recognised, with this qualitative aspect perhaps signposting the directions to be taken by the next phase of this study. This is intended to address both the limitations imposed by measuring attainment over a relatively short segment of a standard grade course, as well as the nature and sustainability of the attainment gains demonstrated so far. The planned coding exercises will, it is hoped, yield valuable information on the effect (if any) of the ICT on classroom practice and pedagogy. The challenge will then be to assess how much any change demonstrated has contributed to gains in attainment and how much the use of ICT itself has been responsible for. Whatever the findings of the next phase of this study, it is clear that there has been a significant gain in the attainment of the intervention group pupils. It is also safe to conclude, from the results and analysis of this study that these gains are due to the embedding of ICT into the teaching and learning in a regular planned pattern, even though the mechanism by which the use of ICT is driving these gains is unclear. There would not have been these gains but for the use of ICT via the GLOW VLE in the way outlined in section 2.0. What appears to have emerged from this initial study is that ICT can be used to raise pupil attainment in secondary schools quantifiably, and perhaps just as important a task as extending this study in the directions planned is starting a much wider debate about the fundamental paradigm shift which is required to make this use of ICT more widespread. This shift is one which will inevitably ask challenging and perhaps uncomfortable questions of education authority officers, school management teams, teachers and pupils, (particularly with regard to capital expenditure and teacher experience and raising attainment and how the effective use of ICT might be able to compensate for teacher inexperience); Questions involving investment, management style and leadership, assumptions, beliefs values and mindsets, and particularly of how to begin to come up with curricular contexts that engage, motivate, and situate learning for today's digital natives. Perhaps at this point it is useful to return to the *How Good is our School* key

dimension of focusing on outcomes, specifically the outcome of raising attainment. If regular planned use of ICT (and in this case, delivered using the GLOW VLE) can be shown to raise attainment by the factor demonstrated by this study, surely the answers to these questions must now be actively sought through a process which not only proceeds within schools, but spreads out to both local authorities and indeed, national policy-makers. Is it time for revised forms of dialogue between all levels of education management at local authority and national level which will create new opportunities for teachers and pupils to take the lead on using ICT in their schools to drive up not only quantitatively-measured attainment but a more widespread re-engagement, not just with education but with the whole process of learning and with the motivation to learn itself? Perhaps a bottom-up approach to these issues (with leadership as a complex and fluid function rather than a hierarchical 'traditional' role) coming from classrooms and schools themselves and at the risk of clashing with the traditional top-down hierarchical structure of education management and the somewhat unbendingly paced and managed local authority corporate ICT agenda prevalent in this country, is what is needed to deliver the transformation of education long expected through the use of ICT. Maybe, just maybe it's worth this risk to keep the lights firmly and unequivocally staying on to light up learning in a twenty-first century Scotland.

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Appendix 1

GLOW/ICT LESSON PLAN

Pupils arrive at classroom and log onto their computer stations. They then proceed to sign in to GLOW whilst lesson administration and registration is taking place.

Pupils will arrive at their GLOW pupil 'home' page from their log-in and find targeted message waiting for them outlining the general lesson themes to be covered for the day. There will be an attachment containing lesson objectives (linked to learning outcomes from the SQA course arrangements document for the subject). Pupils will read through these and minimise the attachment so that they can refer to it as the lesson proceeds and during the final plenary session (see appendix 2)

Pupils then go to their GLOW group (this is a series of pages for their particular class containing materials for the modules in their course – standard grade Biology). They go to the 'documents' store and access the instructions for the particular day. This document (example as appendix 3)contains detailed instructions on how to proceed through the learning tasks for the lesson. Working through these tasks ensures they cover materials which enable them to achieve the learning objectives for the lesson (usually by the end of task 2 or 3).

The list of tasks increases in complexity to allow for different levels of differentiation and more able pupils are challenged and are kept motivated and engaged.

Plenary session (5 minutes) at the end of the lesson to recap and ensure all pupils have achieved the learning objectives for the day (done through questioning verbally or on-line using the GLOW VLE 'meet' or 'chat' tools).

Reflexive analysis of lesson experiences (teacher).

Appendix 2

LEARNING OBJECTIVES FOR TUESDAY JUNE 17th

- Pupils will be able to explain the term 'pollination' and know that pollen is a plant male sex-cell

- Pupils will know the structure of a plant's sexual organs and be able to describe how they are adapted to suit their function.

- Pupils will be able to describe the different types of pollination and how plants are adapted for these different methods.

- Pupils should understand the roles of animals and abiotic factors important to pollination such as wind and water.

Appendix 3

CLASSWORK FOR TUESDAY JUNE 17th

1. Go to the World of Plants page video section. Watch the video 'The problem with Bees' (you will need headphones or turn up the sound on your computer). Think about this question….*What are the possible consequences for the environment if Bee numbers decline?* Post your answer in the 'discussions' section of this GLOW group.

2. Now go to the 'weblinks' section of the World of Plants page. Click on the 'Alien Empire' link. Move through the hive pages until you get the option *pollination*. Click on this option and work through the information. Think about this question whilst you are reading.. *What are the characteristics which make Bees such good pollinators?* Post your answer on the 'discussions' section again.

3. You should look at the other comments left by your classmates. Comment on a few of these *with your opinions…*

4. Now download and work through the PowerPoint presentation *Pollination in Plants.* Use the information in this presentation to help you complete the pollination worksheet. You should do this on GLOW meet whiteboards.

5. If you have time, try to complete the *flower structure and reproduction-advanced* worksheet

6. You should try to complete these tasks and the other worksheets on the *World of Plants* page of your GLOW group at home to consolidate the knowledge and understanding covered in class and during our visit to the RBG Edinburgh.

Appendix 4

A brief history and description of GLOW

Glow is a national schools intranet, digitally linking Scotland's educators and pupils. It is funded by the Scottish Government and managed by Learning and Teaching Scotland (LTS) in partnership with RM. It has taken over five years to develop from it's original conception in 2001. Glow is designed to support educational development using powerful online tools which allow pupils, teachers, parents and educationalists to work together safely and securely, at any location or time.The major components are a national directory and authentication system, collaborative software tools and a virtual learning environment as well as on-line and telephone support services. The system is built using Microsoft Sharepoint software. An interconnect high-speed broadband network links every local authority in Scotland, the Glow data centre, and national bodies such as Learning and Teaching Scotland and the Scottish Qualifications Authority. The GLOW network links the 32 education authorities, 2750 schools, 50,000 teachers and 700,000 pupils across the whole of Scotland from Shetland in the north to Dumfries and Galloway in the south.

Each user has an individual account log-in which takes them to their establishment home page. Targeted news can be sent to individuals or groups of users, and a list of the groups of which a user might be a member is listed on their home page.

Amongst the collaborative tools and GLOW groups facilities, it contains a video-conferencing tool which allows schools to collaborate and 'guests' to be able to contribute to pupils' learning from out with the school. Other attractive features include nationally purchased software such as 'Sunflower Science' and the 'Gigajam' music tuition programmes.

The GLOW groups facilitate collaboration between teaching staff and education managers in different authorities in the form of subject/interest groupings and for career professional development (CPD).

Individual school 'mentors' have been trained and are responsible for disseminating this training throughout their establishments and schools.