Using information and communication technology in lower secondary science teaching in Iceland

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The candidate confirms that the work submitted is his/her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

This study is on using information and communication technology (ICT) in science education in Iceland. The requirement that ICT be utilized in teaching has only been met to a limited extent though schools appear to be well equipped.

Data was collected through a mixed methods approach including a survey, interviews, and an intervention with eight science teachers. The study showed that teachers use equipment available to them but access to computers for pupils' use is limited. The uses are primarily researching selected topics on the internet for writing essays or other products, watching video-clips and taking photos. Use of science specific applications is rare. Support structures for science teachers are weak and CPD opportunities scarce.

Teachers have positive views towards ICT in teaching science. However there are considerable barriers to technology integration, teacher knowledge is a central element and resources, support and time are major factors affecting teachers' use of technology. Four cases are explored through cultural historical activity theory, analysing the contradictions that are at work in the context of teaching science with ICT. This analysis illustrates how resources, knowledge and more latent factors are pivotal in the extent and proficiency of teachers' technology use.

Three interventions with a quasi-experimental design explore the effectiveness of a selection of digital learning resources (DLR). The results show that benefits from using DLR's vary. In two topics the experimental classes scored significantly higher than the comparison classes but in the third it was the opposite. The findings indicate that DLR's will have a more positive effect on learning results the more interactive features they contain. A further finding from the research concerns the expertise and impact of the science teachers' pedagogical content knowledge (PCK). Perhaps not surprisingly, pupils of teachers with strong PCK tended to score higher, indicating that successful ICT based learning is related to teacher PCK.

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Definitions

Information and communication technologies

When referring to information and communication technologies (ICT) in this study it is done so in the widest context. It includes the physical equipment; computers, interactive whiteboards, as well as digital resources and information systems, such as the internet.

Digital learning resources

For the purpose of this study I choose to adopt the definition from OECD (OECD/CERI, 2007) that digital learning resources (DLR) are: *any digital resource that is actually used by teachers and learners for the purpose of learning*. This would include all digital resources, web-pages, videos, photos, e-books, audio files and more, no matter what the purpose of their design, as long as they are used for learning.

1. Introduction and background

This thesis is about the uses of ICT in science teaching in Iceland. In the first part of this introduction I describe why this subject caught my interest and how the study is outlined. The second part outlines the Icelandic context, the school system and relevant research.

1.1. Framing the study

Before commencing on the journey of educational research I had been a teacher in compulsory schools in Iceland for 15 years. In my practice I had always been exploring, learning and trying out new things, then came the time when I could apply for paid leave to go and study for a whole year. I had mainly been teaching science but had a constant affinity for all things computer related and tried my best to apply technology as much as I could in my teaching. When the time came to choose a subject for this thesis the choice was easy or maybe not because I wanted to do everything at the same time: To know what my colleagues were doing, to know if ICT is helpful for learning and not just fun, to know why everyone was not as excited about the possibilities ICT seemed to hold. This thesis is a record of this journey where some of these areas were answered, but many other questions rose.

The first question I felt needed answering was whether it is a correct assumption that teachers are *not* using ICT to any great extent. If the assumption was right it should cause some concern both in that the potential of available technologies is not being utilized, and in that pupils used to computers may consider school science old fashioned and boring. This is a highly relevant issue in the context of diminishing student interest in science studies (Osborne et al., 2003).

From there the next question that arose was ‘what are the factors that affect ICT use of Icelandic science teachers?’ Has it to do with the teachers’ own motivation, and their pedagogy or external factors such as availability of equipment, software and support? I knew what factors I felt were hindering me personally but not the whole teacher population, and so I felt that needed answering as well.

Last but not least is the issue of whether using ICT is more beneficial to pupil learning than conventional teaching methods. In my own teaching I had made efforts to use as much ICT as possible due to my own interest and seeing my students' enthusiasm when they were working with computers. When teaching I never measured effects and computer use was often restricted to optional courses or content that was not the core content of the curriculum. My rationale when designing this study went somewhere along the lines of: research has shown that usefulness has stronger links to usage than was ease of use (Davis, 1989) so exploring usefulness was what I wanted to do.

1.2. Icelandic context

In Iceland compulsory schools for 6-15 year old pupils are run by the municipalities. This study focuses on science teaching in the three last years, of 13-15 year old pupils (lower secondary). Research has shown Icelandic schools to be homogenous in terms of social, economic factors and that the schools have weak links to pupil achievement (Halldórsson et al., 2010). At the time of data collection there were 170 schools in Iceland. A common school has around 3-400 pupils with two classes of around 20 pupils of mixed abilities in each year group. This does not allow for much specialisation of teachers, often there is only one science teacher sometimes two in each school, teaching all the sciences. This sometimes leads to professional isolation of teachers. A recent survey showed that 44% of science teachers have little or very little cooperation with other science teachers and 36% say they participate in no cooperation (Bjarnadóttir et al., 2007).

Two universities educate teachers to teach in compulsory schools. Students choose one or two electives for one sixth of the three years it takes to finish a BEd. degree. After which they were qualified to teach compulsory schools until recently. From 2011 students have to finish a master's degree to become a qualified teacher. Another route to become a qualified teacher is to take a BS or BA degree, and then a post graduate teaching certificate. This has meant that it is not necessary to have any training in certain subjects to be qualified to teach it, and those teaching science often have little or no training in science. A survey of teachers in 2006 showed that of those teaching science at the time 40% had a BEd. degree with at least one of the sciences as an elective and 9% had a BS degree and a teaching certificate(Meyvant Þórólfsson, 2006).

The National Centre for Educational Materials (NCEM) is responsible for publishing teaching materials for schools and there are also small publishers producing teaching materials but so far they have not published anything for science teaching in compulsory schools. NCEM has published a series of textbooks, booklets and guides around themes. Usually there is no choice of textbooks. Teaching has been very textbook oriented and traditional in general (Sigurgeirsson, 1992) as well as in science teaching (Vilji og veruleiki, 2008). Almost all lower secondary science teachers use lecture form and discussions that are prevalent with younger pupils which diminishes the older the pupils get (Bjarnadóttir et al., 2007). Furthermore PISA 2006 showed that practical work and pupil exploration are far less common in Iceland than the OECD average and there is little interaction between pupils (Halldórsson et al., 2010).

Table 1-1 Science websites from NCEM.

Number	Content of website
7	Icelandic nature (plants, shores and oceans, sea life images, small animals, birds and forestry)
1	Environmental education
2	Sex education, one for pupils, one for teachers
1	Multiple choice questions accompanying three biology textbooks
1	The periodic table
1	Web with chemistry textbook supplements
1	Web on global warming
1	Earth science
1	Mixed web, worksheets for online research

In June 2012 there were sixteen websites available from the NCEM suitable for lower secondary pupils as shown in Table 1-1. On the website there is also a good selection of videos as well as teacher guides and printable worksheets accompanying textbooks.

Similarly there are a variety of websites published by institutions and private companies designed for educational purposes, on Icelandic nature, energy and genetics. This selection is much skewed, biology gets more attention, energy (electricity) gets a fair amount but there is close to nothing on other areas of physics or chemistry.

In the Icelandic school system there are three major factors that should influence school development. First is the curriculum, published at national level from which schools write their own more detailed document. Secondly schools are responsible for their own self evaluation. The law states that self evaluation should increase the quality of learning and school activities and facilitate school development (Lög um grunnskóla, 2008). Official guidelines suggest that schools describe and analyse the status of all major aspects of schools and make developmental plans, including the third factor, continuous professional development (CPD) -plans. It has been pointed out that even though these three factors should work in harmony, that has not been the case (Ágústsdóttir and Pálsdóttir, 2011). A recent study explored hindrances to school development in Iceland. As expected less funding caused by the financial situation was a hindrance, but Iceland has suffered from a financial crisis from 2008 resulting in severe budget costs in schools. Arrangements of funding to CPD and clauses in union agreements affecting the organisation of CPD were deemed just as important (Ágústsdóttir and Pálsdóttir, 2011). The arrangements in regard to funding are so that schools can apply for competitive funds and individual teachers can get funds that are then used at their own discretion but not necessarily in line with CPD plans of the schools. The union agreement and employers expect teachers to participate in 120-150 hours per year of CPD mostly out of term time. Indications are from the TALIS study that Icelandic teachers participate less in CPD than in other participating countries

(Ólafsson and Björnsson, 2009). Independent study and informal collaboration though were more frequent.

When ICT was first introduced to the school system teachers were trained in using common applications such as email, internet, word-processing and spreadsheets; courses on subject specific usage, however, with a pedagogic focus have been in short supply.

There have been numerous policy papers for bringing ICT into teaching and learning, the first one emphasising teaching training and publication of educational materials (Menntamálaráðuneytið, 1996). ICT skills were part of teacher training from the 1980s when computers also entered schools. The national curriculum guide from 1989 has a chapter on computer skills but computers are not mentioned in the science section. However the curriculum guide from 1999 expected computers to be used in the teaching of every subject and ICT skills to be taught across subjects which carried on to the present curriculum guide from 2007. Although the policy seems clear, its implementation is not as visible. In 2007 a report on the implementation of policy documents from 2004 -2007 reported less funding for ICT from the Ministry of Education, Science and Culture (MESC). Stagnation could be seen, aims that had been set regarding teacher education, (including CPD) were met only by a fourth, with insufficient dissemination and support, but aims to re-evaluate the policy were considered met (Capacent, 2007). Policy makers counted on initiative from teachers and schools in designing DLRs by funding with grants (OECD/CERI, 2008). The newest policy paper aims to strengthen the use of ICT in teaching by introducing ICT leaders in compulsory schools and increasing the publication of DLRs (Forsætisráðuneytið, 2008).

This thesis was developed in this context. It outlines the relevant literature regarding ICT use in science education specifically how and why ICT may be used in teaching science and the conditions that impact teachers in their use of ICT. Section three outlines the methods employed, in sections four through six the findings are presented, leading towards an understanding of ICT use in science education set out in sections seven. Lastly some conclusions and recommendations for furthering ICT use are set out in section eight.

2. ICT in science education

This literature review has three strands in accordance with the underlying research questions. First, I introduce models useful to explore different applications and then I discuss the affordances of ICT for science education that is, in what way ICT may be used for teaching and learning science. Then there is a brief overview of intervention studies exploring the possible benefits different affordances have been found to have or not. Next an overview is provided as to what reports and research has to say about the extent to which ICT is used in science teaching. Lastly, an overview of the literature on the factors affecting teachers in using ICT is presented.

The Computer Practice Framework (CPF) (Twining, 2002) can be used to describe the key facets of educational practice surrounding computer use. The framework includes three ‘modes’ of computer use where computers are said to support, extend or transform learning. When computers support learning both the process and the content of the learning stays the same. When computers extend learning either the content or the process is changed but could have been achieved without a computer. When the learning is transformed either the process or the content is different and the activity requires a computer. Twining states that the framework is value free, that it does not indicate whether the changes to practice are an improvement or not or how significant they are. But it seems to me that there is a built in value. Exploring levels of change indicates that change is valued. Within the context of talking about computers in education the agenda of wanting computers to make a positive impact on learning whether in content or process is always present.

Another way of exploring digital learning resources is the framework of Newton and Rogers (2003) who make a distinction between properties and benefits. They recognise properties as something that ICT allows you to do and the possible benefits are those that derive from the modes of learning activities in the classrooms. These modes put learners in different roles with different purposes of activity;

Purpose of ICT activity	**Learner's role**
Obtaining knowledge	Receiver
Practice and revision	Reviser
Exploring ideas	Explorer
Collating and recording	Receiver
Presenting and reporting	Creator

When working with ICT, users need both operational skills in working with software and hardware and also application skills, for example problem solving skills through which the full potential of ICT use may be realised.

2.1. Range of ICT use in science education

In order to use ICT in schools a range of equipment needs to be available. OFSTED has summarised the characteristics of good secondary school ICT provision:

- availability of different groupings of resources to match the needs of departments, for example computer rooms, clusters of machines and individual workstations around the site
- computers networked and well maintained with good Internet access from all workstations
- well-lit, comfortable computer rooms with sufficient space for pupils to work away from computers and for teachers to circulate and talk to individual pupils
- effective communication with the whole class using digital projectors or the capacity to control all the computers
- an efficient and equitable booking system for computer rooms.

(OFSTED, 2002 p. 25)

This list is fairly comprehensive though some additions might include cameras and interactive whiteboards (IWBs). For science education there should also be added electronic microscopes and data-loggers. After the start of this study even more gadgets have found their way into education such as smart-phones, tablets, e-readers, social media such as *Facebook,* and online digital storage. These are not a part of this work, however frustrating that may be, for the race of keeping up with technology is perhaps one of eternal consternation for educational research.

Most ICT applications in one way or another can be employed in teaching and learning science and ICT clearly expands the pedagogical resources available to science teachers. Wellington (2004) lists word processing and searching the internet for information, databases and spreadsheets for example in pattern searching; hypothesizing; recording and presenting data; accessing and organizing data, controlling experiments; controlling external devices, using simulations and models; using sensors for gathering and recording data; and graphics for presenting data. All the items on this list can be seen in the Icelandic science curriculum, where the emphasis is much placed on handling and gathering data and information However equipment and computer programmes are also expected to open new opportunities for practical work.

New equipment is coming along quite rapidly now. In recent years mobile phones, tablets, e-readers and other gadgets have found their way into schools. That had not started in Iceland when this study was planned and thus play no part in it.

2.2. Affordances and benefits

Computers and technology have many reported affordances in science teaching, the following list comes from Osborne and Hennessy (2003 p. 4)

- expediting and enhancing work production; offering release from laborious manual processes and giving more time for thinking, discussion and interpretation
- increasing currency and scope of relevant phenomena by linking school science to contemporary science and providing access to experiences not otherwise feasible
- supporting exploration and experimentation by providing immediate, visual feedback

- focusing attention on over-arching issues, increasing salience of underlying abstract concepts
- fostering self-regulated and collaborative learning
- improving motivation and engagement

Wellington (2004) has a similar list including motivation, excitement and pleasure; an improvement in pupils' self-esteem and perseverance; neater work and that ICT can be used to simulate practical work that is too fast, slow or dangerous for the classroom.

Research into the uses of ICT in science education is growing and knowledge slowly accumulating on how best to employ it. Here I only include simulations and web based resources as these kinds of applications were used in the intervention.

2.2.1. Reported impact of interventions with simulations

Though the most obvious advantage of using simulations is that they can depict and model phenomena that are too big, small, costly, dangerous, or lengthy for the classroom, some effort has been put into studying other affordances such as benefits to conceptual change and student engagement. Baggott (1998) stated that pedagogy based on simulations did not exist and that the little research that had then been carried out on their effect on learning or teaching did not give firm conclusions. That seems to still be the case, but some promising results have been reported on student conceptual change (Hennessy et al., 1995; Zacharia and Anderson, 2003; Marbach-Ad et al., 2008) and a better ability to predict and explain (Zacharia and Anderson, 2003). Simulations have been found to help pupils articulate a better understanding of concepts (Marbach-Ad et al., 2008). How the resource is used is important and the guidance that students received was the deciding factor for understanding boiling points and not the simulation use (Ardac and Sezen, 2002) where computer groups showed significant gains in recognizing variables but the regularly taught group did not.

Other interventions with large samples of university students (Steinberg, 2000; Hsu and Thomas, 2002) have failed to show significant difference from control groups on tests. Steinberg concludes that simulations are an excellent tool for conceptual change, and Hsu and Thomas detect a positive impact through interviews. Both Ardac and Sezen (2002) and Steinberg (2000) suggest that the failure might be due to the level of interaction with the simulation, and that to actively manipulate it and infer knowledge is more likely to provide better results. Hsu and Thomas (2003) seemed to blame lack of explanation by the teachers to the students on the simulation before its use, which agrees with Ardac and Sezen's (2002) study.

The general conclusions show that simulations have some potential in promoting conceptual change and understanding of scientific processes but both the nature and quality of the simulations and how they are used play a role in getting the best out of them. There are indications that using simulations in conjunction with practical work gives good results (Zacharia, 2007). Teachers would rather see them as an extension than a replacement of practical work (Baggott La Velle et al., 2004; Kennewell et al., 2007).

Students' views and motivation

Though it is rarely the main focus of studies, many papers comment on how students engage with simulations. An exception is a study of 21 volunteers, aged 14-15 (Rodrigues, 2007) on what guides and influences pupil engagement with chemical simulations. She used two online simulations and screen activities and recorded conversations. From retrospective interviews she identified three aspects that influence the students' engagement with the simulations:

- Distraction and vividness: students were drawn towards eye catching elements on the screen
- Logic and information: the students did not follow the instructions on the screen. They correctly said the instructions were not in a linear order on the page. It seems that these students did not get any instructions before using the simulations, so they were fumbling along by themselves trying to make sense of them.

- Prior knowledge: students drew on prior practical knowledge in their interactions.

Zacharia (2007) has found that a combination of methods may be more fruitful which has some resonance with the last point. Perhaps this is because that gives students increased opportunities of drawing from experience from different sources.

Another factor affecting engagement is the ‘edutainment’ element, of a simulation evaluated by Baggott and Watson (1997, cited in Baggott and Nichol, 1998). A simulated microscope experiment and the same work on a microscope revealed that it was important for the students to have a ‘hands on’ experience, in order to gain a positive view of the simulated experiment. Similarly in Kennewell, et al. (2007) pupils preferred traditional practical work to simulations in science because they enjoyed the physical manipulation of science equipment. The pupils recognised that it is what ‘real’ scientists do and were cognitively engaged by the relative unpredictability of the setting. Interestingly in another study Hennessy et al. (1995) found the novelty of using computers soon wore off. The authors point out that the activities were very similarly structured and the pupils soon learned what to expect, so they recommend more variety and fun. Contrary findings are reported by Wellington (2004) where both students and teachers thought the material was motivating, engaging, and that it gave the students a sense of achievement. The pupils appreciated repeating activities as often as they liked until they understood.

Concerns of teachers have also been reported (Baggott La Velle et al., 2004). Teachers expressed the view that recent changes in technology were less ‘educationally focused’ and more ‘edutainment’ focused and this led to the core of science being lost. It must be an ongoing challenge for designers of educational material to keep up with very vivid material, designed only for entertainment purposes, and at the same time to deliver good content and sound pedagogical strategies. None of the above studies mention that the simulations used may not be the most exciting. I tried those that Roderigues

(2007) used[1] and found some of them confusing and rather unattractive when compared to computer games that teenagers play that are very life-like. Still factors identified by Rodrigues give good indications both for teachers and designers on how to design and plan for the successful use of simulations. Although enjoyment may be an important factor in learning, recognition of previously discussed affordances are just as important.

2.2.2. The internet in science education

This section focuses on the internet as a resource for information, mainly text, but also diagrams, videos, and photos. Referring to the internet as a simple entity is simplistic; the internet includes so many applications.

Being able to search, interpret and question sources of information from the internet is an important part of scientific literacy (McFarlane and Sakellariou, 2002), so ICT therefore plays a vital role in developing those skills. MacFarlane and Sakellariou argue that ICT has potential to further both scientific reasoning and analytical approaches that are both needed for the education of scientifically literate students.

Clinch and Richards (2002) advise that using the internet is a good option to make a topic more interesting, particularly those concepts that students find difficult. As an incentive for discussions their suggestions include graphics for things that are not easily seen otherwise. Interestingly they also recommend websites for fun, albeit educational sites with good science content.

There is now a wealth of science materials on the internet designed for education, professional and commercial use. Wellington and Britto (2004) have discussed the material available for science, also the difficulties and issues such as security, lack of control and the variety of quality. Clinch and Richards (2002) found that good activities that match curricular needs are rare. A slight

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1 http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htmhttp://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm

mismatch in content can make large parts of a website or activity useless to teachers' needs.

There are several issues regarding internet use in teaching. First of all, the vast quantity of websites and diverse quality makes it difficult to leave pupils to work on their own. In schools students need to be guided in evaluating the information they come across. Teachers can also control where students go, with intranets or a list of pre-approved and appropriate websites. Using the internet as a resource in research, for essays and project is a common activity. With that activity comes the issue of how students use the information they find. Teachers are concerned about how much of what students produce is their own work or if it is just a question of 'copy/-paste'.

Wallace et al. (2000) conducted a study with sixth graders, giving them the task of looking for specific information. Pupils interpreted the task differently, and worked on the goal of finding the answer in as few hits on web-pages as possible. They were busy and engaged during the activity but not successful in finding useful information, showing that information seeking is a complicated process. That study ended with more questions than answers, with no suggestions on how the task could have been framed better to get the students to find and read relevant information. Clinch and Richards (2000) however make it their main point that aimless surfing of the web is useless and they give examples through their own work of websites that direct students to appropriate material chosen for them. They also introduce the possibility for teachers to create and upload their own quizzes and tests.

Teachers are concerned with how students can be swamped with information when using the internet, (Baggott La Velle et al., 2004) exposing the need for them to judge the information found. Furthermore, students sometimes gather information and do not use it to learn, even trying to circumvent the task, using only lower order thinking skills (Baggott La Velle et al., 2004). Still the internet is seen as a valuable source by teachers, and they recommend well defined tasks and time limits.

Indications are that the use of ICT leads to higher levels of student involvement and that the uses are motivating for students (for example (Cox, 2000; Wellington, 2004). Cox (2000) has argued that ICT use may keep the school up to date, introducing students to methods of industrial science.

When reading through the literature it soon becomes evident that in order to achieve the reported affordances, an important aspect is not what is used but **how** it is used (McFarlane and Sakellariou, 2002). The role of the teacher is central in choosing, planning, managing and facilitating productive discussions.

Furthermore, after computer use was negatively associated with achievement in a number of countries in TIMSS, Papanastasiou et al. (2003) went back to the data and controlled for social economic factors like computer use at home and comfort with using computers, especially word processing. They found that the greater the home use and comfort, the more likely the students were to have higher levels of scientific literacy. She suggests that it is the lower achievers who get to use the computers most in schools. This might well be. At least in Iceland the availability of educational software for special education seemed to be better than for mainstream students with special educational needs teachers using ICT more than classroom teachers (Guðmundsdóttir, 1999).) Papanastasiou (2003) concludes that: 'The relationship between computer use and achievement is much more complicated than it might initially appear.' (p. 331) and also that how computers are used is most important:

> it must be challenging, focused on higher-order thinking skills, the teachers must be capable of using and teaching it and have the appropriate support. In other words, examining computer use or technology, by itself is not enough to determine its effects on student achievement. What seems to be important, however, is the way in which technology is used. While a number of factors may need to be addressed to improve science education, the appropriate use of computers and other technologies is an important way to upgrade science teaching and learning. (Papanastasiou, 2003 p. 326)

The Impact2 study involved 60 schools, (Harrison et al., 2002) and investigated the relationship between attainment and ICT use. It showed a trend towards higher gains with more use though there were notable variations, leading the authors to suggest that further study of the practice within the schools is needed.

Still there is not as yet a saturated pool of knowledge on how new technologies can best be employed (Baggott La Velle et al., 2003; Livingstone, 2011). Cox (2000) states that 'ICT use in science education should evolve from the *needs of science* and not vice versa' (p.194). This is something that I think teachers will agree with, that technology should not be employed because it is there but because it can benefit the subject and the students in some way. From the above mentioned studies on the extent of ICT use, it seems that teachers are still not fully convinced that ICT use should be an integral factor in teaching science. Teachers' choices are contingent on their perception of usefulness (Cox, 2000) so adding to the growing evidence that ICT use is beneficial to learning and by conducting an intervention in an Icelandic context will hopefully prove to be a worthy undertaking. Nothing similar to the proposed intervention has been carried out in Iceland.

2.3. Extent of ICT use in science education

2.3.1. Internationally

It seems to be a concern in most countries that ICT is not used enough or not in the ways that educators or policy makers would like to see. This concern can be seen both in governmental reports and research papers, as reported below.

The extent of the uses of ICT is still relatively low in the Nordic countries, but as these countries have a comparable society and education system it is likely that the situation will be similar in Iceland. A Nordic report shows over 50% of pupils in Finland, Iceland and Ålands Islands are using computers weekly or less in school but other countries slightly more (Guðmundsdóttir et al., 2010). Two recent studies with samples of 782 and 516 pupils showed that ICT is seldom used in Norway (Lund et al., 2008). A Danish study also showed low levels of use in science education (Brandt and Johansen, 2008). In a sample of 399 teachers in Finland only 7% used ICT occasionally (Aksela et al. 1999 in Lavonen et al., 2003). A Finnish project (Lavonen et al., 2006) involving 25 teachers changed teachers use of ICT over a range of applications from ‘never or seldom’, to ‘seldom to occasionally’ meaning once or twice a week. Another Finnish study showed that students were using ICT less in science than in foreign language studies, Finnish language and humanities (Hakkarainen et al., 2000). This same finding has been reported in the UK as well (Harrison et al., 2002). McFarlane and Sakellariou (2002) however found a jump in the use of ICT in science between 1998/9 to 1999/2000, stating it would be interesting to know what kind of use was involved.

In the USA, Songer (2007) talks of the underuse of ICT in science teaching but blames it on limited availability of software that fits the curriculum and promotes thinking.

2.3.2. Iceland

Previous research on ICT use in Iceland is rather sparse, especially in science education. Currently there are listed[2] 42 masters and doctoral theses on ICT and only one from 2011 on the use of cameras is science related. Another one from 2007 is maybe aptly named ‘This is just something on the side’. Iceland participated in the SITES study (Pelgrum, 2001) which showed that Icelandic schools seem to be very well equipped in terms of quantity of hardware. They had the sixth best ratio out of 24 countries with 12 pupils to every computer and 100% of schools had an internet connection. Furthermore 64% of schools indicated that the internet was used with pupils for instructional purposes. The study also showed that schools had high goals in regard to staff training but poor realisation of those goals. Despite these positive numbers Jakobsdottir (2001) describes how little computers had changed teaching practices .

In the context of science Stefánsson (2006) asked 15 year old students about the role of ICT in their science lessons. The only reported use of ICT in science lessons was finding references for essays. More evidence of ICT use can be found from a large scale research project on science teaching in several districts

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[2] http://skrif.hi.is/rannum/rannsoknir/doktors-og-meistaraprofsritgerdir/ Website of The Centre for Educational Research on ICT and Media at the University of Iceland

in Iceland (Macdonald, 2008b) where there was a focus on what ICT resources were available and what role they played. The main findings include

> Few classrooms have more than one computer though an increasing number have access to a data projector. There are some mainly content oriented web-based science materials in Icelandic developed by the NCEM and the School Web. (p.6).

A survey of 127 science teachers in compulsory schools showed that a third used web-based learning resources, mostly the ones from NCEM as much or very much, and 20 use it little or very little (Bjarnadóttir et al., 2007).

Sigþórsson (2008) observed and interviewed 23 teachers including seven science teachers and reported that apart from finding references for essays the use of ICT seems negligible. He also found that none of the teachers mentioned the use of internet in their teaching. Only one incident of ICT use was observed but there was some indication of the use of slideshows among the teachers.

Þórólfsson et al. (2009) carried out case studies of five teachers who all used ICT in teaching but science specific uses were found to be weak or vague. One school has been a lead school on the use of data loggers (Bjarnadóttir, 2007) and there has been little evidence on that programme being disseminated to more schools.

2.4. Factors affecting ICT use by teachers

Writing this review has felt like carrying coals to Newcastle as numerous studies have explored this issue in both the context of science and other school subjects. The studies reviewed here are either general ones (e.g. Ertmer, 1999; Ertmer, 2005), in the context of innovative uses of ICT (Drent and Meelissen, 2008), a meta-analysis or reviews of a wide selection of studies (Hew and Brush, 2007; Mumtaz, 2000; Bingimlas, 2009) an international comparison study (Pelgrum, 2001) and then studies specifically in the context of science (Rodrigues, 2006; Cox et al., 1999). The studies show a vast array of factors affecting teachers´ technology integration. This review provides a background for exploring what the factors are that affect Icelandic teachers.

The discourse on factors and conditions that affect teachers in technology integration is often in terms of barriers and what factors impede teachers in using ICT in teaching. Other studies focus more on what factors have been found to facilitate ICT use.

The literature reviewed before the design of the research tools in this study were all in the context of science teachers. The one that most influenced this study is by Susan Rodrigues (2006, p.179) who puts forward

> that informed integration and changes in pedagogical practice were due to six key factors: Relevance, Recognition, Resource, Reflection, Readiness and Risk.

More specifically the relevance of resources to teachers current teaching, the recognition of peer expertise, readiness as in actively seeking change; risk, as in the willingness to go outside the comfort zone and try new things.

In the context of science education Cox (2000) lists barriers detailed in official reports and from school inspectors:

- the generic software provided with the school´s network is all that is needed for using ICT within school subjects
- the ICT lessons should be independent of other science lessons
- all pupils must be using the computer all the time during the lesson
- if the system does not work as anticipated, a whole lesson is wasted
- ICT is not relevant to the science curriculum
- ICT does not contribute much to pupil´s learning of science

Casting the net further afield to include literature of teacher technology integration irrespective of subject provides a plethora of models and frameworks summarizing the many factors at play. The most extensive one is a review of 48 empirical studies (Hew and Brush, 2007), in which 123 barriers were found and categorized:

- The lack of resources may include one or more of the following: (a) technology, (b) access to available technology, (c) time, and (d) technical support.
- The lack of specific technology knowledge and skills, technology-supported pedagogical knowledge and skills, and technology-related-classroom management knowledge and skills.
- Institutional barriers may include: (a) leadership, (b) school time-tabling structure, and (c) school planning.
- Attitudes and beliefs about the educational purpose of using technology in the teaching and learning process
- High stakes testing, leaving little time for new methods and failure to recognise what role technology might play in preparing pupils for testing.
- Subject culture, not wanting to adopt new methods seen to be incompatible with accepted methods.

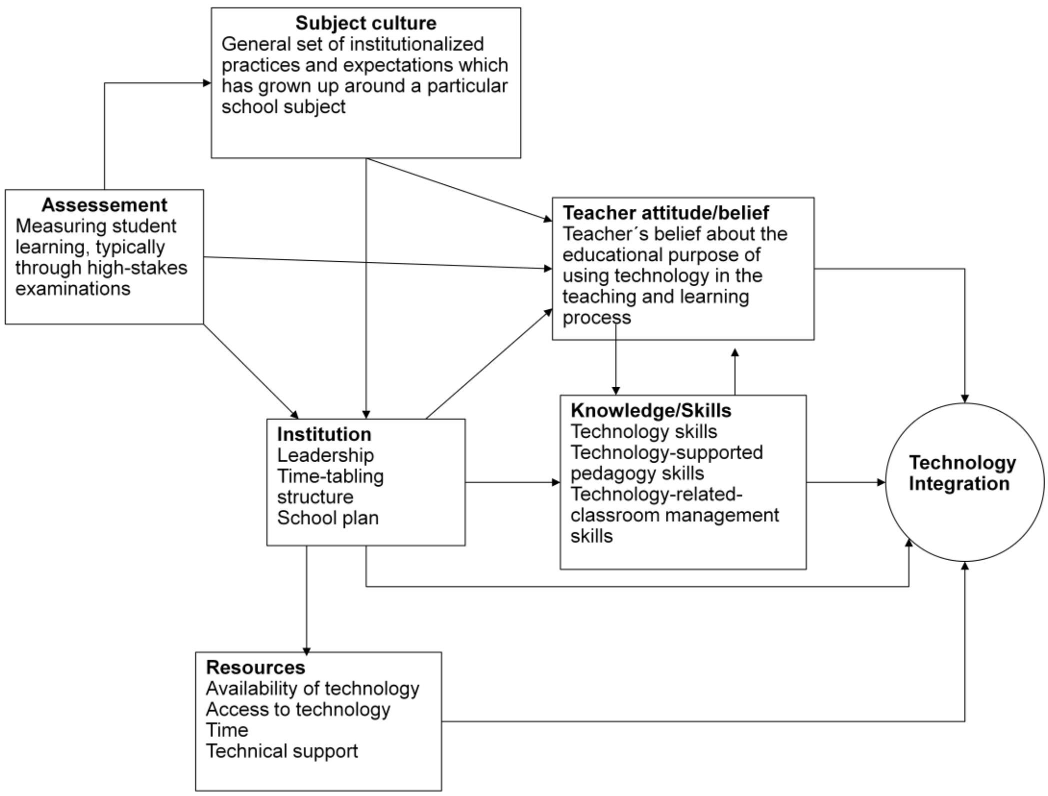

Figure 2-1 A model showing the relationship among the various barriers (Hew and Brush, 2007)

The factors that Hew and Brush (2007) found can be seen in Figure 2-1. In their model (hereafter called HB model) technology integration is said to be directly affected by the available resources, the institution, teacher attitude/belief, and by knowledge and skills which in turn affect attitudes and beliefs. Teacher attitudes are furthermore believed to be influenced by the subject culture, assessment and the institution. The institution is in the model affected by assessment; typically high stakes examinations. In addition the institution directly affects the provision of resources and affects teacher knowledge and skills through provision of professional development. Lastly, the subject culture is said to affect the institution and is affected by assessment.

This review is roughly structured around this model with the exception of assessment. As there are no high stakes testing in Iceland in science, there is little likelihood of them having much effect. Factors assigned to the institution are split into support and resources dependent on the context.

After a survey and case studies, Drent and Meelissen (2008) presented a model showing the relationships of teacher level factors stimulating or limiting teacher educators in innovative use of ICT. The four main factors in their model are:

- ICT attitudes;
- ICT competence – a small indirect effect ;
- Pedagogical approach – where they found a direct but weak relationship between student oriented approaches and innovative ICT use;
- Personal entrepreneurship - a key factor, ´ operationalized as the number of contacts a teacher educator has (both inside and outside the school) for professional development in the use of ICT.´ (p. 195).

Through the use of case studies the importance of a reflective, active and research-oriented attitude was revealed along with the practice of experimenting with different ICT applications exploring their value for teaching. School level factors were not found to have a direct effect on innovative practices but rather influence them. The relationships are compared to a cogwheel where a movement in one part of the system nudges it on to other parts.

The following sections cover the aspects that proved to be relevant to the Icelandic context, resources, subject culture, teacher knowledge and attitudes from the HB model but also support separately and pupils as a separate factor.

2.4.1. Resources

In the HB model resources are identified as one of the four aspects that directly affect technology integration. It almost goes without saying that schools need to be provided with adequate equipment for the kind of computer use that the curriculum suggests. Meelissen (2008) argues that in many developed countries access to equipment is no longer a relevant issue. A recent Icelandic survey of schools (in currently unpublished research) however revealed a similar trend where 26.1% of teachers ranked better access to computers highest as the factor that would encourage them to use more ICT in teaching. Other equipment also scored high (Starfshættir í grunnskólum, nd)[3]. Having equipment that works faultlessly is important. Science teachers have complained of the time it takes to set up, put back and calibrate equipment and of not having enough computers These complaints were all factors that deterred the teachers from using computers (Tan et al., 2006). The availability of relevant resources have been found to influence teachers classroom practice (Rodrigues, 2006).

Time is a frequently cited factor affecting technology integration (Ertmer, 1999; Hew and Brush, 2007; Rodrigues, 2007; Granger et al., 2002; Karasavvidis, 2009). Rodrigues (2006) found that teachers need time to practice and reflect, and at the same time to have access to expertise and equipment as well as opportunities for reflection through systematic follow up. A study by Haydn and Barton (2008) showed time to be crucial factor during a CPD project where teachers were given time to work collectively. Another time related issue is that

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[3] This is from a report made available to participants and published on the website of the project *Research on Practices in Compulsory schools*. The researchers do not recommend referring to it as it is unanalysed data, but I will still do so where the numbers agree with and support the findings of the current study.

teachers feel they have limited time in the classroom because of an overfull curriculum that does not allow time for flexibility (Karasavvidis, 2009; Baggott La Velle et al., 2004).

2.4.2. Support

Many different kinds of support are needed for successful integration of technology. Support in this context is a broad category including support both in terms of where it originates and different kinds of support; administrative, professional, technological and peer. In the SITES study (Pelgrum, 2001) headteachers and technology experts believed that the most noteworthy were not enough supervision staff, lack of technical assistance, insufficient teacher time and insufficient technical support. When working with science specific equipment technical training and assistance are specially important (Tan et al., 2006).

When comparing how well schools managed an internet initiative Lawson and Comber (1999) found that schools that had the most success had among other things a whole hearted management support. Similarly Somekh (2008) reports the vision and motivation of the principal to be of high importance. In the SITES research, headteachers were more active in stimulating use of ICT in high ICT using countries than in low using (Pelgrum and Voogt, 2009). The abilities to build relationships and team spirit, to solve internal conflicts and improve communication between staff have been found important characteristics of headteachers in regard to ICT (Charalambous et al., 2011).

Peer support and collaboration were considered to be a crucial factor to successful integration of ICT in a large UK initiative (Galanouli et al., 2004). Various modes of peer support such as linking online, reflecting on practice, sharing best practice and debating ideas are suggested by BECTA as ways to help teachers use ICT (Scrimshaw, 2004). Lavonen et al. (2006) conducted a project involving varied support for teachers. Their suggestions for a successful project for teachers in the uses of ICT should include:

> (i) empowerment (co-planning of the project and its activities, and dissemination, allocation of resources, and authentic evaluation); (ii)

> communication (ensuring a flow of ideas and creativity, allowing communication and reflection in small groups and in optimal locations); and (iii) context (integration of ICT into teaching methods and cumulative development of competencies in the teachers who use it). (p. 159)

A master's thesis showed that Icelandic headteachers held very positive views of ICT and believed that technical integration is more developed than classroom teachers belived. The author concludes that headteachers views will not provide a barrier to further technology integration (Elfarsdóttir, 2005).

2.4.3. Subject culture

Hew and Brush (2007) identified subject culture as a barrier, defining it as: 'General set of institutionalized practices and expectations which has grown up around a particular school subject'. Ertmer and Ottenbreit-Leftwich (2010) take that discussion further and point out the influence of peers, especially veteran teachers that do not see the value of new ways´. This influence permeates not only subject culture but also school culture. That is especially true for ICT that often changes the traditional way of teaching. One of the barriers discussed by Cox (2000) is the change to the teacher's role from being in the leading role to becoming a classroom manager and facilitator. Then again schools may have a culture that embraces innovation. Nonetheless Ertmer and Ottenbreit-Leftwich (2010) conclude that for the most part schools have not defined a way of practicing and thinking about teaching that includes technology as an integral tool for learning.

2.4.4. Teacher knowledge

To use technology in teaching, teachers need to broaden their knowledge and skills. To change teacher practice teachers need to be approached both in teacher training and in CPD (Ertmer and Ottenbreit-Leftwich, 2010).

Newton and Rogers (2003) talk about two sets of skills needed when working with ICT. First teachers need an operational skill; that is knowing how to operate computers and software. They also require application skills, what teachers have to do and plan before working with pupils using ICT, identifying the learning aims and objectives, organising lessons and tasks and then supervising or teaching them. The authors include as application skills knowledge and skills such as procedural understanding and problem solving skills. They do not expand on other conditions that need to be in place, such as teacher content knowledge or availability of equipment. A more detailed model of teacher knowledge is the model of teacher technical pedagogical content knowledge (TPCK) (Mishra and Koehler, 2006), expanding on the concept of pedagogical content knowledge (Shulman, 1987). The TPCK model combines the three areas of knowledge that are needed for technology integration. Content knowledge (C), is about the actual subject matter that is to be learned or taught. Pedagogical knowledge (P) is the deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims. Lastly technology knowledge (T) is about all technologies used in teaching from books and blackboards, to software and hardware. This includes knowledge that such things exist and how to operate them. Three sets of knowledge result from their interaction (see Figure 2-2). PCK is pedagogical content knowledge (Shulman, 1987) i.e. that is applicable to the teaching of specific content, of pupils, strategies and preconceptions. Plainly speaking, it is the knowledge of content and how to teach it.

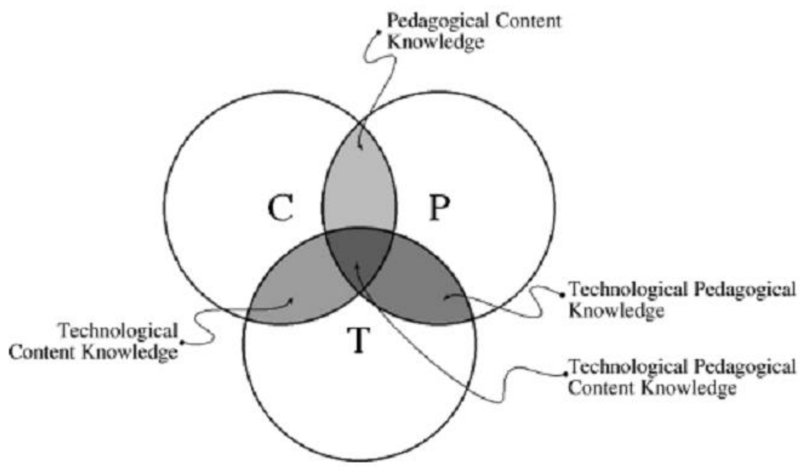

Figure 2-2 Technological Pedagogical content knowledge (Mishra and Koehler, 2006)

Technological Content knowledge, (TCK) is knowledge about the manner in which technology and content act upon each other ‘the manner in which the subject matter can be changed by the application of technology' (p.1028). This in many ways corresponds to what Newton and Rogers call application knowledge or knowing of the possible benefits and affordances that ICT may hold for that content.

Technological Pedagogical Knowledge (TPK) is:

> knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies. (Mishra and Koehler, 2006 p. 1028).

This matches the intrinsic properties that ICT may hold such as time saving or automated responses.

Together these three form technological pedagogical content knowledge (TPCK) which is different for every course, every teacher and working theory. It involves a deep understanding of technology, content and pedagogy in order to choose the appropriate suitable applications for the intended content for a given group of pupils. This is though where the shoe does not fit as in other research teacher knowledge is seen as a barrier to using ICT in schools (Hew and Brush, 2007). Research has shown teachers to be far more concerned with external factors, than their own knowledge on how to use ICT in teaching (Thompson and Parrott, 2003).

The only Icelandic research I could find looking at factors affecting Icelandic teachers was a master's thesis (Jóhannsson, 2008). This thesis involving seven teachers found that they were responsible for their own leaning and learnt things as needed, both how to use computers and how they could be used in teaching.

2.4.5. Teacher attitudes

Teachers' attitudes and choices in regard to using ICT in science teaching and their views have a central role in implementing new technologies (Hew and Brush, 2007; Olson, 2000). Cox (1999) found that teachers' use of ICT was linked to their perception of its usefulness. Studies dealing with science teachers and ICT shed light on teachers' views of ICT. Teachers mentioned in interviews how ICT can motivate and help students learn, especially about the nature of science as well as providing a rich science learning environment and the ability to make abstract concepts more understandable (Thompson and Parrott, 2003). Teachers also value the quality of ICT work and efficiency, and how it makes knowledge more accessible (Rogers and Finlayson, 2004). In Baggot et al. (2004) teachers viewed ICT in science as a powerful tool to facilitate learning.

2.4.6. Pupils

Pupils are not often mentioned directly as an influencing factor though their education and well-being is one of the main reasons for developing better schools. Cox, et al. (1999) suggest that pupils may influence teachers in their use of ICT. Research suggests that pupils can be a powerful influence for either preserving the status quo or promoting instructional change (Spillane & Jennings 1997; in Spillane, 1999; McLaughlin & Talbert 1993).

2.5. Strategies to overcome barriers

Hew and Brush (2007) also review strategies to overcome the barriers: (a) having a shared vision and technology integration plan, (b) overcoming the scarcity of resources (equipment, access, time and support), (c) changing attitudes and beliefs, (d) conducting professional development, and (e) reconsidering assessments.

Programmes offering professional development are important as it changes teachers and their practice (Borko, 2004). However is not enough to provide equipment and training for integrating ICT into teaching but constant support and opportunities to plan are just as important (Bennett, 2003).

A UK project where teachers were freed to explore ICT with other teachers suggest that just giving teachers these means is a more successful way of developing teachers and their practice than pre-described courses (Haydn and Barton, 2008).

Bingimlas (2009) focuses on school and teacher level barriers in his review and gives possible implications for schools and teachers for the integration of ICT into education. His implementation suggestions include ’being open minded towards new ways of teaching' (p. 243) which he mentions after counting the many barriers to technology integration. He goes on to suggest that 'where training is absent, teachers can prepare themselves by enrolling in private sessions or by self training' (p.243). These kinds of suggestions are hardly likely to lead to large scale implementation of technology. Experience and research has shown that individual efforts often peter out (Jóhannsdóttir, 1999). Large scale top down implementation has proved to have limited effects or at least not the revolutionary effects that were expected (Cuban, 2001; Lim and Chai, 2004). A group of Dutch scholars have developed the Four in Balance model suggesting that both these elements are necessary:

> The findings in this study show that most of the identified causal chains on the implementation of computer use involve both 'top-down' and 'bottom-up' elements. This means that for a successful implementation elements of both strategies are necessary. It can be concluded that both strategies are interrelated and can strengthen the outcome of the implementation process (ten Brummelhuis, 1995 p. 94).

The four in the name of the model refers to: vision, expertise, digital learning materials and ICT infrastructure. Of these they claim ICT initiatives must begin with the vision and expertise, the human factor. The objective must be taken into consideration and then what equipment is needed. The Dutch group point out what many have said before them, that technology driven initiatives have had a high failure rate. The human factor includes facilities that match the teachers, that teachers know how to use them, teachers believe in the added value of the applications for education and that there is active leadership (Kennisnet Foundation, 2011). They propose four items for more effective ICT use in schools: leadership to involve followers; formal ICT training in teacher education; linking pupils and teachers in digital learning environments and that teachers need to find out and know what works in teaching. This knowledge needs constant renewal with new technologies.

This section has set forth the relevant the different ways ICT may be used in science education and relevant frameworks to. It has presented the literature on factors affecting teachers technology integrations The next section presents the methods employed in this study.

3. Methods

This chapter is in seven sections. First the aims and research questions are outlined. Then frameworks for data collection are presented, the framework includes three phases described in the next three sections and a section on triangulation of the data of this study. The chapter ends with ethical considerations.

3.1. Aims and research questions

As could be gauged in the introduction to this study, indications are that ICT is not being used to its full potential in Iceland but no detailed research has been done in the context of science. Nor is it known what it is that governs teachers' decisions regarding their choice of teaching materials. The general aim of this study is to explore the uses and advantages of ICT in science teaching and the factors affecting its implementation in Iceland.

In the light of the general aims for this study the particular research questions are:

1. How and to what extent is ICT used in lower secondary science teaching in Iceland?

2. Within the Icelandic context what are the conditions that impact upon ICT use in secondary science education?

3. After a technology supported science teaching intervention will there be measurable differences in pupil achievement on school tests, between an intervention group using digital learning resources and a comparison group being taught in the usual way?

4. Will participation in such an evidence-based science teaching intervention involving ICT have an impact upon science teachers' practice?

3.2. Frameworks for data collection

The research programme for this study is planned in three interlinking phases:

- survey of ICT use in science education in Iceland;
- qualitative exploration of ICT use in science education in Iceland (Interviews, focus groups, case studies);
- intervention, exploring affordances and effectiveness of a selection of DLR´s in science teaching.

Even though this study was planned and reported in three separate phases, these phases are interlinked, complement each other and at the same time answer different research questions. (Figure 3-1 and Table 3-1 provide an overview of research questions and data collection). Some of the teachers participated in all three phases, and insights from all data collection exercises came together in the end to form integrated results. The initial plan was for the intervention phase to be the main aspect of this study. However, it became apparent early in the intervention that pupil scores on the tests would not be linked mainly to effects from using ICT but that the teachers are also a very influential factor in pupil achievement. This drew even more attention to the teachers and though Phase II was planned more to complement the survey, which it did, it also provided a basis for following a small number of teachers all the way through the project. Piloting of the survey and participation in the intervention with numerous interviews and observations gave rich data. Using the lens of cultural historical activity theory (CHAT) the factors that affect teachers´ use of ICT in science teaching were explored on a deeper level.

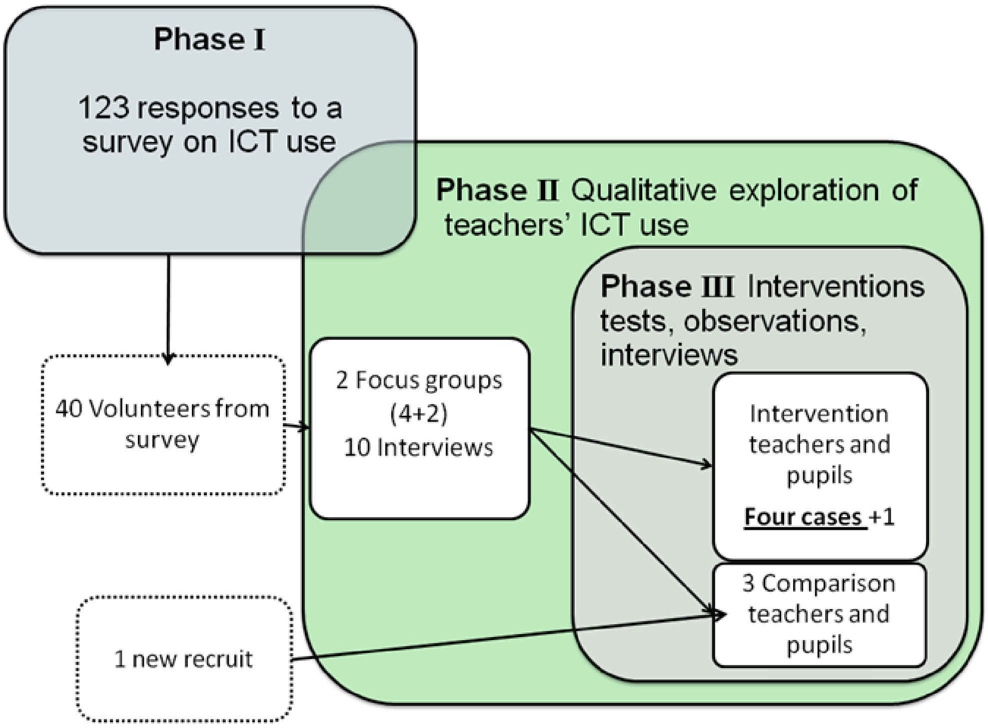

Figure 3-1 Outline of study

Figure 3-1 shows the phases of the study are linked together, phase and numbers of participants. Similarly does Table 3-1 show how the research questions are linked to different phases, the method employed and other particulars. These methods are presented throughout this section.

Table 3-1 Overview of research questions and data collection

Research question	Phase	Data collection method	When	Where and who	Analysis
How and to what extent is ICT used in secondary science teaching in Iceland?	Survey Phase 1	Questionnaire	March 2009	Online- sent to all compulsory schools in Iceland	Produce tables and graphs Use SPSS to explore relationships between available resources and attitudes to reported use.
Within the Icelandic context what are the conditions that impact upon ICT use in secondary science education?	Phase 2	Interviews and focus groups	May- August 2009	Teachers identified from survey, their students	Link to questionnaire, code – opinions and experiences
After a technology supported science teaching intervention will there be measurable differences in pupil achievement on school tests, between an intervention group using digital learning resources and a comparison group being taught in the usual way?	Intervention Phase 3	Pre- post test: Observations: videos Interviews: Questionnaire: student attitudes.	Sept 2009 -May 2010	Iceland – teachers identified from survey, experimental group and comparison group for each intervention	Compare results from pre and post tests from both groups. Compare responses to pre and post attitude questionnaire.
Will participating in such an evidence-based science teaching intervention involving ICT have an impact upon science teachers practice?		Delayed interviews	May-June 2010		Compare uses and attitudes before and after intervention,

3.3. Phase I: Survey

A questionnaire was designed to give an overview and explore the existing practises of ICT use in science education in Iceland addressing the first research question (to what extent ICT is available and used in science teaching in Iceland).

The online questionnaire was piloted with the researcher present by ten science teachers in December 2008 resulting in some revisions before its final administration (see Appendix A).

Background information was collected on the following variables: age; teaching experience (both all teaching and science teaching specifically); education; and school size. Teachers were asked in a matrix form what equipment was available to them and how often they used it. The section 'computer usage' explored the extent of use of generic software and applications; what applications; teachers knew and used both in their personal life, work and teaching. The section 'Internet use in science teaching' asked teachers about how frequently they used science specific software and applications but also included the option 'I do not know what this is', because it was suspected that teachers were not familiar with the different ways of using ICT for teaching science. In order to get examples of how teachers use ICT they were asked to describe a lesson involving ICT and science. The section 'Recent use of ICT' prompted teachers to describe a recent lesson where they had used some ICT to teach science, this form of question was chosen to give more detailed information about how teachers were applying ICT in their teaching than multiple choice questions about access and frequency could provide. To make sure that the descriptions were as similar as could be, the question was split into eight parts: what the pupils were doing; the topic; what task; what equipment and software was in use; what the teacher's role was; and whether the teachers thought the pupils had been engaged and whether the teacher thought the pupils had learned anything. It was also intended that this question would lead me to teachers that had developed successful ways of implementing ICT into their teaching and could therefore provide insights for design of the intervention part of this study. Next were two open questions asking teachers what factors they believed hindered or facilitated their ICT use in teaching science. To further explore factors that are believed to affect teachers in using technology in teaching there was a question about what support was available to them and what kind of training or CPD they had received in using ICT in teaching both generally and science specifically. Next were sections that explored teachers' approaches and attitudes towards ICT use. A list of 15 statements was provided asking teachers to agree or disagree with on a five point Likert-scale.

The design and rationale for item format was found to be appropriate for the information needed.[4]

3.3.1. Participants

Teachers of science to 12- 16 year olds in Iceland were asked to answer this questionnaire. The target age group of 12-16 year olds was chosen because at that age science is most often taught by a subject teacher, whereas younger students are taught by the class teacher who teaches many subjects. It is difficult to estimate the size of the population as no numbers are available on how many science teachers teach the target group. A rough estimate, based on experience and an exploration of school websites, would be 200-230 teachers. Usually only one person teaches science in each school and it is only in the larger schools that two to three teachers teach science.

3.3.2. Data collection

The survey was administered using the website http://surveymonkey.com in March 2009. A web-link in an email was sent to 170 of the 176 compulsory schools in Iceland, asking the recipients (headteachers or school secretaries) to forward it to science teachers of 12–16 year olds. Those schools excluded did not teach the target age group. A reminder was sent out two weeks later. The

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[4] This was discussed in my assignment titled: *Questionnaires and Interviews: Two ways to look at the same thing* , in 2009.

same message was also sent to the mailing list of FNG (Society of Science Teachers in Compulsory schools). 137 people started to answer the questionnaire and 123 completed it answering the majority of the questions.

Table 3-2 Responses to the survey

Collector	Completed	Begun
First email	84	93
Reminder email	26	31
FNG list	13	13

The main concern before the administration of the questionnaire was that only ICT enthusiasts would respond but the high response rate has eradicated that threat of bias.

3.3.3. Analysis

Answers from the survey website were downloaded to *Microsoft Excel* and *SPSS* and analysed to answer the relevant research questions. Questions about current conditions and practice give descriptive data presented mostly through graphs and tables in section 4. Open questions such as 'what factors do you believe hinder you in applying more ICT in your teaching?' were coded and categorised into themes. The analysis of this question is presented in section 5.1 along with other data pertaining to the second research question about the conditions that affect teachers in using ICT in science teaching.

3.4. Phase II: Qualitative exploration

The aim of Phase II was to follow up and get a more detailed picture of the issues regarding ICT use in science teaching than survey data could produce. A further aim was to put the findings from the survey into clearer perspective, as well as to discuss issues in more depth than an online questionnaire allows. The combination of data from multiple sources may be called triangulation, where two methods complement each other or simply 'two ways of looking at the same thing', the subtitle of my assignment. It seems that the bottom-line in research is that methods should be chosen to fit the purpose (Gorard and

Taylor, 2004; Cohen et al., 2007). With that in mind this project was planned; so the survey would provide an overall view and set the scene. Interviews and focus groups would allow closer scrutiny of details. The purpose of talking to teachers both individually and in groups was to identify the conditions which affect teachers' use of ICT in science teaching and to draw on their expertise in successful ways of employing ICT. Talking to pupils would both draw out their views as important players in this context and corroborate or put a different perspective on teachers' testimonies.

3.4.1. Sampling

As phases II and III overlap in terms of sampling, the whole sampling procedure is presented here (see Figure 3-1). All participants in phase II and III were found through the survey. At the end of the survey teachers were asked to volunteer to participate in further stages of this project. A total of 41 teachers from all over Iceland volunteered.

The first interviews were meant to have a twofold purpose. The initial plan had been to identify exemplary cases from the questionnaire, so as to draw on their expertise in successful ways of employing ICT to inform the design and implementation of the intervention phase. Secondly the intent was to identify the conditions which affect teachers' use of ICT in science teaching and for that purpose a range of users was meant to be chosen. As it turned out, the level of use did not vary to a great extent. The 22 volunteers from within 170 km of the Great Reykjavik area (a trip manageable within one day) were approached either for interviews or focus groups. The interviewees were chosen out of the 41 volunteers from the questionnaire to represent different genders, school sizes, age and teaching experience. Thirteen teachers were approached and a mutually convenient time could be arranged with ten of them.

The interviews and focus groups were conducted in late May 2009. This is a very busy time for teachers, but teachers were quite happy to have me visit them and it was relatively easy to organise the interviews for times that were mutually convenient. On the other hand it was obviously much more time consuming and difficult asking them to come to a set time for focus groups in another school. The intention had been to have groups of 6-8 people and volunteers from the questionnaire were invited via email. Sadly teachers either could not come or did not reply, so more invitations were sent out to additional teachers found through school websites and personal connections. The results were poor as can be seen in Table 3-3. In group A, two more teachers had agreed to come but did not attend on the day.

Table 3-3 Participation in teacher focus groups

	Invited	Attended	Minutes
Group A	25	2	52
Group B	10	4	90

Those who participated in phase two were asked if they might be approached for further involvement in the study. The selection was also guided by feasibility issues such as distance and time. Table 3-4 breaks down how each participant was involved in Phases II and III. In the table we first see the teachers that participated in all phases. They are given pseudonyms and numbers where the first digit corresponds to their classes in the intervention. The last columns for them show which intervention they participated in and if they are presented as a case in section 5.2. Then we see teachers who only participated in phase I and II, they are numbered T9 – T17. The last column for them explains why they either were not asked to participate in phase III or declined if asked. The second column shows whether the participant was interviewed individually or in a focus group.

As Iceland is a small community special care has to be taken in reporting individual cases, even though participants came from various towns and are both male and female I decided to report all the participants as females because the majority or 79,8% of teachers in Icelandic compulsory schools are female.[5] (Statistics Iceland, ND). Female pseudonyms are used throughout this thesis, regardless of whether the participant is female or male.

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[5] http://hagstofa.is/

Table 3-4 Participation in Phase II and III.

		Phase II		Intervention phase III				
Pseudonyms	**NR**	**Interview**	**Focus group**	**Genetics**	**Chemistry**	**Ecology**	**Delayed interview**	**Profile in section 5.2**
Eva	I100	✓		✓	✓		✓	✓
Anna	I200	✓		✓	✓		✓	✓
Helga	I300		✓		✓			
Olga	I400	✓		✓		✓	✓	✓
Ellen*	I500		✓		✓	✓	✓	✓
Dora	IC600	✓			✓	✓		
Tara	C700		✓	✓	✓			
Tina**	C800			✓	✓			
	T9	✓				stopped teaching		
	T10	✓				busy with another project		
	T11	✓		Why not in intervention		did not reply to e-mails		
	T12	✓				too far away		
	T13	✓				too far away		
	T14	✓				too far away		
	T15		✓			only teaches physics		
	T16		✓			study leave		
	T17		✓			said no		

I= intervention, C =comparison, T=teacher

*Ellen was asked to be a comparison teacher, but only wanted to do the intervention because she was already planning to use at least one of the resources

** Recruited from volunteers when T11 did not reply to emails

The group of volunteers might be considered skewed in two aspects. First that perhaps their willingness to participate in a study about ICT use might stem from their interest in the use of ICT. Secondly in the sense that nine of these sixteen teachers (ten from interviews and six from focus groups) had some form of further education, of which four were in science education.

3.4.2. Interviews

An interview schedule was prepared to address the aforementioned aims of learning how they use ICT in their teaching and the conditions that affect them. The interviews were semi structured; this approach was chosen for its flexible nature as interviews are believed to be useful for many purposes to both gather information and opinions, and explore experience, motivation and reasoning (Drever, 2003). The items raised in the interviews were:

- Teachers' use of ICT in their science teaching: what; how; and, why
- knowledge of and availability of equipment and DLRs
- knowledge and use of science simulations and data loggers
- strategies and methods when using ICT
- perceived level of personal technical expertise
- perceived level of personal content knowledge
- what factors most affected teachers' decisions about ICT usage
- role and availability of support

These items were not raised in any specific order. All interviews began by asking them to describe their use of ICT. Different issues were then raised for each teacher based on their responses to the questionnaire. As ICT use proved rare and generic I tried to probe mostly what factors they believed were hindering them by asking what they thought it would take for them to try out more ICT based teaching and learning resources

Ten interviews were conducted (see sampling p. 37). The interviews lasted from 22 minutes to 49 minutes and took place in the participants' classrooms which also provided information about the availability of resources and access to equipment. All interviews were audio recorded and transcribed.

These interviews also provided a more detailed background for the choice of participants for the upcoming intervention. At the end of each interview teachers were asked whether they would be willing and able to participate in an intervention as either an experimental or a comparison teacher.

3.4.3. Teacher focus groups

Two focus groups with teachers were planned to further explore the same issues as the interviews. Whereas the interviews provide rich data on individuals, a focus group provides the opportunity for exchange of ideas and opinions on top of 'illustrating and confirming' (Wolff et al., 1993 p.124) data from the survey. The intention was not only to confirm findings from the interview but also to unearth any contrasting views. Handbooks on focus group discussion (see for example, Krueger and Casey, 2000) advise one that to get participants talking, dichotomous questions should be avoided and teachers should be encouraged to talk to each other to facilitate an exchange of opinions. The composition of the group should be homogenous but with enough variation for difference of opinion to be possible. With this in mind I made sure to invite veteran teachers, newly qualified teachers, both genders, and older and younger aged teachers.

A list of prompts was devised to get the groups talking about their experience of using ICT. These prompts asked them to share their experience of using ICT in teaching, to express their concerns regarding ICT use, what they thought about the current extent and the future of ICT use in science teaching.

Both focus group interviews were held in science classrooms (see sampling p. 37). The sessions were audio-recorded and transcribed. I found that it was quite easy to get Group B (which consisted of four people) talking but harder to keep them on topic. Nevertheless a good discussion developed covering all kinds of issues regarding the topic. The two people 'group' never had the elements required to be a focus group, rather it functioned as an interview where they quickly responded to the prompts for the focus groups. I also used items from the interview schedule to keep them talking.

3.4.4. Pupil focus groups

Focus groups with pupils were also conducted in two schools. One from a teacher who from the questionnaire appeared to be a high level ICT user and another who seemed to be an average user.

The purpose of these focus groups was to collect pupils' views on what kinds of activities are perceived as useful or useless, engaging or boring, and also to validate the questionnaire and interview data from their teachers. A list of topics was compiled for the sessions to meet those aims. The teachers were asked to nominate five to six pupils of mixed abilities and preferably those who find it easy to articulate their opinions. In both schools I first asked the headteachers for permission. The teachers then provided me with a list of parents and phone numbers. I obtained verbal permission from the parents and the pupils then brought written consent forms to the sessions. In school **A** we were invited to use the library for the focus group. Eight pupils participated from year 10 and the session lasted for 35 minutes. The teacher nominated more pupils not trusting them to show up as the session was to take place at a time they were free to go home. However all invited pupils attended. In school **B** we were assigned a classroom. Six pupils participated, two from each year group and the session lasted 34 minutes. In this school pupils were excused from lessons to participate. Both sessions were audio-recorded and transcribed. Excerpts from them were chosen to reflect the general views of the groups and are presented in section 4.4. on pupils previous of experience ICT.

3.4.5. Analysis

All teacher interviews and focus groups were transcribed and then analysed using *NVivo* by coding in recurrent themes what participants said. These themes were largely pre-formed from the literature in section 2 but others emerged from the data. This approach to analysing data has similarities to *grounded theory* (Strauss and Corbin, 1990). This procedure has been described, for example by Böhm (2004) and is similar to the one I followed. I first looked at what issues were being addressed and categorised these. I then looked at the relationships between the issues identified. Böhm (2004) refers to this as axial coding:

> This step serves to refine and differentiate concepts that are already available and lends them the status of categories. One category is located at the centre and a network of relationships is developed around it. (p. 271).

This process resulted in a revised model of factors that affect teachers in their efforts to use ICT in their teaching. These factors were introduced in section 2.4 and the revised model can be found in section 7.2.

In the analysis the importance of a phenomenon was gauged by the frequency of comments about that issue. Wherever possible, I quantified the number of people that talked about an issue. The process was iterative in the sense that I kept going back to the data to explore issues arising during the intervention and to support and cross-reference topics from the survey. Those comments relevant to research questions (about what factors affect teachers and the different kind of practices in regard to ICT in teaching science) are then presented later in the relevant sections of chapter 5. Individual teacher profiles are presented in section 5.2. I searched for how these teachers had talked about the issues that seemed to be most prevalent in all data sources and organised the profiles around them. Furthermore the TPCK model (Mishra and Koehler, 2006) was used for reference when exploring their knowledge bases, Mishra and Koehler (2006) have suggested this as an analytic framework for such purposes.

3.5. Phase III: Interventions

To answer the third research question about whether there are significant differences in learning when learning science with or without ICT, interventions using a quasi-experimental research design were conducted. In one of my assignments[6] I reviewed the methodology employed by studies involving ICT and science teaching and found that the main methods employed in this kind of research are:

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[6] *Intervention studies and experimental design* January 2009 **EDUC 5029M**

- Experiments; which are hardly ever used in educational research due to difficulties in randomly assigning students to experimental and control groups.
- Pre-experiments; which are often used but have no comparison group and usually a focus on designing software or applications.
- Quasi-experiments; which are often used, with control/comparison groups consisting of intact classes, data collection is done with pre- and post-tests and most often combined with interviews and/or observations.

So for the intended purpose a quasi-experimental design was deemed appropriate and doable with intact classes, using pre- and post tests as measuring tools. As the intention was to explore how existing applications can be integrated into current practice, an important aspect was getting the teachers' views on the exercise through interviews. Furthermore questionnaires were administered to students which investigated their attitudes to whether learning with ICT affects their views on learning in science and their views on learning using the websites.

Instead of one larger intervention this phase consists of a series of micro interventions. A number of reasons were behind this decision. In a short, well focused intervention it seemed more likely that the ICT use would be the deciding factor on achievement than in a longer one where many other factors might interfere. It was thought easier to get teachers to participate in short interventions which would not really disturb their coverage of the syllabus. As the intention was not to design a new application and my main interest lies in the overall usefulness of using ICT in teaching a series of smaller interventions using a selection of DLRs would give a broader picture of benefits. Bearing in mind that students tend to find new things exciting to begin with, a short intervention might capitalise on that effect.

3.5.1. Participants

Of the 16 participants in Phase II, all nine suitable candidates were asked to participate in the intervention. Table 3-4 (p. 39) shows all the participants and the reasons for those not chosen. All but one of them (T17) agreed to participate. A teacher (T11) then later dropped out as she did not reply to emails. She was then replaced by one of the initial volunteers (C800) from the same area and age group as the dropout. Helga (I300) and Ellen (I500) were both initially approached to be in the comparison group but as they had both previously used the websites planned for the intervention they were moved to the experimental group. Three lived too far away for me to go there frequently for observations of lessons; two were not teaching at all that winter; one only taught physics; and one was planning another project that promised to take up much of her time. The interventions the teachers participated in depended on whether they were teaching the chosen topics in the school year 2009-2010.

The aim when assigning teachers to conditions was to have in both groups teachers with long and short experience of teaching science, both genders and similar experience of using ICT in their teaching. As is turned out the group was too small to fulfil these criteria so they were only used as an approximation. Table 3-5 outlines the participants in the intervention and the data collected for each participant. In the numbering system the first number refers to the teacher the second to the topic and the last to separate classes from the same teacher. For example class 320 and 321 and both taught by Inga teacher 300, they participated in the second intervention and the last number distinguishes between the two classes. INT refers to an intervention class whereas COMP refers to a comparison class.

Table 3-5 Outline of intervention data

		Genetics					Chemistry					Ecology				
Teacher		Class	Pre and post test	Pupil ques tionn aire	Pupil inter views	Obser-vations	Class	Pre and post test	Pupil ques tionn aire	Pupil inter views	Obser-vations	Class	Pre and post test	Pupil ques tionn aire	Pupil inter views	Obser-vations
Intervention (INT)	Eva	110	✓	✓	✓	3x40 min	120	✓	✓	✓	3x40 min					
	Anna	210	✓	✓	✓	2x80 1x40	220	*	✓	✓	2x40 min					
	Inga						320	✓	✓	✓	2x40 min					
							321	✓	✓	✓	2x40 min					
	Olga	410	✓	✓	✓	3x40 min						430	✓	✓	✓	3x40 min
		411	✓	✓	✓	3x40 min						431	**	✓	✓	1x40 min
	Ellen						520	✓	✓	✓	2x80 min	530❖	✓	✓	***	1x80 min
	Dora						620	✓	✓	✓	1x40 min					
Comparison (COMP)	Dora						621	✓	✓	✓	1x40 min	630	✓	✓	✓	1x40 min
												631	✓	✓	✓	1x40 min
	Tara	710	✓	✓	✓	1x40 min	720	✓	✓	✓	1x40 min					
	Tina	810	✓	✓	✓	1x80 min	820	✓	✓	✓	2x80 min					
		811	✓	✓	✓	2x40 min										

* no post-test ** no pre-test *** pupil interviews could not be arranged ❖ same pupils as I520

3.5.2. Choice of topics and digital learning resources

For this intervention a selection of websites were chosen. The criteria behind their choice were that they had to be readily available, without cost to teachers, and preferably in Icelandic or involving little use of language. They should target different topics from the National Curriculum and age groups that would make it possible for a teacher to participate in more than one topic. The websites should have a different focus and preferably demonstrate one of the reported affordances from the literature. I also considered that they could be taught early in the school year so my timing and the teacher's planning would coincide, but that did not happen as teachers themselves decide when to cover different topics and there were all kinds of variations. I also wanted applications that from my experience are not widely used and the survey shows are not popular. Though data loggers are a very science specific application they were ruled out due to them not being available in schools. Besides this point, there is an ongoing project in Árbæjarskóli in Iceland (Bjarnadóttir 2007) where the use of data loggers is being piloted. Although the questionnaire only gave some examples, but still the indication is quite strong that teachers are not using interactive simulations, quizzes or learning websites so the chosen applications are of this ilk and available free online. It became apparent to me that using one application is not effective in terms of exposing teachers to many possible uses of ICT in science education. I therefore suggested several websites for each topic, but for each topic there was one website that all were required to use. The websites used are outlined in Table 3-6 but a detailed description of them and the reasons behind their choice follows in the next sections.

Five of these resources are in English and one is written in Icelandic. The survey has already shown that 60% of teachers agreed or strongly agreed with the statement 'Most of my pupils can use software in English', 23% were not sure and 15% disagreed. The websites in English do not rely on language and all relevant instructions were translated on worksheets to make sure everyone could use the websites.

Table 3-6 Overview of topics and applications in intervention

Topic	DLR	Normally taught by	Main issue	Description
Classical genetics	*Erfðavísir*	Reading from a book, lecturing, taking notes and listening, answering questions from textbook.	Is reading from a screen with interactive questions better?	Web pages, learning environment
	Bug Lab	Answering questions from a book, doing family trees.	Will this help with understanding?	Simulation
Balancing chemical reactions	*Chembalancer*	Balancing equations on paper by hand, teachers give instructions.	Drill and practice: helps by drawing for students, is this useful?	Online exercise, with assistance and feedback
Eco-systems	*Sunny Meadows*	Discussions and readings about cause and effect in ecosystems.	Will running the simulation improve pupils' understanding of eco systems?	Game like interactive simulation.
	Mysteries of life		Does it matter that it is in English?	Cartoon
	Eco Kids		Will a simple visualisation help with understanding?	Simple exercise in organising a food chain

Classical genetics, year 10

The main website used was *Erfðavísir*, http://www.erfdavisir.is/index.html see Figure 3-2. This website has been translated into Icelandic from English. The original is called *DNA from the beginning* http://www.dnaftb.org/, a website from Dolan DNA learning Centre. http://www.dnalc.org/websites/dnaftb.html. The website states that the material is written for all age groups at all levels of education. It is in three sections and selected pages from the first two sections were used 'Classical genetics' and 'Molecular genetics' as they fit the content of the curriculum and the textbook. This website consists mainly of reading material but also has a small number of pictures and diagrams that move and multiple choice questions where the text turns red if the response is wrong or the user is taken to a response page with more reading material if he/she answers correctly. A worksheet was written to help pupils navigate the web, give the lesson a purpose and keep the pupils on task[7].

Baggott and Nichol (1998) criticized many CD-ROMs for being little more than books on a screen and this website has little to offer beyond books. My interest in including this resource in the study was to explore whether reading the subject material from a website on a computer screen beside the small interactive features this website has, is in any way better than the normal way of lecturing, and reading and answering questions from a book.

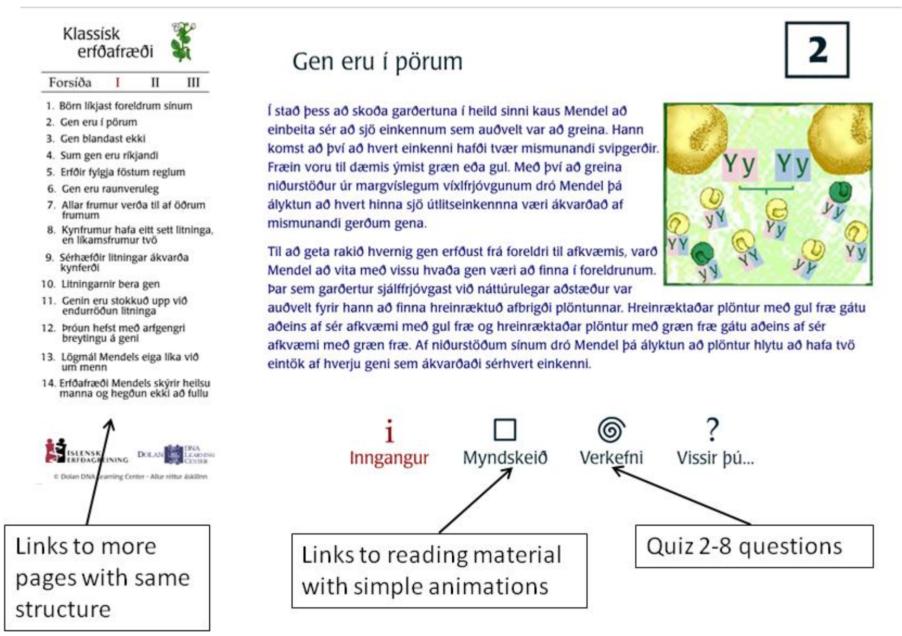

Figure 3-2 Screenshot from *Erfðavísir*

Teachers were also introduced to the simulation *Bug Lab* http://www.channel4.com/learning/microsites/G/genetics/activities/shockwave-bug.html an interactive simulation with built in tasks or experiments for pupils to solve. The simulation is in English and the user can manipulate the bugs' environment, choose bugs to see their genotype and see phenotype ratio as the simulation runs (see Figure 3-3). A worksheet was written to help pupils navigate the simulation and give translations of the more difficult concepts.

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[7] Supplementary materials can be found at http://svavap.wordpress.com/edd-thesis/

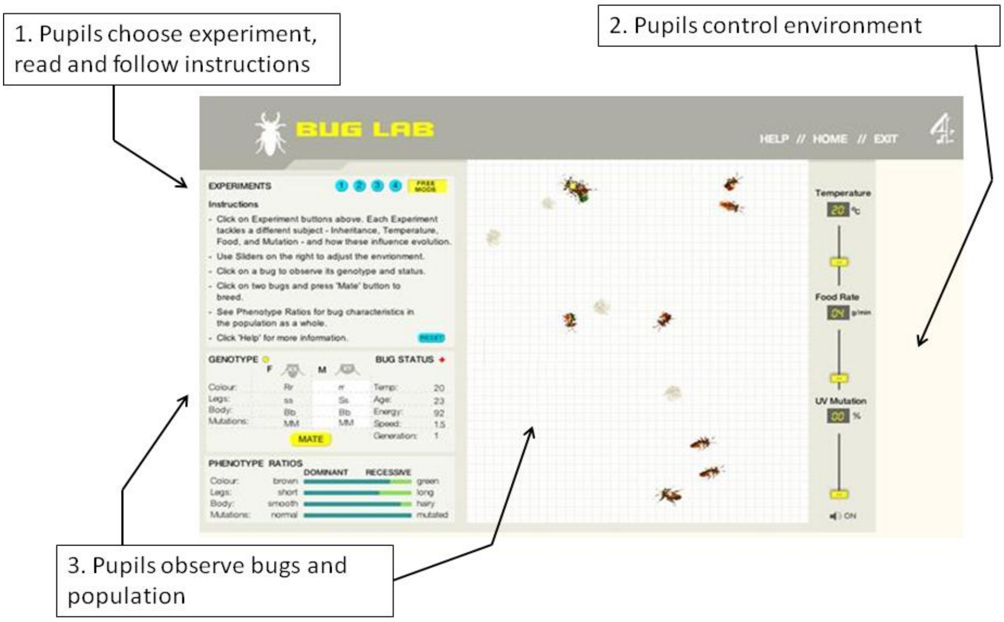


Figure 3-3 Screenshot from *Bug Lab*

The final website which was included in the instructions for the teachers was http://www2.edc.org/weblabs/Mendel/mendel.html a storyline simulation where the user goes through a series of experiments with Mendel. The website has lots of reading material and questions in English. None of the teachers showed any interest in the website and they were not pushed to use it. Why that is, is impossible to say for sure but likely language requirements and level of complexity played some part in that, if the teachers did in fact consider the resource seriously. This website plays no more part in this study.

Chemical reactions and balancing chemical equations, year 9

The main website used in the chemistry intervention was *Chembalancer* http://funbasedlearning.com/chemistry/chembalancer/default.htm a game type exercise in balancing 11 chemical equations. In the website pupils enter numbers for each of the molecules in the equation and are then given simple diagrams that they can use to count atoms and balance the equation. When they thought they had got it right they clicked the balanced button to get feedback in the form of a written message. If they got it wrong, they had to try repeatedly until they got it correct. Accompanying the website is a worksheet that I modified and translated into Icelandic.

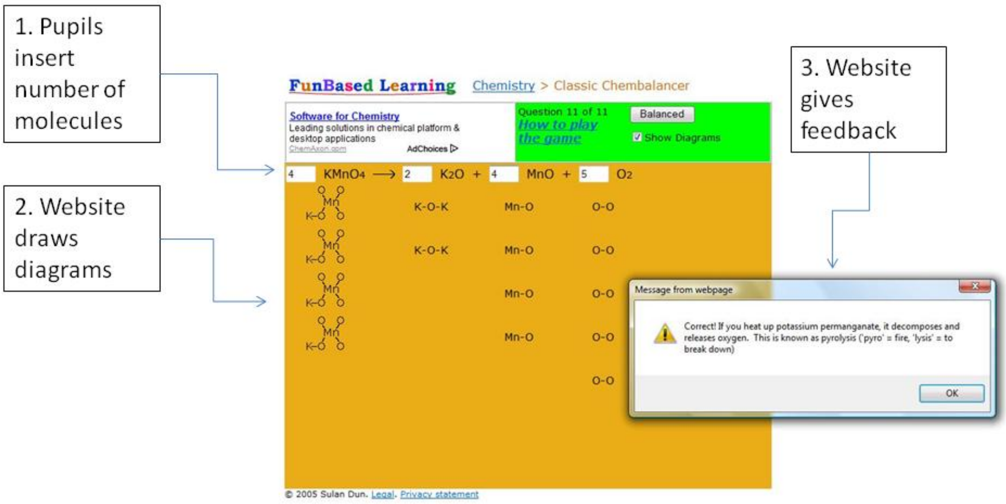


Figure 3-4 Screenshot from Chembalancer

Balancing chemical equations was always considered very hard by my students and it was one of the topics mentioned by teachers in the survey as a topic that was difficult to teach and that pupils find it difficult to master. I had used this website several times and found it really helpful for many students, but that was only my own perception not a measured finding. Including *Chembalancer* in the intervention explores if such a simple resource can be helpful in a task considered difficult.

Teachers were also introduced to a very simple simulation of a chemical reaction http://www.chem.uci.edu/undergrad/applets/sim/simulation.htm and encouraged to use it as a whole class discussion stimulant or lesson starter. In the simulation, two colours of circles represent two different elements that move around and form compounds represented by the third colour.

Ecosystems, year 8

The main website used in the ecosystems intervention was Sunny Meadows http://puzzling.caret.cam.ac.uk/game.php?game=foodchain%20, a game like simulation where pupils enter the number of foxes, rabbits and grass and then the website simulates how the species fare over a 50 year period. Users can watch what happens in three different ways: with diagrams of emerging or disappearing organisms; a graph showing the number of organisms; or a biomass pyramid. After running the simulation it gives the user a score indicating how well he/she has done. A worksheet was prepared, where pupils were expected to record their results in trying to find a well balanced ecosystem with all species surviving 50 years.

This resource was chosen because of its game-like quality, visual representation and low language requirements. The affordance here is that it shows in a short time a process that in actuality takes years to take place. This is an example of an experiment that could never be done in a classroom but here the technology makes it possible to at least get a basic representation of how an ecosystem works. The question with this resource is then both whether pupils would be engaged with it and whether it would help with understanding cause and effect in ecosystems.

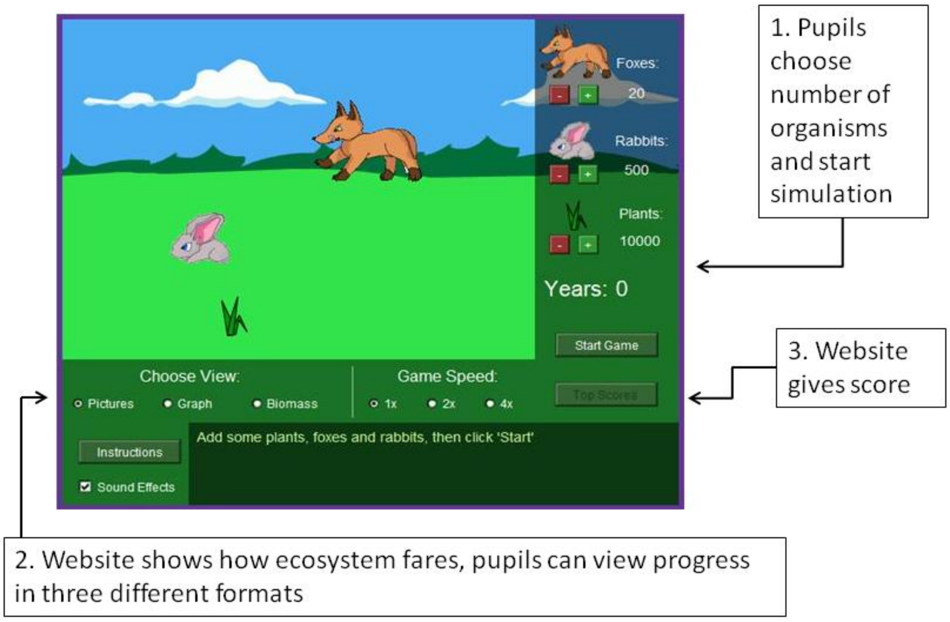


Figure 3-5 A screenshot from *Sunny Meadows*

Two more websites were suggested for use with the whole class. The first of these was *EcoKids* http://www.ecokids.ca/pub/eco_info/topics/frogs/chain_reaction/index.cfm an introduction to vocabulary needed for talking about food chains including a simple exercise in putting together food-chains (see Figure 3-6).

Figure 3-6 A screen shot from *EcoKids*

Secondly a cartoon in English about the balance in a ecosystem called *The mysteries of life* http://magma.nationalgeographic.com/ngexplorer/0309/quickflicks/brainpop/foodchain/mysteries.swf was also suggested. The cartoon also explains all the same concepts as *EcoKids* and gives diagrams and visual explanations (see. Figure 3-7) of the different categories of organism in a food chain.

Both these websites were chosen because of the visual representation of concepts with the expectation that it would engage pupils and help them learn and remember.

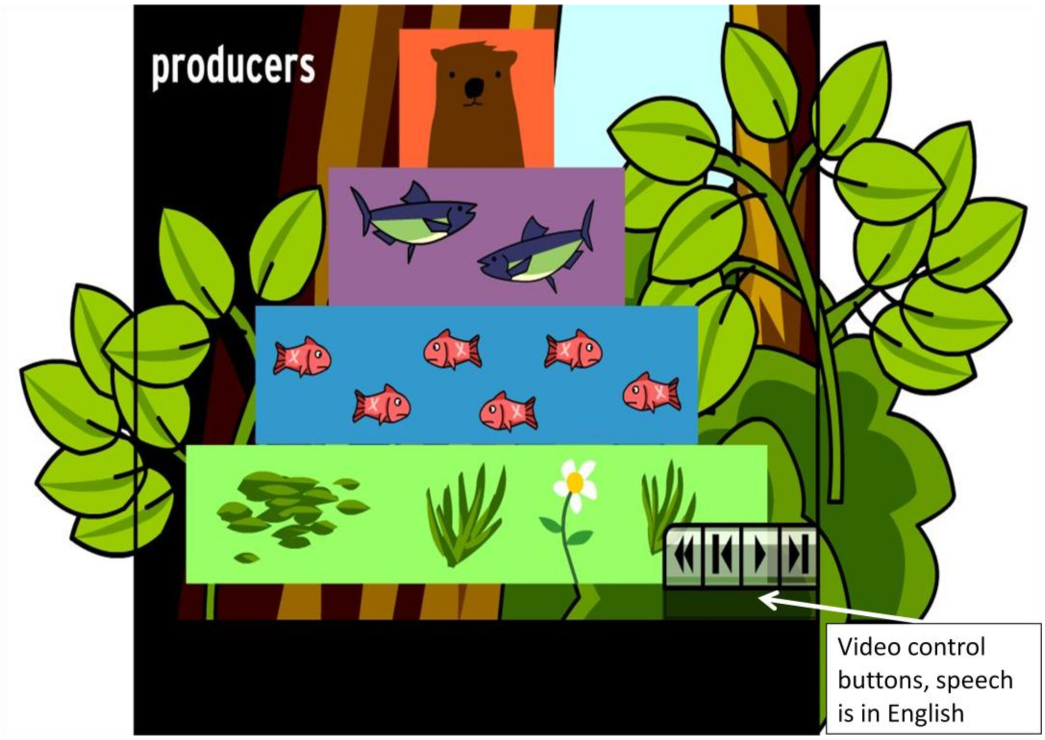


Figure 3-7 A screen shot from *The mysteries of life*

3.5.3. Tests

The purpose of the pre-tests was to establish a base line for the classes to ensure they were of comparable learning abilities but not to explore their ideas. A score was calculated to compare the classes. The pre-tests were designed by choosing and adapting tasks from previous research exploring children's' ideas about the particular phenomena[8]. Items on the pre-test were to correspond to what the pupils should have learned before the intervention according to the National Curriculum. The next sections outline for each topic what learning goals can be found in the National Curriculum, both what pupils should have learned before and what they should learn during the intervention. A description of the tasks is given as this thesis does not have room to include all pre and post tests.

The post tests were all designed to be the actual test for the classes. They were developed using questions from the pre-test, tests provided by the textbooks used and from standardised tests from the *Icelandic National Testing Institute.* To make sure the questions were valid and appropriate for the pupils teachers

[8] The tests can be found at http://svavap.wordpress.com/edd-thesis/

were asked for comments about content and the length of the tests. For all the tests an answer sheet was prepared. For open ended tasks a system was worked out for each item so the score would be higher the more understanding pupils showed in their responses. For example:

- 0 points = no answer or wrong answer
- 1 point = partial understanding
- 2 correct answer
- 3 or more points if the question asked for explanation or asked for more than one item.

Multiple choice questions or selections from lists were scored 1 point for a correct answer. The points were then added up, divided by the total number of possible points and multiplied by 10 so the test scores were on a scale of 1-10. As the tasks on the tests differed this in reality gives an ordinal scale where there is no certainty that the intervals between numbers represent equal difference in pupil achievement. Still for this kind of study it is the best that can be done. The scale was used to make the different test-scores as comparable as possible. An added benefit was that this scale is the most common one used in Icelandic schools so all parties involved knew what they represent, that is the proportion of right answers.

Genetics: The subject of genetics is taught in year 10 of compulsory education but pupils should have been introduced to some basic ideas of inheritance before that. Pupils after year 7 should know that offspring inherit characteristics from their parents (Menntamálaráðuneytið, 2007). In middle school (years 4-7) pupils should learn that characteristics are determined by genes that are inside cells and realise that DNA (erfðaefni) controls genetics of organisms.

In research on children's ideas in genetics, data collection is most often done by interviews trying to elicit the pupils' understanding of the phenomena (Venville et al., 2005). This provided some difficulties in compiling a written pre-test with the purpose of comparing quantitatively children's ideas about basic genetics.

Questions were either adapted to the written format or new tasks were composed to meet the above aims. The test had five sections:

- can pupils differentiate between a collection of organisms (containing DNA) and material things (not containing DNA) (nine items)?
- can pupils differentiate between genetically inherited traits and socially and culturally acquired traits, four items (based on Venville et al., 2005; Solomon et al., 1996)?
- do pupils know how cell, gene, chromosome, DNA look and their location? One task making diagrams and another ordering these things by size (based on Lewis and Wood-Robinson, 2000; Saka et al., 2006).
- do pupils know the role and importance of DNA and genes, four items (based on Lewis and Wood-Robinson, 2000)?
- do pupils have an idea about gender decision, inheritance and chance (two items)?

The post-test included most of the same questions in addition to typical multiple choice questions both from the teaching guide that accompanies the textbook and some questions from standardized tests of science from previous years.

Chemistry: Middle school pupils are supposed to have learned about changes of chemical state and that mixing two chemicals may result in a new chemical with new properties (Menntamálaráðuneytið, 2007). Chemical change and chemical equations are to be taught in year 8-10. The pre-test consists of two sections. First a task from Stavridou and Solomonidou (1998) where pupils are asked to categorise 19 instances of everyday phenomena, ten of which represent chemical change and nine physical changes. Before taking the pre-test the pupils have already studied changes of state of matter and 2–3 years earlier they have studied solutions so it was expected that they would recognise these phenomena. Pupils were marked for recognising a minimum of instances, placing these into categories and naming the categories correctly. The second section was a collection of multiple choice questions about conservation of matter (Holding, 1985). The third task involved pupils recognising a diagram of a chemical reaction (Agung and Schwartz, 2007).

Post-test: As the web page used in this intervention only helped pupils balancing chemical equation it would have been sufficient to have pupils solve a few equations to determine their ability to successfully solve them. However in order to increase the likelihood of the pupils taking the task seriously the teachers were provided with a test which included the categorisation task from the pre-test, some of the questions on conservation of matter and other questions about chemical change mostly from standardized tests in science. Also included were four chemical equations to be solved. Most of the teachers administered the test without any changes but all included enough of the same questions to provide comparable grades for all the groups. A grade was calculated for the questions that all teachers included and also a grade for solving the four chemical equations.

Ecology: The National Curriculum expects that pupils should learn about food chains and food webs in middle school and that species interact with each other. The concept of ecosystem is to be introduced in years 8-10 along with the effects of disruptions to food chains and webs (Menntamálaráðuneytið, 2007).

The pre-test was about choosing species for an ecosystem. In the original task (Leach, 1995) pupils were asked to choose six organisms, **and** asked 'what does it need?' and 'where do they get it from?'. This was not included as the point of the pre-test was only to establish a baseline for the classes. Pupils were asked to choose six organisms and the choices scored were a food chain, including a producer – a herbivore – a carnivore, which gave full marks. Fewer categories were given lower scores. Three open questions were also included probing pupils' understandings about the workings of ecosystems.

On the post-test the same task was given but pupils were also asked to form a food chain and answer collection of multiple choice questions from the teaching guide that accompanies the textbook. In addition they were asked two questions from standardized tests of science from previous years and two questions related to disruptions in an ecosystem.

3.5.4. Pupil questionnaires

Pupils completed questionnaires at the beginning of the intervention about the extent of ICT use and their views on ICT use before the intervention. These were administered along with the pre-test.

After the intervention they completed a questionnaire with open questions about the tasks they had done during the intervention. These questions differed for the experimental classes and the comparison classes. The comparison classes were asked about how they liked the topic, what they thought of answering questions from the textbook, lectures and discussions in class and whether they had done anything else while working on the topic. The experimental classes were asked also about the topic, lectures and discussions, but then about each ICT website they had used. The questions were very open encouraging pupils to express their opinions. Lastly all classes were asked what resources they had used to study for the test to gauge their trust in the resources.

3.5.5. Data collection

After the teachers had agreed to participate in the intervention their headteachers were approached by e-mail and in some cases also in person or by telephone. All head teachers gave permission readily. In one council was it necessary to notify school authorities more formally. The Icelandic Data Protection Agency was notified of the study. Before data collection, pupils took home consent forms for parents to sign, which the teachers then collected.

As this study has a quasi-experimental design where the use of ICT resources is the independent variable it was important that guidance and counselling to the teachers was controlled and as similar as possible. For this purpose a guide was written for each intervention, which detailed learning goals as stated by the curriculum, a rough outline of possible lessons, links to the websites they were to use with accompanying worksheets and a further list of links to other useful websites. I visited the teachers once before each intervention to go through the instructions and how the intervention would proceed. Otherwise communication with them was mostly through email but also by phone. A website was set up where both comparison and experimental group of teachers had access to all materials they were to use. Teachers were asked to administer the pre-test and the attitude questionnaires before they started work on the topic. By having such limited contact with the teachers and not having them meeting as group made the circumstances more realistic as science teachers usually work alone, thus reducing the effects of being in an experiment (Shadish et al., 2002).

During each intervention I strived to visit and interview both intervention and comparison teachers at least twice to observe and videotape key lessons (see Table 3-5, p. 46). Firstly to observe a regular lesson and secondly to observe lessons where ICT resources were in use. Regular lessons were observed to see the teacher's pedagogical styles, to gauge their grasp of the topic and to observe pupil work and engagement. The same purpose applied to observing the ICT lessons plus keeping a special eye out for pedagogic strategies the teachers might employ and pupil interaction with the websites.

The observed lessons were videotaped in whole or part. The purpose of the videotaping was to have a record of the lessons for later reference. As so many factors were under observation taking only field notes did not promise to catch all aspects and would not allow later comparison. The camera used was a Nikon E90 ab, which can only take 20 minute clips at a time. This was sufficient but required monitoring to restart it after the 20 minutes. It rarely mattered as in the middle of the lesson the pace seldom changed but it was most important to see transitions, that is when the class was given new instructions and how a task was started and wound off.

During and after each observation I made notes, focusing on things like:

- how the lesson was structured;
- had the teacher prepared for the lesson and thought it through;
- how comfortable the teacher was with the technology;

- how proficient the teacher was with the lesson content basing my opinion on how and if they used science vocabulary and concepts, did they use examples not from the textbook, did they answer the pupils' questions correctly, did they understand pupils' questions and seem to have an idea about what misconceptions they were dealing with;
- what tasks the teacher gave the pupils, and how the tasks were presented;
- what the pupils were doing, were they working on the tasks, did they ask questions;
- in ICT based lessons especially, I tried to hear whether the pupils were using science concepts and if they seemed to be engaged in the task and stayed on the website.

All the time I had in mind, that if significant difference between the groups were found, what might explain these differences apart from different teaching materials.

To collect information about other lessons not observed the teachers were asked to make a record of the number of lessons used for the topics and what learning resources were used. Only two teachers did so but as the intervention progressed I relied more on gathering this information from interviews during the last visit to collect tests and administer questionnaires.

Post interviews: After each lesson I asked the teachers some questions. To the comparison teachers I mostly asked if this was a typical lesson, if these were typical tasks given to pupils, and if they used any other resources. To the experimental teachers I usually asked what they thought of the lesson, what went well and what would they do differently next time. Experimental teachers were also asked if they would use this website again. Did they think the worksheet helped and if they planned to do anything more on this topic? If something had caught my attention during observation I also asked them for clarification on something they or their pupils had done during the lesson.

Post-tests: The teachers administered the post-tests. All the teachers used the whole test that I provided and all except one used it as part of their assessment. This teacher only told the pupils as they were starting the test that is was not part of their assessment.

The post attitude questionnaires were administrated by me whenever possible. I explained to pupils that their opinions were valuable for my study and asked them to explain in detail what they thought. By being present I hoped they would more freely express their opinions as I collected the sheets and not their teacher. I also interviewed a group of pupils asking them to expand on the open questions from the attitude questionnaire, as well as discussing with them their views of computers both for learning and fun. Here the teachers were asked to nominate five pupils of mixed abilities who were likely to express themselves freely. Talking to pupils in person gave the opportunity to probe their opinions further as it was suspected that they would not give very detailed opinions and observations in writing. I could not meet Ellen´s pupils, a second visit was not possible as the school year was drawing to an end (for overview of interviews see Table 3-5, p.46). Instead I talked to some of them during the last observation, but as I was starting to hear the same things again data saturation seemed to have been reached so I most likely did I not miss any new information.

3.5.6. Analysis

Analysis- pupil questionnaire

Pupils answered open questions about the DLRs used in the interventions and for comparison, about other learning resources or teaching methods used. Open ended questions were thematically coded and categorised by how positive pupils were towards the learning resource or teaching method being used. The questions were phrased '*name of resource*. What did you think of it? Why?'. Pupils were asked to be as specific in their answers as they could be. Many gave explicit answers but still a large number did not refer to specifics, rather giving responses such as 'it was fine' or 'it was boring'. The responses were categorised by how positive or negative they were:

- Very positive replies: pupils liked the resource AND thought it had in some ways been helpful for learning.
- Positive responses: pupils liked the resource OR thought it had in some ways been helpful for learning
- Mixed feelings: had both positive and negative factors, for example, 'I liked the task though I did not really understand it, it was so difficult' or 'it was boring but I got it'.
- Rather negative replies gave a specific reason, often that the topic was difficult.
- Very negative replies: negative without saying why, replies such as 'boring' 'I don't like science'.

Statistical treatment of test scores

All test scores were entered into Microsoft excel and SPSS statistical software. Table 3-7 gives an overview of the statistical tests used in this study. Pre-test mean scores were compared with an independent t-test between conditions. This ascertained the extent to which the groups were comparable at the beginning of the intervention, in terms of having similar knowledge of prerequisites or similar pre-conceptions. To further explore if there were any significant differences between the classes, a one way analysis of variance (ANOVA) with a Games Howell *post-hoc* procedure was conducted. The Games Howell procedure does not assume equal variance between samples and is appropriate for this sample where variance was not equal in all cases. Post-test scores were similarly explored with independent *t*-tests conducted to compare mean test scores between conditions. Furthermore the classes were compared by one-way analyses of variance. The size of the effect of the independent variable, if any, is determined by Cohen´s *d.* For the purposes of this analysis, a Cohen´s *d* value between 0-0.20 is a weak effect, a value of 0.21-0.50 is considered a modest effect, 0.50-1.00 a moderate effect and all values over 1.00 a strong effect (Cohen et al., 2007 p. 520).

Post-test scores between intervention classes and comparison classes as groups were also explored by analyses of covariance (ANCOVA), adjusting for pre-test scores.

Table 3-7 Statistical tests used in this study

	Data preparation	Statistical tests	Main purpose
Pupil pre-tests	Tests scored on 0-10 scale	*t*–tests independent samples ANOVA with Games Howell post-hoc, Cohen´s *d*	To investigate pupil knowledge base before intervention, and sameness of schools/classes
Pupil pre- and post-tests	Tests scored on 0-10 scale	*t*–tests independent samples; ANOVA with Games Howell post-hoc, Cohen´s *d* ;general linear model, ANCOVA	Explore differences between conditions on post-test

In the ANCOVA, the independent variable is the learning resource, the dependent variable is the post test scores, and the covariate is the pre-test score. This analysis controls for the effect of the pre-test scores and thereby gives a clearer information about whether pupils' results on the post-test is affected by the pre-test score or teaching materials. Whether the assumptions behind the ANCOVA are met is presented for each intervention.

The significance level for all tests was set at 0.05.

Other intervention data

Field notes in a mixture of Icelandic and English were taken, along with notes from viewing video recordings and the recorded chats I had with teachers around each observed lesson. Such interactions have been called informal interviews (Gall et al., 1999; Cohen et al., 2007) and due to the nature of these interviews their exact number was difficult to determine. This data is used to explain and discuss differences, if any, between the groups and, in combination with data from interviews, to give a record of four case studies. The methods employed were the same as described in section 3.4.5.

3.6. Triangulation

This study draws upon many different data sources and methods which are meant to support each other or triangulate with each other. Bloor et al. (2001) declare triangulation a buzzword; with an uncertain definition, nonetheless it is omnipresent in research handbooks. Cohen, Manion and Morrison (2007) say:

> Triangulation may be defined as the use of two or more aspects of data collection in the study of some aspect of human behaviour. .....By analogy, triangular techniques in the social sciences attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint and, in so doing, by making use of both quantitative and qualitative data. (p. 141)

They go on declaring it to be a powerful way of demonstrating validity but Bloor et al. disagree here:

> Research methods are not readily substitutable: in any given research setting one particular method will be more suitable for the particular research topic than any other (this is, after all, why research texts are read). Why then should we reject the findings that are the product of a superior method simply because they have not been confirmed (triangulated) by an inferior method? (2003, p. 13).

However they do agree that triangulation has its merits, namely that by corroborating findings from one method with findings from another method reduces the likelihood of measurement bias.

In the design of this study a guiding principle has been to look at one problem from all angles, to have findings from quantitative methods supported by qualitative methods and vice versa. Data from interviews are used in this study to support and triangulate findings from the survey. Data from pupil focus groups support findings from tests, which yet again are made clearer with data from observations and interviews. The methods all support and extend each other. The conclusions of my essay on questionnaires and interviews was that in both Gorard (2004), Gorard (2007) and in Cohen et al. (2007), the idea that research methods should be selected to fit the purpose is a main idea (p. 153, 354, 408, 413). From that perspective, the confluence of data from a questionnaire, with a quantitative approach and from semi-structured interviews with a significant qualitative element was chosen as a doable and sensible undertaking. Though now I would add, having seen firsthand how all the different actors in educational research affect each other, that pure statistical data have a poor chance of answering complex questions about a complex reality.

3.7. Ethical considerations

In all research with people there are bound to be ethical issues to consider. In this study there are many participants and every possible precaution has been taken to interact with them in a fair and ethical way. Ethical approval was gained from **AREA Faculty Research Ethics Committee University of Leeds** (Ref:AREA 11-074) and **the Icelandic Data Protection Agency** was notified of my project with a detailed description and was accepted without comments.

The issues I considered in regard to teachers were mostly how to preserve their anonymity as was discussed previously in this chapter but also to not make unfair demands on their time and commitment. The latter proved a strange dilemma. Finding the right balance was at times difficult when trying to get teachers to fully commit to the project, in terms of familiarising themselves to the resources and being fully prepared to use them in teaching. Regular procedures such as those described in most research handbooks (see for example Cohen et al., 2007), were observed. Teachers were informed about the purpose of the study and how data will be handled. They signed a written consent form that informed them of their right to withdraw at any given moment.

The ethical issues considered in regard to the students were that their studies would not be disrupted in any way. The topics covered in the intervention would have been taught anyway and are part of the National Curriculum. Another consideration was that the experimental group might be getting a preferential treatment, assuming beforehand that the intervention was better than the traditional way of teaching. Furthermore the experimental group and the comparison group came from different schools to avoid the comparison group becoming de-motivated as computer use is still considered fun by teenagers. Parental consent was acquired in writing for all pupil participation and school administrators were asked for permission to work with the pupils through email and sometimes in person.

4. Mapping of ICT use in science education

This chapter outlines all data regarding research question 1: *How and to what extent ICT is used in lower secondary science teaching in Iceland?* More specifically, what equipment is available how is it used and to what extent? What do teachers and pupils think of using ICT in teaching and learning? Data for this mapping was collected both through Phase I, the survey and Phase II, the qualitative exploration. Section 4.1 outlines availability and teachers' knowledge and use of equipment. Section 4.2 is about how ICT is used in classrooms with pupils and 4.3. describes the teachers' views towards ICT and 4.4 shows how pupils from two schools describe their experience with ICT in learning.

4.1. Potential for using ICT

The whole survey can be seen in appendix A, including the responses to closed questions.

4.1.1. Availability and use of equipment

Having access to equipment is one thing but actually using it is another. Teachers were therefore asked whether they use the equipment to which they have access. Figure 4-1 shows the percentage of 123 teachers that say they have access to the various kinds of equipment. Equipment available inside the classroom is used often by the majority. In all of the schools visited in this study there was one computer in the classroom which was always on the teacher's desk, intended for teacher use. Caution should be taken with the word 'often' as interview data shows that this is a very loosely defined term. Teachers who said they used things 'often' turned out to mean very different things such as; once a term for computer rooms, or once day for the computer in the classroom. Only 20% of respondents had two or more computers in their classroom presumably for pupil use. Equipment less used is usually situated outside classrooms; the computer rooms or small clusters and the laptop trolleys. Interactive whiteboards were only to be found in 12% of schools.

About 26% of respondents have both a laptop and a desktop computer available to them and only 7% have neither (see appendix A). Science specific equipment is however rare. Only four teachers say they have some kind of data loggers and 11 have digital microscopes when asked if they had access to any other equipment than the one listed in the question.

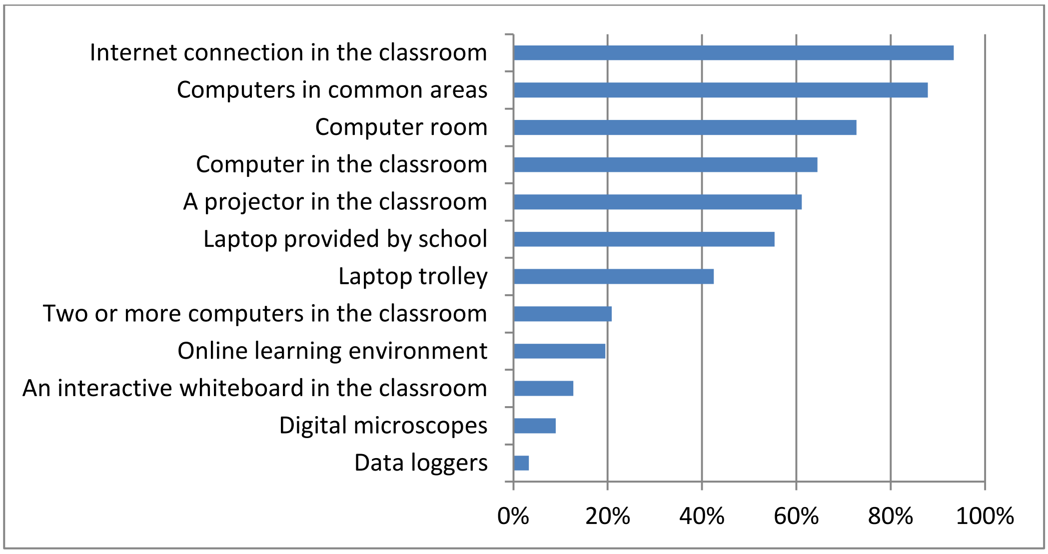


Figure 4-1 Availability of equipment

Most of the schools visited in this study had some kind of a booking system for the open slots in the computer rooms, with a first come, first served policy.

4.1.2. Use and knowledge of applications

Teachers were asked about their use of applications in different contexts which were personal use and work both with and without pupils. This item was fully or partially completed by 121 teachers.

Typical applications such as internet, email, word-processing and presentation software are all used by over 70% of the teachers in more than one context. The average number of applications that teachers use was calculated for different applications and contexts (see section 5 of appendix A). Generally the numbers are highest for other jobs in school. Teachers use on average 6.2 of the 16 applications queried for other jobs and 6.1 for personal use. They used only 5.2 with pupils in class, showing that teachers do not apply everything they know to their teaching. The difference is largest for the communication tools (email, chats and forums) where the personal use outweighs other contexts. However over half never use chats or forums. Applications used more with pupils than in other contexts were publishing software, digital cameras and educational software. Applications teachers used most for jobs within the school other than teaching were the internet, presentation software, word-processing, spreadsheets and mind-mapping software. Internet, publishing software and word-processing are the most frequently used applications with pupils. The least used applications with pupils were databases and data loggers.

4.2. Self reported use of ICT in the classroom

In this section all data pertaining to how teachers use ICT with pupils is presented. Section 4.2.1. is an overview of the described lessons. Section 4.2.2. is a presentation of the tools, task and applications used with pupils that had some presence in all data collections. This includes Table 4-6 which gives a summary of the activities reported in Phase II

4.2.1. Described lessons

Teachers were asked to describe a recent lesson involving ICT. The question was in eight parts. Out of the 123 respondents 78 responded to this item. The first part asked about the organisation of the lesson or how pupils worked (see Table 4-1).

Table 4-1 Organisation of described lessons

N=78	**No of lessons**	**Percentage**
Pupils worked individually	13	17%
Pupils worked in pairs	19	24%
Pupils worked in groups	21	27%
Whole class activity	6	8%
A mix of pairs, groups	12	15%
Unclear	2	3%
Non ICT lesson described	5	6%

Classroom activities fell into seven categories. These activities are described in section 4.2.2 except correcting exercises but in these lessons the teacher used a projector to show answers or solutions and pupils were correcting homework or work done in class.

Table 4-2 Pupils activities in described science lessons with ICT.

N= 78	**No of lessons**	**Percentage**
Essays-projects	51	65%
Watching videos	8	10%
Finding ideas for practical work	3	4%
Reading designated websites	5	6%
Correcting exercises	4	5%
Simulation- whole group	1	1%
Simulation - individual work	1	1%
Non ICT	5	6%

The descriptions were also analysed regarding topic. Almost half of the lessons were biology lessons and a fifth were earth science lessons as Table 4-3 shows.

Table 4-3 Topics of described lessons

N= 78	**No of lessons**	**Percentage**
Biology	35	45%
Earth sciences	16	21%
Pupils choose	7	9%
Chemistry	7	9%
Physics	6	8%
Scientists	2	3%
Non ICT	5	6%

The equipment and software reflect the activities. The internet is used in 60% of the lessons along with either word-processing or presentation software. Other equipment and software was used considerably less in these lessons as Table 4-4 shows.

Teachers were asked what their role was during these lessons Answers are categorised by level of control (see Table 4-5). First there are lessons where the teacher controls the lesson, often showing a video or correcting exercises. Then two words were used in most of the descriptions to be of *assistance* (aðstoðaði) and g*uide* (leiðbeindi). The former implies helping pupils when asked for

Table 4-4 Equipment and software in use in described lessons

N=78	**No of lessons**	**Percentage**
Internet	47	60%
Presentation software	28	36%
Projectors	20	26%
Word processing software	20	26%
Laptops	9	12%
Video player	8	10%
Video editing software	5	6%
Smart board	4	5%
Video recorder	3	4%
Computer room	2	3%
Publishing software	2	3%
Other (text-to-speech, pupils chose)	2	3%
Printer	1	1%
Camera	1	1%
Sound recording device	1	1%
Speakers	1	1%
Microphone	1	1%
Photo editing software	1	1%
Non ICT	5	6%

assistance but the second suggests more active guidance with interference and corrections where needed. However the distinction is often blurred. When both words were used the answers were categorised as more controlled. Lastly four answers indicated that the teacher was only watching the pupils and monitoring their work without assistance or interference.

Teachers were asked if they thought pupils had learned anything during the lesson and if they had been engaged. For the described lessons 67 teachers said that students were engaged during the lesson and a further 11 stated that most students had been engaged. Even though this question was open, these two questions were unfortunately worded so that they could be answered with a simple yes or no. A vast majority simply said ‘yes’ with no further explanations. These two questions were supposed to be an improvement from the pilot where teachers were asked ‘how do you think the lesson went’, to which and the most common answer was the single word ‘well’.

Table 4-5 Teacher activity in described lessons

N=78	**No of lessons**	**Percentage**
Teacher focused lesson, whole class	14	18%
Teacher guided where needed	24	31%
Teacher helped if asked for	30	38%
Teacher monitored and/or assessed	4	5%
Unclear	1	1%
Non-ICT	5	6%

When asked whether teachers thought that pupils had learned something during the recent lesson described, 74 gave a definite positive answer. The remaining four gave neutral responses, like ‘as can be expected’ or ‘probably something’.

4.2.2. Tools, tasks and applications

In Phase II teachers were asked about what experience they had of ICT in science teaching. In Table 4-6 the activities the teachers mentioned either in interviews or focus groups are ticked. The activities are sorted into three sets:

- Pupil activities: where pupils work at computers either in school or at home, by themselves, in groups or pairs.
- Whole class teacher-led activities: where the teacher is in charge; lecturing, demonstrating or searching while pupils watch on a monitor or an interactive white board.

- Teacher activities where pupils are not present.

In the following section evidence of these practices is presented from the survey and qualitative exploration.

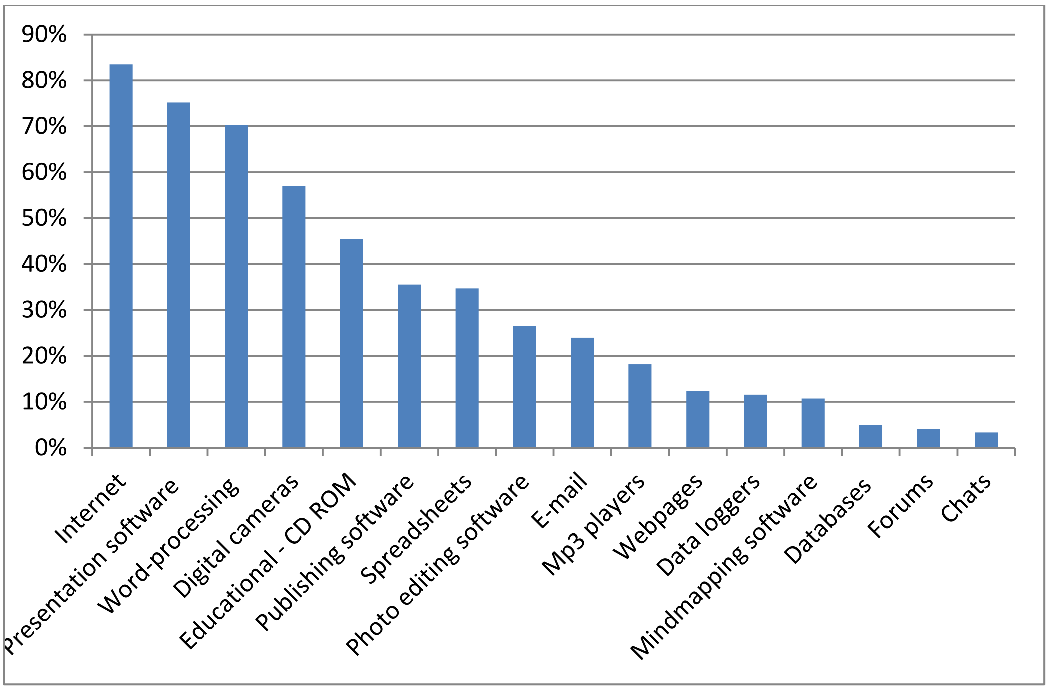
Table 4-6 ICT Teacher practice from phase II – before intervention

	Activity	Eva	Anna	Inga	Olga	Ellen	Dora	Tara	T9	T10	T11	T12	T13	T14	T15	T16	T17	Total
Pupil activities	Research from internet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	15
	Making PowerPoint slides	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	13
	Writing essays- word-processing		✓	✓		✓	✓		✓		✓	✓	✓		✓	✓	✓	11
	Browsing/reading websites	✓					✓					✓	✓	✓			✓	6
	Videos of practical work			✓			*			✓	✓						✓	5
	Browsing/reading CD-ROM		*								✓				✓		*	4
	Booklets with publisher						✓				✓	✓	✓					4
	Work with simulations					✓						✓	✓					3
	Taking photos of practical work		✓							✓						✓		3
	Audio books	✓		✓														2
	Digital microscopes				✓												✓	2
	Electronic tests								✓									1
	Calculating with spreadsheets										✓							1
	Making websites											*						1
	Writing in a wiki								✓									1
Whole class teacher led activities	Lecturing with slides	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	14
	Showing videos	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓		✓			11
	Showing websites on projector	✓	✓	✓	✓	✓		✓			✓	✓	✓				✓	10
	Simulations				✓	✓								✓			*	4
	Searching online with class	✓						✓	✓						✓			4
	Digital microscopes				✓													1
Teacher activities	Sharing info or text on website											✓	✓	✓				3
	Teachers learn from the internet														✓		✓	2
	Email to pupils												✓					1

✓ activity from ongoing school year (data collected at end of year) * activity from previous years

The applications teachers (from the survey) said they use with pupils can be seen in Figure 4-2. The organisation of this section is based on this figure.

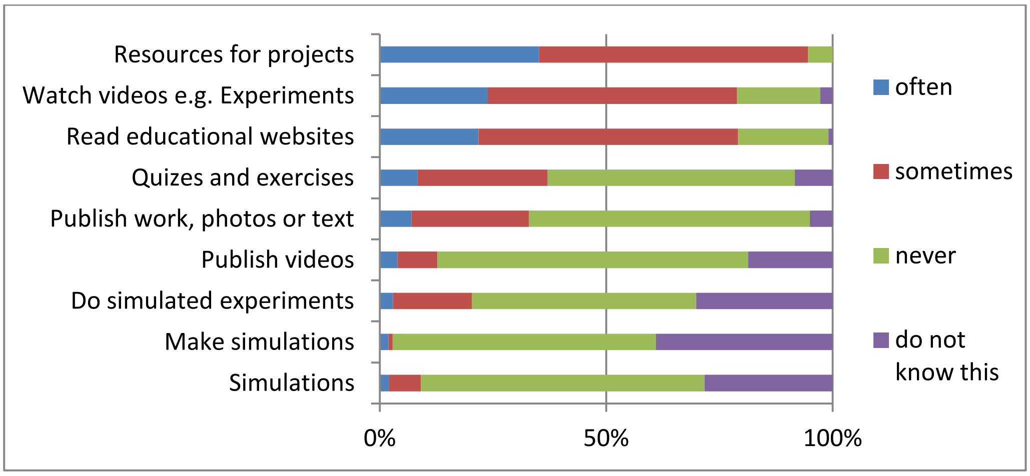
Figure 4-2 Applications used with pupils



The internet

The internet offers many different kinds of uses so teachers were asked about the main categories separately. Figure 4-3 shows the percentage of teachers that say they do have pupils carry out the different activities *often* and *sometimes*.

Figure 4-3 Internet use with students in class



Though 80% of teachers (see Figure 4-3) say they had pupils read educational websites less than a third of Phase II teachers told of such activities that were not for project work (Table 4-6). Eva had her pupils read a sex education website[9] because she thought they would appreciate reading that kind of material in private. T17 said she had prepared worksheets to accompany reading from several websites. Dora had pupils explore *The energy game*[10] in conjunction with building a model of a power plant. T12 and T13 had had pupils read a variety of websites in carousels. Teachers also used the internet with the whole class showing pupils photos, diagrams or videos on websites and discussing specific topics. For example: '*I show them a little, go to the astronomy web and show them photos of stars and such'* (Anna) and *'I am now always turning on the eagle'* [a live webcam monitoring an eagles nest]).

A further use emerged in Phase II where four teachers spoke of how they use the internet spontaneously in class to answer questions that arise or explore issues with pupils. This practice was well described by T9 : *'I can say that when any questions arise in class then I just pop to the computer, have the projector on and we just google whatever, chemical or phenomena, well we do that and spend some time on it.'*

Watching videos, either short clips from websites such as *Youtube* or longer ones from *NCEM* appeared in all data collection methods. They were described in a tenth of the lessons (Table 4-2), 80% of survey respondents (Figure 4-3) and 11 of the 17 teachers from phase II spoke of such practices (Table 4-6). Teachers expressed how convenient it is to show videos with projectors than having to wheel televisions with much smaller screens into the classrooms. Many used the videos from NCEM, nonetheless, *Youtube* was the most frequent resource for videos. Some teachers talked of using short clips as a starter to a lesson or a topic but also showing long videos sometimes with question sheets afterwards. T12: '*I always begin lessons by showing them some news, either from the internet or even a video from Youtube'.*

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[9] http://www1.nams.is/kyn/index.php

[10] http://eyjan.lv.is/popup.htm

Online quizzes or exercises were used by over 30% of survey respondents. T12 and T13 had their pupils do quizzes and exercises in the carousel work as revision or exercises but T9 however was experimenting with a virtual learning environment (Blackboard) for assessment with multiple choice questions.

Examples of published pupil work on the internet can easily be found with an internet search; over 30% (Figure 4-3) had published pupil work. Two teachers told about publishing; one from a digital camera and one from videos of practical work.

Finding ideas from the internet for practical work was described in five lessons and also mentioned in Phase II, where pupils were expected to go online and find videos or ideas for practical work. The accompanying tasks differed from pupils showing the videos with explanations to the class to duplicating the practical exercise with their classmates.

Presentation software

Presentation software is the second most used application after the internet. Phase II showed that it is used by all teachers to some extent for lecturing in class with pupils as receivers (see Table 4-6) but it is also used for project work.

Project work

The activity that all Phase II teachers had done in one way or another was some kind of research/project work. Of the 16 teachers 15 of them mentioned having their pupils search for information online and in books and then process that information into slide presentations, essays or booklets. The one who did not mention online search talked about writing essays using *Word*. Five teachers said their pupils did one project every year. Two teachers (Dora and T9) described projects stretching over several weeks.

Project work was also apparent in the open descriptions of a recent lesson involving ICT and science (see Table 4-2). A lesson that involved students going online and finding some kind of information and presenting it either with a *Power Point* presentation or in an essay was described in 51 of 78 responses.

In the survey more than three quarters said they use the internet and word-processors (often and sometimes) with pupils (Figure 4-2).

Spreadsheets

Spreadsheets are used by 35% of teachers with pupils but no instance of their use was found in the descriptions. Only one phase II teacher (T11) used spreadsheets with her pupils. She had a background in the business sector.

Science specific software

Simulation activities from the web were done by less than a fifth of the teachers (Figure 4-3). Software on CD-ROM is used by 45% of teachers with pupils. Teachers in Phase II were familiar with the two currently available CD-ROMs available in Icelandic and three had CD-ROMs in English that they used for demonstration purposes and as resources in projects. Also available in Icelandic is a suite of simulations and tasks called *Sunflower learning* [11]. None of the participating schools had bought access. Though most of the teachers were aware of it they had refrained from asking or been denied buying access due to lack of funds in the schools. One teacher (T14) had an evaluation copy and was very impressed by how easy it was to explain complicated things such as waves using the simulations. Two examples of simulation use came from the described lessons. One was a lesson in genetics where the teacher demonstrated a simulated mouse cage where the mice could procreate and the offspring investigate. The other was a lesson in earth sciences where pupils worked on their own building a planet.

Science specific hardware

No use of data loggers was described, neither in the survey nor Phase II. It is striking that almost 23% claimed they did not know what data loggers are (see Appendix A, section 5). Two teachers in Phase II had digital microscopes. One had developed a way where pupils prepared slides and viewed them through regular microscopes. Good examples were then viewed by the whole class

[11] http://www.sunflowerlearning.com/ and http:a4.is

and/or photographed with the digital one. The other teacher had only used it for demonstration purposes.

Photo and video

Digital cameras were used by 57% of teachers. Three teachers in Phase II said they had had pupils take photographs. Two of these were of plants and talked about pupils making videos and two of which were of practical work. Five of the described lessons clearly involved pupils working with photo or video. In one of these descriptions the teachers stated '*They were working with a browser, power-point, and some video editing software that I do not recognise*'. Teacher 10 also described how she just sent the pupils off to work on their own in the computer room and she also neither knew how to work the video editing software nor what it is called.

Other uses

Email was said to be used by 24% of teachers in the survey. Only T13 gave an account of using email with pupils. When she sent pupils to a computer cluster she sent instructions in an email what websites to visit and what to do there.

4.3. What teachers think of ICT in science teaching

The respondents to the survey had very positive views toward ICT in science teaching as a large majority of them either agreed or strongly agreed to a collection of statements (see appendix A, item 12). A collection of quotes from Phase II also give indications of what teachers think of using it in with pupils.

The reasons teachers mentioned in this study as to why they use ICT were as follows:

- to add variety to teaching methods;
- helpful for learning;
- clearer representation;
- visual aid;
- easy access to information;
- pupils like ICT;
- pupils know ICT.

One of the most common reason teachers in Phase II gave as to why they try to use ICT in their teaching, was that they want to add variety to their teaching and that ICT has many opportunities to do just that, by providing alternatives to traditional book learning with research, group-work and more vivid presentation.

Teachers in the survey felt ICT is helpful for pupil learning with 91% agreeing or highly agreeing to the statement '*I think students learning will benefit from ICT use'* and 89 agreed or highly agreed that ICT might have a positive impact on the way we teach.

When asking Phase II and III teachers about their ICT use it was overall the same. The ICT they had tried had rarely been with the purpose of teaching science concepts or content for tests, so almost no opinions about the effectiveness of teaching science concepts with ICT could be found. One of the rare occasions was from T14, who had tried several simulations and felt that they helped with pupil understanding. T9 had done a big ICT based project with her class. When I asked her if it had been effective her response was:

> *Do you mean, will they score higher on a end of year written test?... No, not after this, but they are probably more ready for self study and to find out things on their own.*

That ICT had the potential to make science more visible and therefore help with understanding of concepts and phenomena was mentioned often. Statements about how ICT makes science more visible include: *'it has the potential to give clearer representations of phenomena through graphic means'* (T14) and, *'it gives helpful visual aid, for difficult things, forces and cells*' (T12) and six comments specially mentioned this affordance. Ellen also mentioned that pupils took more notice of explanations with visual features: '*yes, if it just moves then suddenly everybody wakes up.*'

Another affordance mentioned by 15 teachers was mentioned by Olga who said *'it (the internet) is such a vast sea of information'.* This is related to having that vast sea just a fingertip away and searching for it with the class when needed. Teachers felt this both taught pupils how they themselves could find out things in science and also that it often sparked interesting discussions in class.

The fact that teenagers use ICT to a great extent in their lives for recreation and socializing was the second most stated reason for using ICT in science teaching. '*It is just teenagers today, they live and breathe in computers and they just flourish more with them and the lower achiever can take advantage'* (T12). *'It is everywhere in the pupils environment'*, *'it is the future'* (T13), '*it's the current thing and the future'* (Eva). T14 also added '*it is their reality, what they know, you got to keep up with them, may kindle interest in science'*. Olga agreed with this. When talking about a previous lesson where pupils were researching a specific topic, she said:

> *well, I mean, there are many pupils that dug pretty deep, at least they then became interested enough to go home and continue exploring the topic, came back with printouts of what they had found, I am not saying they were many, but it kindled interest in some….*

Generally it was also the teachers' perception that pupils enjoy working with computers, '*there is simply more joy*' (T13) and

> *It is like, if I say to the kids: physics, then I get a general ohhhhhhhhhhh, you know it is just the word physics, it is something difficult and negative, and if I say to the kids: botany then just ohhhhhhhh, but if I say let's go outside and make a video, you know (T10).*

This notion that pupils enjoy ICT work more than traditional lecturing is closely linked to why teachers choose to use ICT in their teaching, T10 goes on and says: '*we are always trying to find ways to make the learning more easier and more fun'*. T17 described in a focus group, and the others agreed, how when pupils are given the choice to use books or internet for research, none of them will choose books. Ellen also talked about it being easier to manage discipline in the lessons involving ICT because pupils were preoccupied. Dora talked extensively about fun, that she wanted the teaching to be fun, and that she wanted the pupils to have fun in the lessons. When asked why fun was important it emerged that she and T13 believed that if the lessons were fun the probabilities of pupils gaining an active interest in science were increased. As the interviews where semi-structured it is highly likely that other teachers also have this view though it did not arise in all of them.

Other reasons for using ICT include that pupils work faster and they produce neater work (T17, T14, T9), and others added that using word-processing had benefits for those who are not good at handwriting. Only one (T9) mentioned that pupils will need to be familiar with computers when they join the workforce.

The teachers themselves are also interested in ICT. Many Phase II teachers had many tried some ICT applications in their teaching and had generally positive views towards ICT. When they had tried something they usually did it again. Maybe it is an indication of the willingness of teachers that 123 took the time to answer the survey and a further 40 volunteered for further participation, perhaps in the hope that there would be opportunities to learning ways of using ICT in their teaching. At least in informal chats during the intervention some teachers said that was one reason for volunteering.

Even though 85% agreed to a statement about believing that ICT may make teaching easier that view did only occur once in the interviews where Ellen expressed that she thought using educational software made the work easier given that you had good software to work with.

I also asked teachers a utopian question about what they would ask for in an ideal world. Even though they knew that the interview was in the context of ICT use and I would have expected them to talk about wanting more computers or training, many of them talked about resources for practical work and out-door teaching. It seems that teachers feel very pressed to engage in elaborate practical work as questions about ICT use also often led the teachers to tell me about practical work. This was especially so for the questions about data loggers and availability of equipment.

4.4. Pupils' views and experiences of ICT

The attitudes pupils have towards using ICT for learning and life were explored both through focus groups in Phase II as was described in section 3.4.4. and in a questionnaire before the intervention (see section 3.5.4)

Previous experience of ICT work

Pupils were asked to describe what ICT they had used in science in that school year (the focus groups were conducted in May). One group was from a teacher who came out of the survey as a high level user (T9, group A) and the other (Dora, group B) as medium level user. These pupils should therefore have some experience to talk about. Teacher and pupil descriptions concurred. Both teachers had spent a considerable amount of time with pupils on project work covering only a small topic, or one chapter from the textbook.

These two teachers had organised the work quite differently. Group A rarely used computers in school. They organised and discussed what was to be done in school but the actual computer work was supposed to take place at home. The groups had different tasks covering one chapter, using different media. Group B on the other hand said they had rarely spent time in the classroom and that it would be better to have a more equal balance between project work and classroom work.

In group A pupils thought they had not learned as much from the project work as they would have from regular teaching. Group B talked more about not having read anything, having had mostly projects and few tests: '*this has been a strange winter, lots of group work and essays but only one test, working in Word or PowerPoint, finding information online…..*' Both groups however agreed that more ICT work sounded pleasing but it had to be better organised, better monitored, and more to the point, as one boy (group A) put it '*if the right method would be found, you see, one that would perfect the way she used it would be much more fun*'. The teacher in this case had also realised that the project had gone out of bounds and said that if she were to do it again she would scale it down and mentioned the same things the pupils had (that she had lost an overview and had intended to do too much in a first time attempt).

Both groups talked about difficulties associated with group work. Group B was concerned that the assessment of work was not fair. Group A was more concerned about unfair division of labour, where pupils were given different roles.

Pupils' perception of extent of ICT use in school

Pupils in the intervention were asked to respond to statements about their computer use both at home and in school. The questions were Likert style statements with a four point scale written for this study. A total of 278 pupils in 18 classes responded. The results are presented in Table 4-7 where 1 means *highly agree* and 4 means *highly disagree*.

Table 4-7 Pupil views of ICT use and extent

	N	Mean	Highly agree	Agree	Dis-agree	Highly disagree
We often use computers at school	272	2.89	1%	24%	61%	14%
We often use computers in science	274	3.25	0%	7%	59%	34%
I like to use computers in science	271	2.20	21%	51%	23%	6%
I use computers often at home for fun	275	1.38	63%	33%	3%	1%
I often use computers at home to study	274	2.28	17%	56%	19%	8%
I think computers are helpful for studying	274	1.81	38%	52%	5%	4%

The responses show that pupils do not think they use computers much at school with 75% of pupils disagreeing or strongly disagreeing to the statement 'we often use computers at school' with a mean response of 2.89. In focus groups pupils talked about using computers occasionally in languages and mathematics, but only rarely, like once a semester for project work. When asked about computer use in school it was clear from the pupil responses that they did not consider whole class activities such as watching videos or teacher presentations to be computer use, but rather only where they were at a keyboard active in some task. This could be seen from the fact that even though teacher interviews and observed lessons revealed the teachers to use the IWB or projector in almost every lesson their pupils still said they never used computers in school.

For the statement ´We often use computers in science' 86% of pupils disagreed with an average of 2.89. The average is even higher for the statement 'We often use computers in science' (3.25) indicating that pupils believe that they use computers even less in science than in school in general. In group interviews after the interventions, pupils gave no descriptions of previous computer use in science lessons, with the exception of two who mentioned looking for resources for essays. In three schools pupils said that the intervention was the first time they had used computers in science.

I was present when pupils answered the questionnaires and they frequently complained that they missed having a middle option saying their views were not very clear. For the statement about liking using computers in science they really wanted a middle option, with one pupil saying in a focus group ´*how am I supposed to know if I like it or not ! We never do it*´. Still 68% of pupils agreed to the statement with an average of 2.20, indicating perhaps beliefs rather than experience. In focus groups those who had received the intervention generally agreed that they had enjoyed the experience not considering the different DLR used (their views on different DLRs are presented in section 6.1.3, 6.2.3 and 6.3.3). What the pupils seemed to like most was the break from routine; '*it was fun, doing something different*' and also compared to usual activities '*it is more fun than sitting on your arse and writing stuff*', '*it is better than always doing the same thing*'.

Home use

94% of pupils agree to the statement 'I use computers often at home for fun'. In focus groups they were also asked about how much time they spent on the computer. The responses ranged from 'it is always on' to 'hardly ever' with most of them estimating the time spent on computers to 2-4 hours a day. The uses they mostly mentioned were games, Facebook, MSN chat, and downloading websites. They also watched movies and *Youtube* videos with such diverse subjects as cosmetics, religion, politics, thunder and lightning being mentioned. All pupils said they had a computer in their bedrooms or good access to them at home.

Pupils were also asked if they used computers at home for studying and 94% agreed that they used them often. In group interviews, few pupils said they never used computers for studying but most that they did it occasionally; for essays, for looking online for notes from other schools, to look for answers to textbook questions, to use dictionaries, calculator and some to write their own notes. When asked to compare how they used computers at home and in school this was a typical response:

> *Pupil: At home I use it for games and in school for learning, sometimes a bit the same.*
>
> *Interviewer: But do you all use them as much in both places?*
>
> **General laughter**
>
> *Pupil: no much more at home!*

To get pupils to talk more about how they used computers at home I asked some groups what they did when they wanted to know something or needed information. The unanimous answer was '*we google it'.* Some also asked their parents. When the question was phrased more along the lines if you do not know something or need help with homework, parents were named first, then the textbook ('*we know it is in there'*) and the internet last. So the bottom line seems to be that pupils regard the internet as a source of information but trust the textbook and parents to give quicker and better tailored answers; '*it is more pleasant to get help from a person, and sometimes it is not correct what the computer says if you go on google, some websites are just rubbish'*, '*the tests and tasks are only from the textbook, so you should not need to search elsewhere*'. Despite this, the statement about the usefulness of computers for studying showed that 85% of pupils believed them to be useful (Table 4-7). No questions for the focus groups were about usefulness of computers generally for studying. What mainly came out in the discussion, apart from the internet being a good source of information, was that many felt that it was easier to write with computers and present work neatly.

4.5. Summary

A survey revealed that there are not enough resources for technology to have yet made a big impact on science teaching in Iceland. The use of science specific applications is especially low. Teachers are experimenting with ICT though and the most common uses involve using the information for resources, writing essays and giving presentations. Use of photo and videos are also widespread. Teachers value ICT for giving, fast up to date information. There is a big gap between the extent that pupils use ICT in schools and at home.

5. Conditions that affect teachers

The second research question is about the factors that affect teachers in their use of ICT. Section 5.1presents one part from the survey where teachers were asked what factors on the one hand inhibit their ICT use and on the other hand what encourages them. The most prevalent factors are outlined in this section, based on what teachers said in the survey and combined with quotes and opinions from Phase II and III. In section 5.2 four cases are presented, illuminating how different factors manifest in the stories of these teachers. The cases are explored through cultural historical activity theory, introduced in section5.2.

5.1. Factors that Icelandic teachers say affect their ICT use

The question in the survey was open, asking teachers *'What factors do you think inhibit you from employing ICT with pupils?'* When responding to this question teachers often gave long answers commenting on more than one issue. These responses were split into comments and then categorised. The categories that emerged can be seen in Table 5-1. Equipment was the factor that most teachers mentioned as a deterrent. Next were pedagogical issues and teacher knowledge followed by DLRs, time and professional support.

The survey did not ask teachers directly why they use or should use ICT in their teaching, but the question '*What factors do you think make it easy for you and encourage you to employ ICT with pupils?*' provided 75 responses. These responses could be split into a total of 86 comments. The comments mainly described what affordances and possibilities teachers could see in ICT use. The comments are categorized in Table 5-2.

Table 5-1 Factors that teachers think inhibit them in employing ICT with pupils

N= 79, 112 comments		**Negative factors**
57	Equipment	Lack of: computers, projectors, connection problems, poor equipment
22	Pedagogical issues	How to organise lessons, not to lose control of pupils, ICT distracts pupils, loaded curriculum, pupils do not know the ICT things they need, usefulness
13	Teacher knowledge	Lack of pedagogical, technical and/or content knowledge and what is available of DLR´s
9	Digital learning resources	Lack of, questionable quality, interactivity, Icelandic, censoring
6	Time issues	Lack of time for preparation, to learn new things
2	Professional support	No head of department, only teacher in the school
2	Nothing	Nothing deters me

Table 5-2 Factors that teachers think make it easy or encouraging to employ ICT with pupils

N=75, 86 comments		**Positive factors**
23	Equipment	Having good equipment or access to equipment
11	Pedagogical issues	(fjölbreytileiki) variety in teaching,
5	Digital learning resources	Access to interactive quizzes, videos of experiments, cartoons, variety in learning resources
3	Teachers	Like working with computers, have good knowledge of ICT, access to information on how to use ICT with pupils
15	Information	Good access to a vast amount of information on the internet
6	Pictures and diagrams	Having access to pictures and videos
22	Pupil related	Pupils used to working with computers, more interest and engagement, more active
1	Negative comment	'*I almost never use ICT. Nature interprets itself best. Pupils should rather come warmly dressed to school to be able to go outside rather than to hang over the content rare advertising bullshit of the internet*'.

5.1.1. Availability and access to equipment

Availability and access was at the top of the list both as an encouraging factor and a barrier. Teachers appreciate '*having the equipment always at hand a computer, projector and internet connection in the classroom*' and '*good access to computers and other equipment*' was said to be encouraging.

The other side of the coin is that not having this access was the most frequent barrier in the survey (see Table 5-1). Teachers talked about not enough equipment, or dated or faulty equipment:

> *The kids here do not have access to computers, there are three bad ones at the library, 10 bad ones in a study room which you cannot even use unless a teacher accompanies pupils, which is an contradiction because that is not possible, I can never take my class to the study room because it only has 10 computers that actually are unusable* (T9).

Some complained; '*the internet connection here is so awful that if I took the laptops in to the classroom, then it would not work'* (T11). The availability of equipment and teachers views of it was also the subject of chapter 0.

5.1.2. Pedagogical factors

Pedagogical factors in the sense 'the effect that ICT has on teaching, learning and pupils' were categorised together in Table 5-2 where teachers gave these kind of reasons either as barriers or facilitating factors.

Teachers often gave similar or the same reasons as to why they feel they should use ICT (see section 4.3) and as a factor that encourages them to use ICT. Teachers believe that computers add variety to what goes on in the classroom and mention that as a factor that encourages them to use ICT, *'Makes the teaching more varied and easy to show how things work.'* They are also encouraged when they find tasks that fit with the topic at hand, '*What we are working on at the moment*'. The visual element was also mentioned '*to be able to show instantly photos of amoebas or other things related to the topic*'. In addition, a further reason expressed frequently was pupil interest in computers; '*Pupils show more interest when working on computers*' and '*Pupils are used to working with computers*.'

Even though pupils' interest and enjoyment was one of the prevalent factors in why teachers decide to use ICT, some also thought it deterred them from using it. Things like pupils get distracted by the internet and they do not have the ICT skills needed were mentioned, T14 talked about these contradictory views:

> *Yes, I think it can kindle their interest, and to say, this is their world,… actually it always surprises one a little how these computer-guys that spend their whole time on the computer how little they actually know, they are just submerged in their own world, the world of computer games*.

When asked about the girls she and other teachers said they used social applications such as *Facebook* and *MSN* more, but often had few practical skills. Common complaints of pupils included losing their own work, not knowing where they had saved it, forgetting their logon names, not knowing basic word-processing skills and not being able to work independently.

Issues about digital learning resources were mentioned only seven times. These included: the lack of them; that the resources sometimes are of a questionable quality; that they lack interactivity; few are available in Icelandic; and that popular websites such as *Youtube* are often closed in schools.

On the other hand teachers did talk about how the internet is helpful; '*Access to a huge amount of interesting information*', '*It is so easy to use the internet to find good information in science*'.

Other pedagogical factors that teachers mentioned were things like difficulties in organising the teaching around the available equipment, often related to them having to send groups from the classroom to work on computers and thereby losing control and not knowing what they were up to. This is closely related to the knowledge teachers need to successfully implement ICT discussed in section 2.4.4.

Three comments were made about there not being enough time to use ICT as the curriculum was overloaded as it is. Other time issues are outlined in section 5.1.5

5.1.3. Training

In implementing new technologies training must be an important factor so teachers were asked in the survey about any training they had received. The respondents in the survey did not seem to consider training to be an all important issue. None of them mentioning training specifically as a deterring factor but 13 references were made to lack of knowledge which could be gained through training or courses. When asked about training received 44% of respondents said they had received some training in using ICT generally in teaching and 56% had received no training.

Of the 81 that said they had had any training, 40 gave further descriptions (see Table 5-3) where the majority said the training had either been in their initial teacher training or courses in schools. Though some referred to educational applications such as IWBs and mind-maps, Phase II suggests that in answering this question teachers were referring to general ICT training, such as using *Microsoft Office* software, with very little pedagogy associated.

Table 5-3 Types of training teachers had in using ICT in teaching.

N=42		
Teacher training	13	31%
Courses	14	33%
Self study	4	10%
Further education	6	14%
Other courses not teaching related	5	12%

Only 9 out of 94 respondents said they had received training in using ICT in teaching science. Seven gave more details, referring to their teacher training and one introduction to *Sunflower learning.* Many of the Phase II teachers had also attended this introduction. One teacher had also gone to an introduction to data loggers given by the seller of equipment and the school developing worksheets.

Most of the teachers in Phase II and III had at least five years of teaching experience and some considerably longer. Two talked about ICT in their teacher training. Anna had finished her training two years earlier and was very critical of the teacher training she had had. Even though she had ICT as an elective she complained that there had been no concrete instruction in how to use ICT in teaching. Ellen, who was in her first year of teaching, also said the same thing but had much more confidence in ICT use than Anna.

One teacher in the survey thought it encouraged her to be able to find knowledge: *'Access to information about how to use ICT in teaching science.'* Five Phase II teachers talked about searching online for teaching ideas.

5.1.4. Support

Table 5-4 breaks down the different kind of support teachers in the survey said they have access to (Appendix A section 9).

Table 5-4 Support available to teachers

N=105	Teachers	Percentage
Support of colleagues within the school	63	60%
Support from management team	71	68%
Subject leader of science within the school	14	13%
Subject leader-consultant of science outside the school	4	4%
ICT subject leader - consultant within the school	18	17%
ICT subject leader - consultant outside the school	2	2%
ICT technician	43	41%
Support in setting up computer equipment	44	42%
Support in using software	32	30%
Support for preparation of practical work	5	5%
Support (assistance) during practical work	4	4%
Other	2	2%
None	5	5%

All the phases of data collection indicate that teachers do not have much active support in trying out and integrating ICT into their teaching. The support available to teachers seems to be rather limited, the question reported in Table 5-4 only asked what support teachers had access to but not what support is active and they actually take advantage of. The following sections present what teachers said in both Phase II and III about professional, technical and managerial support.

The two items about support with practical work is a little bit outside the Icelandic context. Technicians like English science teachers have are unheard of and teachers are expected to handle all their preparation, often from purchasing the equipment to setting up and clearing up themselves. From comments to this question, it was clear that the few teachers that say they have some support with practical work are referring to classroom assistants who usually follow special educational needs children and can sometimes be asked to assist with the whole class (for example in splitting it into groups).

Professional support

The issue of isolation and lack of cooperation often came up in Phase II. Teachers feel they are too alone and need contact with others to find out what is available and what others are trying out *'it is often not till you meet people that you find out about these things'* (T10), meaning information about teaching materials and methods. T9 was very critical of the system, not having a subject leader and this was her first and last year teaching in compulsory schools. *'I do not understand why no one is organising this, Why don´t I have anybody to talk to who is subject leader in science,... Why are we all doing the same thing in our own corner?'*. Only 13% of teachers have a subject leader and 4% say they have access to subject leader or a consultant outside the school. In two areas, the teachers meet occasionally and share ideas on teaching science. Three teachers spoke of having a subject leader: T16 '*it usually falls on me to be subject leader',* Dora: '*I am supposed to be subject leader*' and T10 said her school had a subject leader who was on maternity leave. No references were made to active support from heads of departments.

It surprised me when working with one of two teachers in a school on the intervention, how little cooperation there is between them. In phase II there were two references to active support of peers. In at least four of the schools there were two science teachers. Only in one of them was there active cooperation between the two teachers (T12 and T13) and they had developed inventive ways of integrating various methods of ICT use into their teaching. The cooperation between them seems to be one of the deciding factors in the very successful and innovative teaching of science in that school. In the second school there seemed to be some cooperation between the teachers. In regard to ICT issues the interviewee (Olga) said they had discussed some things like a collection of web-links for pupils but nothing had been put into practice. In the other two schools the teachers taught different year groups and had no active cooperation between them.

Technical support

In Table 5-4 it can be seen that technical support for teachers seems rather limited with 41% having access to a technician. ICT subject leaders (consultants) in Iceland may be educational staff within or outside the school which teachers could go to for advice either on how to use specific applications themselves or how to use them in teaching. These advisers would in some cases also be those that would coordinate the teaching of ICT within the school and or even teach ICT themselves. Only 17% say they have access to such support within the school and 2% have access outside the school. T17 talked about this need for support within the school:

> T*here is no one that has the role of leading us in ICT implementation,……. It is my dream that there is somebody in the school that knows more than you, which you can learn from, it has happened on occasion and then you learn a lot, I think that is the best ICT learning that I have had, not in the university or in some courses, but when you are working with people that know more than you do*.

The support with the equipment is more common with 41% saying they have access to an ICT technician (somebody teachers can go to when some hardware or software is not working or they need purely technical assistance). Similarly support in setting up computer equipment is available to 42% of respondents and support in using software to 30%. Several teachers (T17, T9, T16, Olga) talked about the technical management and policy not being suited to schools. T9 who taught in a large area with many schools and an outside IT department said*:*

> *The focus here is wrong, the IT department is trying to force tools and gadgets on the teachers and they choose the things for us, but of course it should be me that tells the IT department what I need, you see the focus is just wrong.*

Similarly Olga in an area with just a few schools was unhappy with not being able to update software for the IWB or get the software for the digital microscope installed when she moved rooms:

> *We have had some problems, the IT technician has been dragging his feet in updating this, this is not his area of interest so it is not at the top of his list of things to do.*

Though Olga had the technical expertise to do these things herself the teachers did not have access to install software or make changes. Other teachers had similar complaints and felt restricted by the fact that the same filters applied to them as pupils so they could not access material they felt was useful for them. This experience though was not unanimous and some (T11, T16, T15) spoke highly of the technical assistance '*we have a computer guy that does everything for us*' (T11).

Managerial support

In Phase II and III there were few references to support from management. No references were made to active support from headteachers but albeit teachers were not prompted about this. That is not to say that headmasters seem unsupportive in teacher accounts, just that the initiative rarely comes from them:

> *We have really good headmasters, they follow us totally, that is just great, we get what we want, uhm but not the equipment, heheh the big things, but then again we have not really asked for them either.*

This is T12 talking and it is obvious who is in charge: the teachers come with the ideas, ask for what they want and are granted their polite wishes. Dora also mentioned management in the context of getting new equipment;

> *well there has been talk of it and somebody said it would be great to get them [IWB's] but not by the management, especially not now, you know how everything is, we are not going to get new boards in the near future, that is for sure.*

T9 was not so happy with her headteachers. She was amazed that there was no policy within the school on computer-based communications (*Facebook*, *MSN* etc) with pupils and even more amazed when she found out that the school had access to *Blackboard* and that the management team was not aware of it. This lack of policy and vision was one of the reasons that this was T9's only and last year of teaching in lower secondary schools.

In the last interview with the intervention teachers, I asked them whether their co-workers or headteachers had shown any interest in what they were trying out. Only one of them said so and that person was a personal acquaintance of mine. It was never mentioned in any way that teachers felt any pressure or even encouragement from headteachers or co-workers to use ICT in their teaching.

5.1.5. Time and workload issues

Time and workload issues seem to be a hindrance to teachers exploring how they can use ICT in teaching, to learn about new things and search for new possibilities. The time issue is somehow connected to how teachers approach their work, one said grumpily *'I think that many of these teacher that really use ICT, they do it in their own time out of their own interest'* while another said *'I find it all so exciting, I just sit at home with the laptop'*. Another (T14) stated that he was not going to use time as an excuse ('*You can always use that as an excuse*') meaning that there are always many demands on teachers' time and that it is more a question of prioritisation. Most teachers also said something along the lines that they had been meaning to look into what was available on the internet but that they simply have not given themselves the time. Some were aware of the possibility that ICT also holds ways of saving time with, for example, online tests. Only one was experimenting with such tests and two others said it would be time consuming to begin with, though it might pay off in the long run. The time issue was especially mentioned by those who had recently started teaching science, like T11 said, '*It has taken so much time to simply learn the topic material that I have barely had a life*'.

It may also be mentioned here that even though it is not the subject of this study issues regarding practical work raised frequently in Phase II. Teachers felt they were not doing enough practical work. They expressed similar views regarding practical work as ICT, explaining that they lacked knowledge, both in terms of resources and subject content knowledge, to meet the demands they felt from pupils and the curriculum for more practical work. Such demands were not mentioned with regards to using ICT use in their teaching.

Time and workload issues are also explored in the four cases in section 5.2.

5.1.6. Teacher knowledge

Teacher knowledge turned out to be a salient theme through all data collection exercises. Teachers mostly talked about what they did not know and less about what they did know. The concept of knowledge here is treated loosely to mean both knowledge and skills. The model of TPCK (Mishra and Koehler, 2006) (see section 2.4.4) frames the following section. The TPCK model argues that teachers need pedagogical, content- and technical knowledge for successful technology integration.

Technical knowledge

From the literature the issues of teacher confidence in working with computers seemed more prominent. The survey contained a list of statements regarding teacher confidence rather than knowledge. Three were about teacher confidence when using ICT in class (see Appendix A item 11). Over 83% of teachers agreed or strongly agreed with all of these statements, which were about not being afraid to make mistakes in front of a class, feeling confident using ICT in front of pupils and managing a class using ICT.

Phase II and III showed that teachers generally know how to use computers and generic software but are different in how competent they feel. Two said their competence was a hindrance to them and they really had to struggle to keep up with technology. '*You need to learn them [programmes] so well.....when you are figuring them out you somehow always hit a wall*' (T10), '*I am always learning something new and fiddling around with them*' (T11).

Four teachers talked about their willingness to take risks and let the pupils help them when they know better. They agree with the 83% that said they were not afraid to make mistakes in front of pupils. Some also are not bothered by pupils knowing more than they

> *Well maybe [it is bad] when they have more skills than you do, but I, you know, well still, maybe I am a little less confident, but it is anyway they may just as well have more skills than me.* (Dora).

Two of the teachers (T9 and Olga) are ICT specialists and clearly had more knowledge than they actually use in their teaching. This can probably be said for many of the respondents to the survey as section 4.1.2 showed that teachers generally use a higher number of applications in their out of class work and personal life than with pupils.

In the survey (see Table 5-2) two teachers mentioned their knowledge or skills as an encouraging factor; *'I like working with computers and use the projector to show notes, photos and videos'* and *'My knowledge of the possibilities of ICT and the internet'.*

Subject content knowledge

Indications of teacher subject content knowledge come from all sources of data collection but have no specific measure. The education of teachers gives an indication of what they may know but also their own opinions and views of what they find difficult to teach (see Appendix A, section 13).

Table 5-5 Difficult topics of science

N=66	**Difficult to teach**			**Difficult to learn**	
Physics	24	36%	Physics	30	45%
Chemistry	15	23%	Chemistry	24	36%
Biology	18	27%	Biology	14	21%
Other	14	21%	Other	12	18%
Practical work	5	8%	Practical work	0	0%
Earth sciences	5	8%	Earth sciences	6	9%
Nothing	3	5%	Nothing	1	2%
Lack of resources	2	3%	Invisible things	8	12%
Number of comments	86	130%		95	144%

In order to help choose topics for the intervention teachers were asked what topics they thought they found difficult to teach and pupils found difficult to learn, and which ICT might help with. The question was answered by 66 teachers who mentioned many things and gave broad categories such as just physics. The answers were categorised and presented in table Table 5-5. When asked what they thought pupils found difficult to learn the responses again, were often broad categories but here teachers speculated more about how ICT might help, than in the question about what they thought difficult. The possibility of making visible all the things science is about that are not visible to the naked eye, such as molecules, forces or solar systems was most often mentioned as an affordance.

In Iceland there are two universities that train teachers. Trainees finish with a BEd degree after 3 years[12], which provides a qualifications to teach all subjects to 6-16 year olds. In those three years students have some choice over what subjects they take. Where Table 5-6 says 'teachers with some science' there are teachers that have for example chosen biology as one sixth of these three years, in some cases more, depending on when they did their teacher degree and from what university.

Table 5-6 Education of science teachers

N= 123			
Teachers with some science training	57	46%	57%
Science degree + teaching qualification	7	6%	
Science degree	6	5%	
Teachers without any science training	36	29%	43%
Other degrees	9	7%	
Trainee teachers	2	2%	
Other	6	5%	

Teachers with a BEd degree with some science modules were the largest group (46%). This is a similar proportion from a report on the education of those teaching science in lower secondary schools in 2006 where 40% of 263 teachers had these qualifications (Meyvant Þórólfsson, 2006). The other route usually taken only by those planning to teach in upper secondary schools (students 16-

[12] This will be four years from autumn 2011

20 year old) is to do a science degree and then a teaching qualification (PGCE). In the survey of 123 respondents only 13 had a degree in a science related area and seven of those also had teaching qualifications. One sixth of three years is not much, still those participating in Phase II and III who had that training felt fairly confident in their chosen subjects (chemistry, physics or biology). All but one of them still had to teach all three science subjects and frequently expressed their limitations in other areas: '*I for example did more physics before I graduated, needed more biology and have been studying a lot*' (Ellen) and '*I on the other hand did biology and have after that just been studying myself, physics, astronomy..*' (T16).

Those that had no science in their teacher training also expressed their limitations:

> *I begin by having them make a dictionary, hehe I had to do it myself when I started to teach them, I mean there were so many new concepts that I had never seen so I had to connect with them myself to be able to mediate them to the pupils* (T10).

When asked about what hindered her in using more ICT Anna said:

> *well, it is my own lack of knowledge, I do not lack the will, I would like to do more, but I am for example not a qualified science teacher, I am and Icelandic teacher*

She later stated that it was difficult and that she felt unsecure teaching science.

Pedagogical knowledge

From talking to the teachers it seemed that they had not given it serious thought how to have pupils use ICT as an integral part of their science learning. Only 66% of teachers agreed that they were aware what role ICT should play according to the National Curriculum and 26% were not sure. None of the Phase II teachers mentioned curricular demands for the ICT uses they had tried out.

A statement from the survey; '*I feel confident managing a class using ICT*' that 86% agreed to, could both give indications about technical confidence or pedagogical confidence. Technical confidence meaning that they had enough technical knowledge to help pupils with the software or hardware and pedagogical in that they felt confident monitoring the pupils around the computers. Either way it gives indications that the respondents have confidence with classes working with ICT. Issues with managing pupils and equipment were mentioned though. This included sending pupils to work in different places in the school where the computers might be located, thereby making it more difficult for teachers to monitor their work. Other organisational aspects that hindered the teachers was monitoring the work of big classes (Ellen, class of 28 pupils) or wanting to split the class between computer work and other tasks but not being able to be in two places at a time, nor get assistance (Olga, T13). Despite these issues the feeling is more that teachers are willing and able to teach in different arrangements. This can be seen from the statement '*I only use ICT when students can work individually on a computer*' which only 8% disagreed to, indicating that at least teachers do not believe that they need one computer for every pupil and can organise different arrangements. That could also be seen in the lessons described (see Table 4-1 p. 69), where the most common organisation are group and pair-work and the least is individual work.

The knowledge that teachers thought really hindered them, was not knowing what resources were available to teach science. Thirteen of 111 comments about factors that hinder teachers in using ICT in their teaching were about lacking knowledge (Table 5-1). Seven comments were about general lack of knowledge '*I just do not know*' or more specific as '*I do not know where to look for such things online*'. Teachers also provided other reasons like '*There is little time to look into what possibilities there are and I do not know them'*, or '*my knowledge in these matters is limited, it is mostly Word and PowerPoint, but I am interested in learning more to be able to increase the chances of more varied tasks*'. This was repeated in one way or another by all participants in Phase II. It turned out that for all of them there was at least one way of using ICT in teaching science that they were not aware of. The only exception to this was Ellen who was in her first year of teaching and really interested in ICT, but still regretted not having any experience in using data loggers, though she knew of them. Still it was striking that teachers, even newly qualified teachers (Anna), did not know what data loggers were, ‘*hang on, data loggers, what are those?*’. When asked about virtual experiments/simulations replies like ‘*what is that ?*’, ‘*well I have never heard of this*’ and ‘*I did not even know such thing existed*’ were common and as was said before that 23% were not aware of them. Tara pointed out that teacher guides with Icelandic science textbooks do not give much guidance on how to use ICT in teaching.

On the other end it seemed to encourage Ellen in her attempts to integrate ICT into her teaching as she knew from her teacher training about the positive affordances and effects from using ICT.

The factors affecting teachers as they appear in Icelandic context are discussed and combined into an amended model in section 7.2.

5.2. Illustrative cases

Four of the five teachers in the intervention group participated in all phases of the study and in two of the three micro interventions so the data collected on them is rich and varied. The data includes their responses to the survey, numerous interviews, observations and informal conversations from a whole school year. This gives the study a longitudinal aspect with a considerable amount of data (see Table 3-4 Participation in Phase II and III.). The intention had been to use the phase II interviews to complement the findings from the survey but the individual cases proved to give interesting stories as the study progressed.

The purpose of this section is to illustrate how the factors and issues outlined in section 5.1 manifest themselves in individual cases in context. Some of these factors are common to all of the teachers but are still nested in different ways, in each case in a complex interplay of factors from their background and current situation in both personal and professional lives. The issues from each teacher that stands out are highlighted, taking into account that what affects human decisions and actions is always a combination of a plethora of dynamic aspects.

The stories of these teachers are presented and analysed as cases seen through the perspective of cultural historical activity theory. References are made to the survey data where appropriate. The next sections see a brief introduction of the analytical framework applied and then the cases are presented.

5.2.1. Analytical framework: activity theory

I became aware of Cultural Historical Activity Theory (CHAT) late in the data analysis process trying to make sense of what it is that affects teachers in learning to use and implement new technologies. That is why the theory and how it used is introduces so far into this thesis.

The genesis of activity theory may be traced back to the beginning of 20th century to cultural psychologists in Russia and Marxist ideas. The most prominent of these psychologists, Lev Vygotsky introduced the notion of unit of analysis and psychological tools along with their role in human activity. Aleksey Leontiev summarized ideas around activity into framework of activity theory that grew out of their studies of the development of the mind (Kaptelinin and Nardi, 2006). Many schools of activity theory have emerged comprising many concepts and main ideas. Among them ideas about the hierarchical structure of an activity, the object orientedness and the social nature of the human mind. Following is a brief introduction of the concepts and ideas that were used in this thesis. The approach influencing this thesis is the one developed by Engeström (Engeström, 1987; Engeström, 2001)though not all aspects such as learning phases are represented.

CHAT has the promise (Watson, 2006; Engeström, 2001) to be a useful tool when considering something as complex as the implementation of new technology into teaching. CHAT has been used to investigate changes in institutions and how work develops through the use of new tools. The basic unit of activity theory is the interplay between subject and object mediated by tools. The theory also takes into consideration the social situations that activities take place in, the rules within the situation, the society, and the division of labour. All the features of the system affect each other as seen in

Figure 5-1 which shows that all the elements of an activity system are interlinked (Engeström, 1987, p. 78).

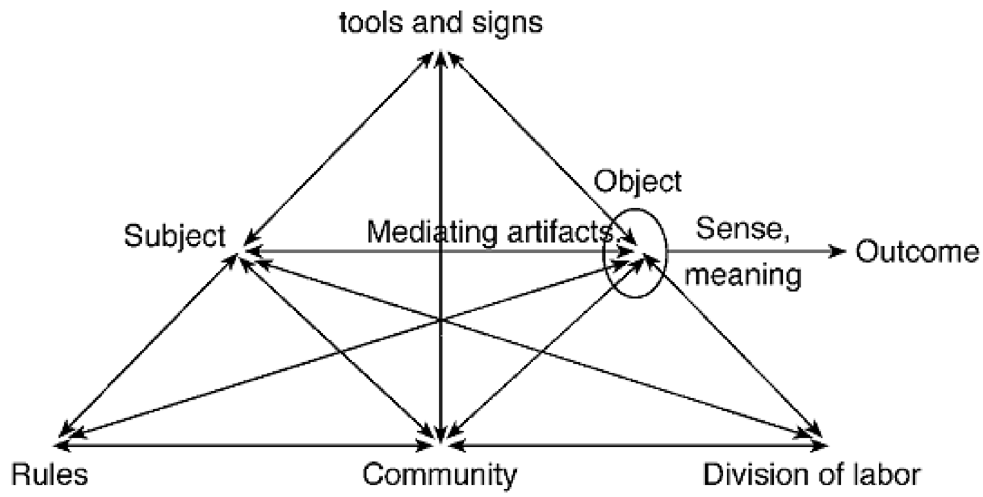

Figure 5-1 General model of an activity system (Engeström, 2001)

The theory includes the five principles of activity theory (Engeström, 2001) which are recounted below along with how activity theory can help with analysing aspects of this study.

The first principle is that 'a collective, artefact mediated and object oriented activity system seen in its network relations to other activity systems, is taken as the prime unit of analysis' (Engeström, 2001, p. 136). Individual or group actions can also be seen as the unit of analysis but only understood in relation to the activity system as a whole. This principle guides the analysis of the teacher profiles in the next section where teaching science mediated by ICT is the activity within the social structure of the schools where it takes place.

The second principle is about multi-voicedness of activity systems (Engeström, 2001), that in communities there are many points of views created by the division of labour, different histories and multiple layers visible through artefacts, rules and traditions. This multi-voicedness 'is a source of trouble and a source of innovation, demanding actions of translation and negotiation.' (Engeström, 2001 p. 137). When looking at innovations such as the integration of ICT in schools there are certainly many points of views to consider. This principle drew attention to factors affecting the teachers in this study which otherwise might have been overlooked or interpreted differently. All these voices surface in the presentation of the cases.

The third principle, that of historicity, to understand problems and potentials of an activity system and its history is a reminder in this study that the implementation of ICT into science teaching is just one aspect in the long process of school evolution. This aspect needs to be considered as is done in the introduction of this study.

Contradictions can drive change and development in practice such as schools. 'Contradictions are not the same as problems or conflicts.' (Engeström, 2001 p.137), but something that causes disturbances to the activity and does not quite work.

> When an activity system adopts a new element from the outside (for example, a new technology or a new object), it often leads to an aggravated secondary contradiction where some old element..... collides with the new one.(Engeström, 2001 p. 137).

Dealing with the contradictions may lead to innovative solutions and development of activity.

The fifth principle is about expansive transformations, that activity systems gradually overcome contradictions towards expansive transformations. They move through the zone of proximal development of an activity, redefining the object and the purpose of the activity, learning how to work in new and improved ways (if not they become stagnant). Contradictions can occur at different situations outlined in Table 5-7 Overview of contradictions.

Table 5-7 Overview of contradictions

Contradiction	Initiated by	Locus	Main characteristics
Primary contradictions	Participants question the practice of the activity	Need state – a need for change within an element of an activity system	Ideal/real practice
Secondary contradictions	Outside changes cause disturbances	Between elements of an activity system	A change in one element can lead to secondary contradictions
Tertiary contradictions	New forms of practice tried out, some participants resist change	Between new and old forms of practice	Appropriation of new forms of practice. New forms begin as deviation from the norm
Quaternary contradictions	Changes in one activity system can create disturbances in a neighbouring activity	Between activity systems	Need for collaboration to co-configure activities.

Based on (Engeström, 2001; Jóhannsdóttir, 2009)

These same contradictions are presented in the expansive learning cycle (see Figure 5-2). The expansive learning cycle show changes in an activity starts with a need state, where participants in some way question the current practice. The learning then goes through trying out and modelling new solutions, meeting contradictions on the way to consolidating new practice both from elements within the system and from neighbouring systems. The cycle may halt at any time when the contradictions become too much or go on to a new need state.

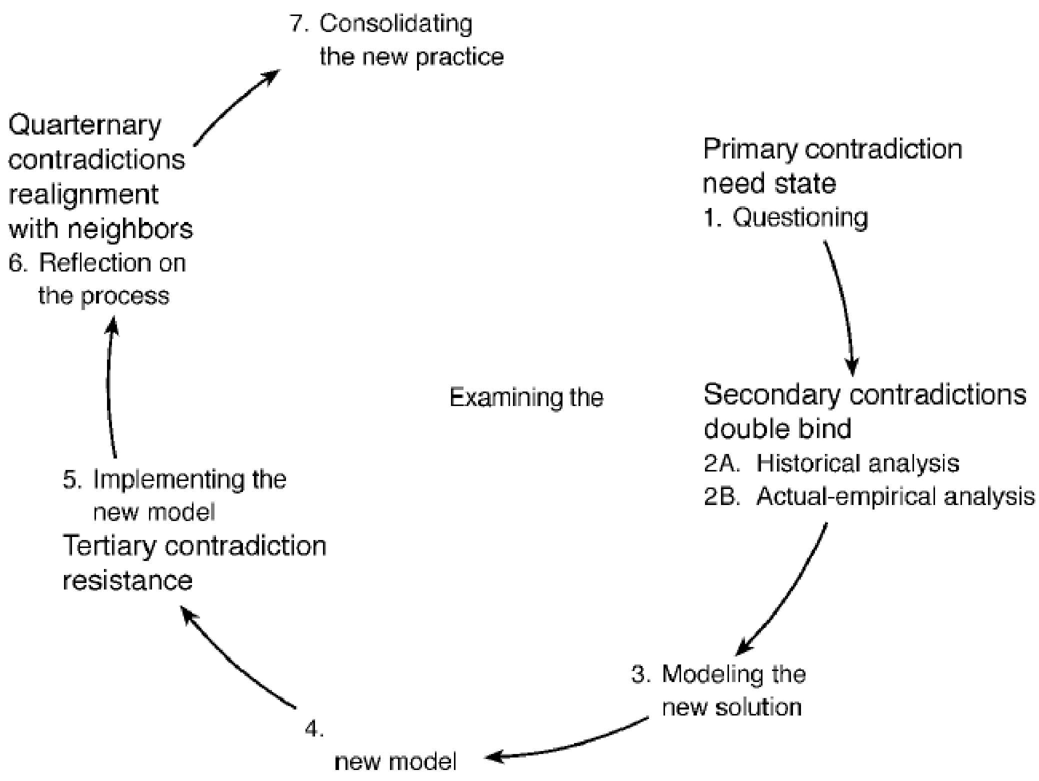

Figure 5-2 The expansive learning cycle
Strategic learning actions and corresponding contradictions in the cycle of expansive learning (from Engeström, 2001).

Activity theory in research on education and ICT

CHAT has been used to analyse situations where technology and teaching come together (see eg. De Lange and Lund, 2008; Lim and Chai, 2004; Bracewell et al., 2007; Stevenson, 2008).

How activity theory is used in this study

In this thesis activity theory is not considered to be a methodology, but rather as a framework for exploring the complex interaction between the individual teacher, the tools in question and the systemic characteristics of schools. As Kuutti (1995) puts it 'a philosophical framework for studying different forms of human praxis as developmental processes, both individual and social levels interlinked at the same time' (p.23).

The contradiction analysis is helpful both in locating what it is that hinders teachers in technology implementation and investigating how these teachers have handled the 'new' tool that is ICT to teach science. For each case at least one area of difficulty, disturbance or problem is identified by applying the framework of activity theory and the expansive learning cycle. In section 5.2.3 - 5.2.6 the situation of each teacher profile is described through the elements of the activity system, mapping the contradictions each case faces and where in the expansive learning cycle each teacher and the schools where they teach are at the time of data collection. Each case is described briefly, outlining what factors the teachers say it is that either hinder or facilitate their use of ICT in teaching science. In that sense analysis through activity theory acts more as a framework of reference helping to identify and articulate the conditions that affect each teacher. When revisiting three of their previous studies, Issroff and Scanlon (2001) did not find activity theory useful in providing new insights. They did however find it but useful to present results to others and in providing the language and a framework to understand their topic of active learning. The intention by applying the framework of activity theory here is precisely that to provide the language and a framework to further understand the forces at work. Furthermore, contrary to Issroff's and Scanlon's experience, the analysis has provided insights by drawing out more latent factors than first met the eye.

The unit of analysis in this section is the teacher in the action of teaching of teaching science to pupils, preferably using ICT as the curriculum dictates within the school activity of educating pupils. The subject is the teacher who has the object of teaching science to the pupils, whereby the pupils are the object or actually the task of educating pupils where their education or knowledge the desired outcome. The community consists of a number of actors including other staff in the school, parents and other stakeholders (anyone who has an invested interest in the activity). Many written and tacit rules apply in this system. The written rules are laws on education, the curriculum guides, policies of the councils that run the schools and the timetables. The tacit rules are the traditional customs and conventions of classrooms. Activities can be mediated by the community or the rules just as well as tools. The next section presents factors or contradictions that affect all teachers. Thereafter each case is outlined and a diagram is included showing the contradictions that seem to be at work.

5.2.2. Conditions that apply to all the cases

Some of the contradictions that the cases face are common to them all and are the same factors that act as barriers to technology integration as seen in section 5.1. These contradictions or barriers (see Figure 5-3) are listed next with the letters A- E, as found in Figures 5-3 through 5-7. These contradictions are described first instead of repeating them for all cases, but they are further outlined where appropriate how they appear in each case.

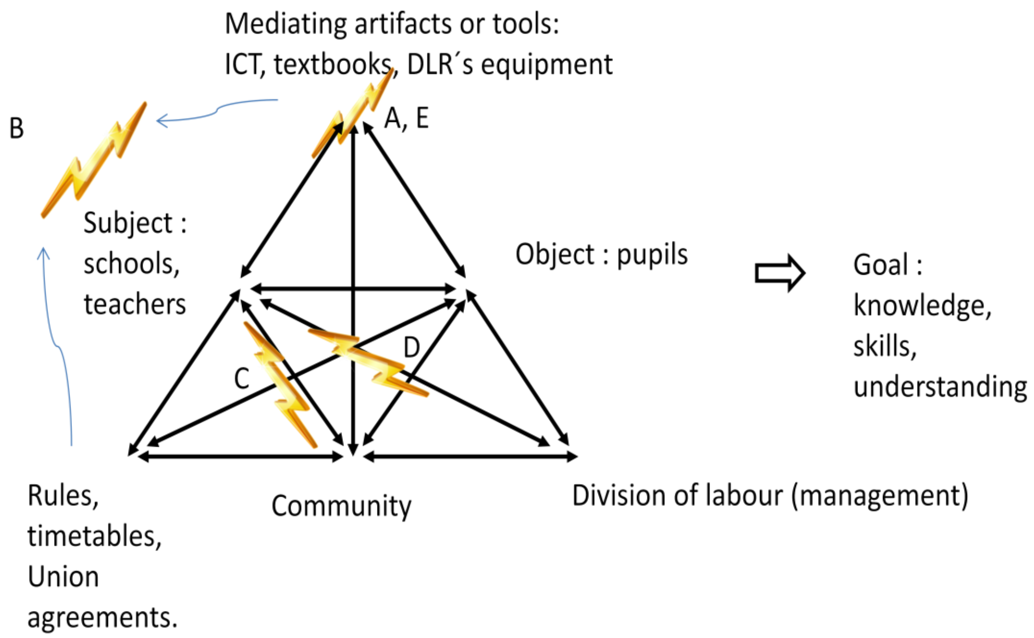

Figure 5-3 Contradictions all teachers face

A. Primary contradiction within the tool

ICT not only has the potential of bringing to pupils new and useful information but also a range of distractions especially on devices with an internet connection. Some teachers in this study complained that pupils got distracted and wanted more to play games or go on *Facebook*. This is a contradiction between the use value, the educational potential and the exchange value so there is also potential for the set learning goals to be interrupted by the tool but not in exchange for possible use value. This can lead to disruptions in the system, manifesting themselves in secondary contradictions, with a need to evaluate and adapt this tool to practice or the practice to the tool. That is when using computers teachers need to change their practice and learn new skills to reap the benefits of their use.

B. Secondary contradiction – tools and rules

The first contradiction that schools stand against is that ICT often disrupts the classical set up of one teacher talking and one class sitting quietly and listening in a classroom. Firstly, pupils in some cases will have to move to other rooms, sometimes work in groups and then even manage the pace of their work themselves. This requires that the rules about how to manage a class around the technology need to be adapted to fit the tool. This problem is related to teacher knowledge in the sense that they need new or adapted pedagogical knowledge to work with the tool.

C. Secondary contradictions between the subject and the community

Access to equipment: This is a secondary contradiction between elements of the activity system. The elements are the subject (teacher) and the community (teachers and headteachers in this case) mediated by the rules (timetables, booking systems) about how access to the clusters is distributed and who gets to use them. The input of new tools into an activity system often requires the rules to be changed. Schools do not seem to have accommodated for the technology by changing the structure of timetables, nor allowed for adequate access. There is also a mismatch in the way ICT is supposed to be used according to policy papers and the National Curriculum on the one hand and the provision of equipment on the other hand.

D. Secondary contradictions between subject and management.

Lack of support: Stevenson (2008) calls the division of labour element ‘management’ in a pedagogical context. A barrier or tension that was observed with all the cases, though they did not articulate it themselves in so many words, is that they all lack the support of a community in using ICT in their teaching. I choose to put this down as a secondary contradiction between what is expected of teachers (the subject) in the curriculum (which act as outside rules) and the conditions in which they carry out these expectations. Organising these conditions is a role of management. In this instance the headteachers that organise the timetables and decide who is going to teach what, which also includes if a teacher is teaching the subject alone or part of a team. This is mediated by the rules, the school organisation and Union agreements that map out the working environment, allocating time for preparation and teaching hours. However time to find resources, learn and prepare was one of major barriers mentioned in the survey (see section 5.1.5).

Rules for outcome guarantee are missing in this system, though none of the teachers articulated it. There is limited inspection or follow up to see if the curriculum or policy is being followed in anyway. An incentive to change practice does not come through that channel but rather through teachers' own initiative. In that way the teachers have little motive to change the activity as their true motive is to educate pupils which has usually worked with the traditional tools.

E. Lack of knowledge - instrumentality

All the cases to some extent face the problem that using is ICT a relatively new practice and their TPCK is limited. In some cases the knowledge lacking is knowing what resources are available and often how to use generic and specific software in teaching. TPCK has a resonance with the concept of instrumentality:

> The notion of an instrumentality refers to the entire toolkit used in an activity, understood as a multi-layered constellation, which includes both material and conceptual elements (Engeström and Toiviainen, 2011, p. 35).

Here the knowledge of ICT and associated pedagogy can be conceived as conceptual elements which need to be developed further. This is a problem in that teachers know they could or should be using the tool, but lack the knowledge to really utilize it to find a solution. There is a mismatch between the actual practice and the ideal type of practice.

Another facet is that the management provides professional development opportunities. Here there is also a mismatch between written expectations and the CPD on offer. The tool making activity that needs to take place in the sense of developing teaching methods to fit the equipment is not being supported.

For the individual cases only the labels (A, B, C, D and E) are included in the diagrams to refer back to this section. Table 5-8 provides an overview of the factors affecting the cases presented. The deterring factors for each case were decided either if the teacher herself talked of them as hindering her ICT use in any way or if these factors were observed as hindering either their execution or organisation of the observed lessons.

Table 5-8 Cases profiles - deterring factors

	In this table the question is 'Do these factors seem to be deterring this teacher?'			Shaded cell indicates deterring factor
Factor/Teacher	**Anna**	**Ellen**	**Eva**	**Olga**
Experience teaching	Been teaching for 6-10 years, always mixed subjects, some science.	Less than 5 years of teaching,.	Has over 10 years teaching experience but less teaching science	Over 16 years of teaching experience, mixed subjects but mostly ICT. Second year of science teaching
Training	Yes, only some optional courses in teacher training. No ICT CPD.	Did sciences in her teaching training, some ICT within that training.	Yes, only did biology in her teacher training. No ICT CPD.	Did science in her teaching training. Some CPD, ICT skills.
Equipment/ resources	Limited resources, mobile OHP, limited access to clusters, faulty booking system.	Fixed OHP, laptop trolley, cluster.	Mobile OHP, two clusters. Felt restrained by booking system, and access to computers.	An IWB in classroom, computer cluster, and two smaller areas, restricted access.
Contextual factors	Teaches Icelandic as well, that takes time energy and precedence over science.	Large class was what she believed was deterring her, did affect the quality of the lessons.	Has young children, did not give herself much time to go the extra mile.	None, or maybe that she is only starting to teach science but has really good ICT skills.
Attitudes + ICT use from survey	Positive, very low classroom use (2), very low personal use (2).	Positive, low classroom use (4), very low personal use (3).	Positive, very low classroom use (2), very low personal use (3).	Positive, low classroom use (5), high personal use (16).
Experience ICT	Had used two CD ROMs, and pupils done essays using online searches and word-processing.	Had tried a variety of websites and online simulations, uses laptops frequently for classroom work, essays and online searches.	Used some websites and essays.	Taught ICT skills, but only once had pupils do presentations in science.

Peer/professional support and cooperation	Yes, co-worker is a novice she mentioned this once, they work together but more in the sense that she mentors her co-worker.	Yes, no cooperation with co-workers. But she did not mention it.	Yes, no cooperation with co-workers. Talked about it bothering her.	No, did not talk about it during the intervention, has a co-worker
Technical support	None mentioned, nor ticked in survey, would benefit from technical help	None mentioned, on survey ticked 'Support in setting up computer equipment'.	Talked about having fairly good access to technician.	Felt the technical assistance got in the way, that is was slow and bureaucratic. Policy within council to block websites also hindered.
Time issues	Yes, other subjects compete for time.	Did not mention them.	Yes, lacks time to learn.	Yes, lacks time to learn.
ICT Technical knowledge	Yes, lacked knowledge, claimed confidence, but had problems with simple things	No, worked confidently with all equipment and software	No, worked confidently with all equipment and software	No, worked confidently with all equipment and software
Content knowledge	Appears weak.	Appeared rather strong.	Biology good, but frequently states that her chemistry and physics were no good. Appeared patchy.	Appeared patchy, used poor examples in explanations and f got sidetracked instead of focusing on main ideas and concepts.
Pedagogical knowledge and skills	Observed disorganisation, especially in computer room.	No, good skills.	No, good skills.	Yes, losing control of class, maybe more to do with, risk taking. Integration to science.
Knowledge of resources	Yes, had little knowledge of affordances, still more than she thought.	No, knew of affordances and availability.	Yes, had little knowledge of affordances and availability.	Yes, had an idea of affordances but not availability.
Management support	None of them were bothered with it, all said their headteachers were supportive but no signs of active support.			Management used computer room for substitution even though she had booked it.

5.2.3. Olga

Olga did science and geography in teacher training but has mostly taught ICT. This was her first year teaching science full time. She had a computer and an IWB in her classroom and which she used to show videos, presentations and project from a digital microscope. Pupils had only once worked on posters using information off the internet. Her responses to the questionnaire showed that even though she knew every application and used them in her private life and other jobs than teaching in school, pupils rarely got to use ICT. When asked about this discrepancy she said:

> *Well one does not know why that is, I guess it is because you do not quite trust the kids, or….. to put it differently, I probably do not trust myself to get started, am too afraid to lose control, …….. that everything will go wrong, I have just recently began to teach science* (Type B)

Later after talking about the lack of a science lab and access to computers (Type C) she says:

> *The main obstacle is really just me, one is just not flexible enough in just letting go, just try it, like I did in that project, then I let go a little bit and sent them to the cluster, there were problems, disciplinary, and of course some of them were just playing games instead of working, but it worked fine, most of the groups finished with a decent product, so I think I will do it again* (Type A).

When asked about online simulations she again says *'I freely admit that I am not efficient enough in [taking the time to find out what is available] …… it is just there are too many distractions/tasks'* (Type D).

Her subject knowledge seems to be patchy and she easily goes off on a tangent when talking to pupils. There were silences when she was reading from the book to get information. Working with pupils on an ecosystem simulation in a cluster was easy for her. She came well prepared and introduced the lesson in the classroom on the IWB before going to the computer room. In the computer room, the focus of the lesson soon shifted from the science concepts to the scores the simulation gives for finding a balance in the system.

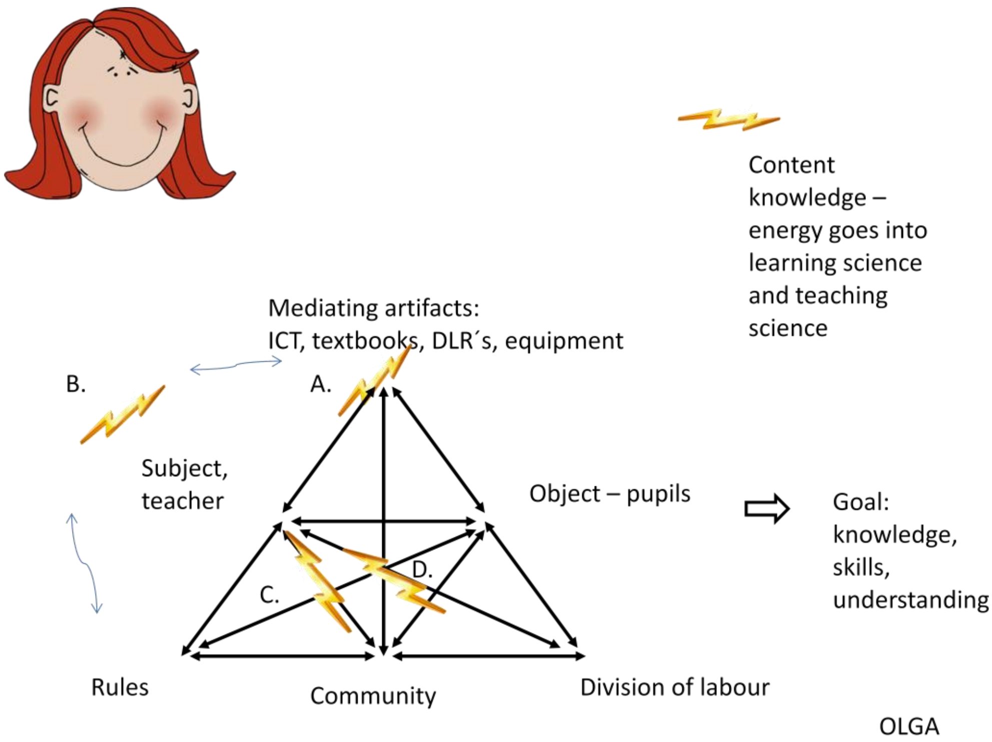

Figure 5-4 Olga Type A, B, C and D

Even though Olga's ICT competence is good, having taught that for many years she still has to appropriate it as a tool for teaching science. She had issues with control or classroom management where ICT does not fit with her current mode of practice or where she did not know how to apply it in teaching science. To expand her learning she needs to adapt her practice to the tool or the tool to the practice. Olga's position has changed from being a teacher of ICT to teaching science and her science knowledge appeared to be patchy. She had not mastered the activity to be able to teach in an engaging way (many pupils lay their heads on the desks in her lessons in the classroom in spite of her attempts to make the subject interesting). She used the usual mediating artefacts, the textbook, putting her energy into mastering them first and brushing up on her science content knowledge before tackling integrating ICT tools into teaching science. She in her practice is just starting the learning cycle in terms of implementing ICT into their science teaching. There were indications that she was questioning her practice and bumping into walls in her initial endeavours of using ICT in teaching.

5.2.4. Anna

Anna did science and Icelandic in her teacher training. She has taught some science but teaching Icelandic seems to be closer to her interest. She sometimes had a mobile projector in the classroom. The school has a cluster and a few computers in the library. Her use of ICT was of the typical kind; using a projector to show videos and photos from the web and having pupils research and write essays.

She like Olga was just starting the learning cycle, wanting to use more technology in teaching but finding many barriers in her path. She discussed at length about how bad the computers were and claimed her main hindrances were not enough access to equipment (Type C). Her technical skills were rather poor, though she did not believe that to be a hindrance. Her subject knowledge seems good (in genetics) but she herself claims not to be a science teacher.

> *It is my lack of knowledge, that is no less a barrier, I do not lack the will, I would definitely want, and do more, but I am for example not a qualified science teacher, I am a Icelandic teacher* (Type D and E).

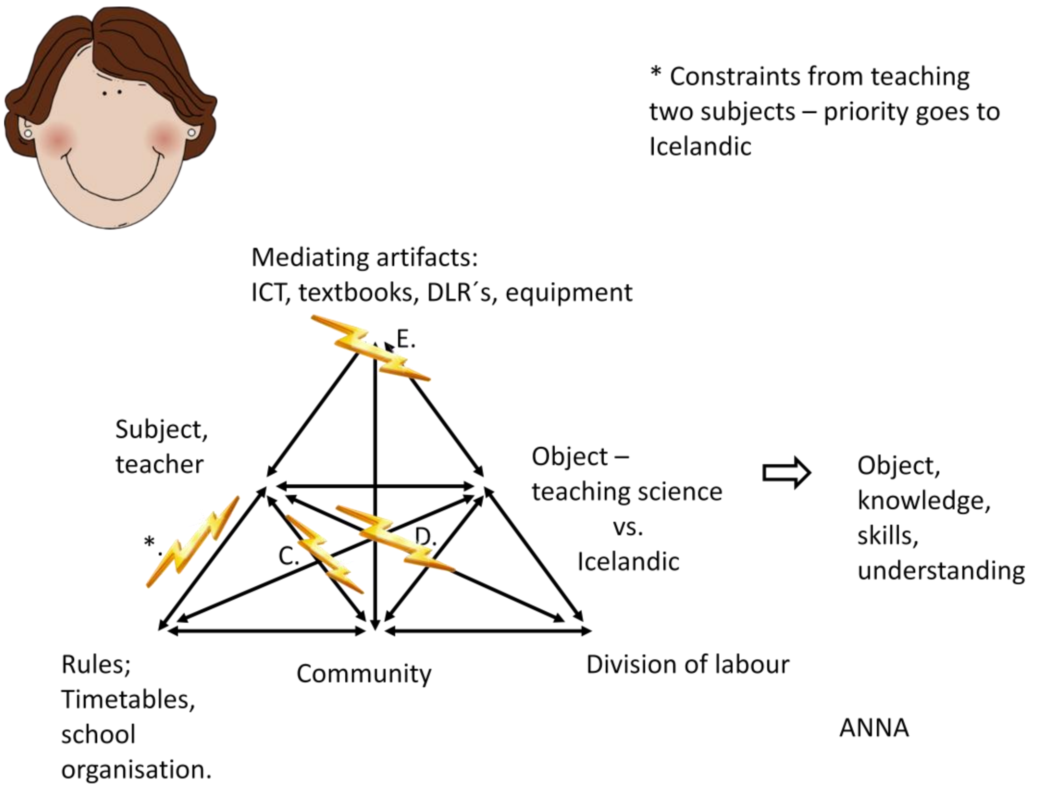

Figure 5-5 Anna Type C, D, E and constraints from teaching two subjects

Her classroom management was good but some insecurity was noticed when working with computers.

In this case there is tension created by the fact that Anna is teaching two school subjects (science and Icelandic). This secondary contradiction is between the subject and the rules mediated by division of labour (1).

Anna is a teacher who wants to do well in her job and is open to new things that improve her teaching. It became more apparent through working with her that in spite of her proclaimed reasons for not trying out more ICT, these were not the main reasons. She teaches both Icelandic and science; more than half of her lessons are Icelandic. During the intervention she frequently arrived poorly prepared to the lessons and claimed not to have had time to properly go through the websites or properly plan the lesson.

> *No, I have just not found the time, as you see here I just received 60 essays and the Icelandic teaching swallows the time a bit, it is so difficult to teach both science and Icelandic, it is so much work*'.

Teaching is a demanding job and teachers often have to prioritise the tasks at hand. I am not aware of any research on how Icelandic teachers regard different subjects, but traditionally Icelandic and mathematics have been considered the most important. The Icelandic language is highly regarded and Icelanders put an effort preserving it (Holmarsdottir, 2001). It seems that when teachers have to choose where to put their efforts Icelandic comes first.

5.2.5. Ellen

Ellen is young and in her second year of teaching. She did science in her teaching training. She has a ceiling mounted projector in her classroom which she uses a lot, displaying PowerPoint presentations, websites and videos. The school also has a large cluster. She has a laptop trolley in her classroom, supposedly for all teachers to use but she said she had it pretty much to herself. This trolley was in the room in six of the seven occasions that her lessons were observed.

She has a positive attitude towards ICT and had used a variety of ICT with pupils. Her only challenge seemed to be that she teaches in a really small classroom and the class that took part in the intervention had 27 pupils. This is a lot by Icelandic standards where classes tend to have around 20-22 pupils. Her voice is also quite weak and she really had to work at having all the pupils pay attention. However it was quite clear that her classroom management skills were improving rapidly. Though she is also a young mother, like Eva, it did not seem to affect her work. She set time limits to our meetings if she had to leave to pick up her child from school and was always very well prepared.

Her technology skills are very good. She uses all equipment without any hesitation and used different ways of engaging pupils. By her own evaluation she has a good grasp of the content which is supported by the observations.

In Ellen's case, no primary or secondary contradictions seem apparent. She is very determined to do well in her teaching and considers ICT useful. She twice mentioned having read positive research reports to that end and also referred to her own experience. However she believed that she did not know enough about the availability of resources and how ICT could be used in science teaching (Type E) and she found it difficult to book time for cluster use (Type C).

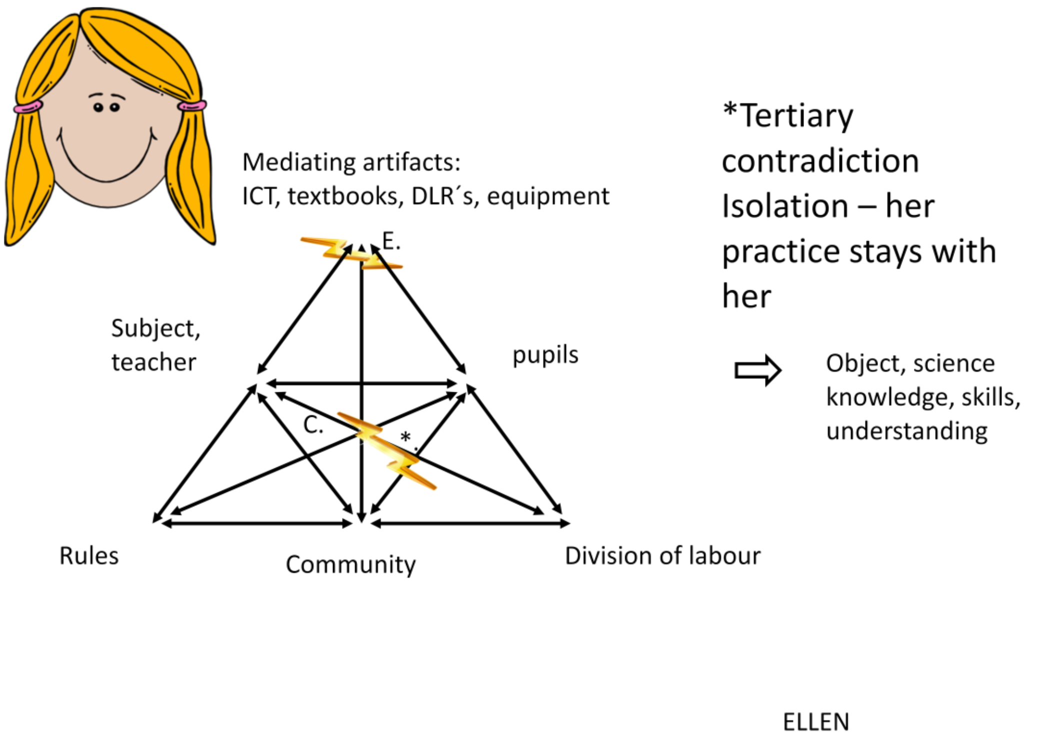

Figure 5-6 Ellen Type C, E and isolation in practice.

Ellen is isolated in her practice and there is little chance of her ways of working to become the general norm within the institution. The other science teacher in the school usually teaches one year group and there was no cooperation between the science teachers in the school. This is a tertiary contradiction when some participants resist change to new forms of practice. Actually, there is nothing for other teachers to resist as no effort is being made to change their practice and they do not function as a learning community. It still means though that the cycle of expansive learning that Ellen is in comes to a halt here with Ellen as a pioneer taking advantage of the technology with the others unaware of the knowledge being accumulated. The learning and habits that Ellen has formed will most likely leave the school with her and so it is really not 'expansive learning'.

5.2.6. Eva

Eva did general biology in her teacher training. She has taught for 10 years, mostly 10–12 year olds but is now teaching science. She had had no training in using ICT in teaching. This is reflected in her knowledge. Her subject knowledge is weak but her teaching skills and classroom management are strong. As an example of this she could explain well the mechanics of balancing a chemical equation, but did not put the equations into a relevant context for the pupils by naming the elements and explaining the reactions they were balancing. She was teaching chemistry for the second time and did some of the practical exercises from the textbook. Nevertheless she did not use them as an opportunity to connect them to the equations.

Before the intervention she had tried out some ICT work with her pupils. They had done presentations, used a sex education website and 'googling' spontaneously for information with pupils. Her attitude towards ICT use is positive and she wants to try out more things: *'I want to try if this medium will not reach them better, because they understand this medium so well'.* The reasons she gave for not using ICT more were time issues:

> *Well there is just….. too much to do I just haven't had the time to explore this medium, I haven't the time somehow to sit down and get*

> *to it, especially as I am teaching all the science for the first time* (Type D).

When working with her it was repeatedly observed that she left the school early to pick up children from day-care. A deterring factor was that she also talked about a lack of awareness of available learning resources or relevant websites (Type E).

She has a standalone digital projector in her classroom and had problems getting an image in two observed lessons in the classroom. These problems did not demoralise her in anyway, she chatted with the pupils and asked for their advice and it all went very smoothly. Working in the computer clusters was easy for her. It helped that the pupils are used to going to the clusters and there were no problems with logging on, nor other technical difficulties.

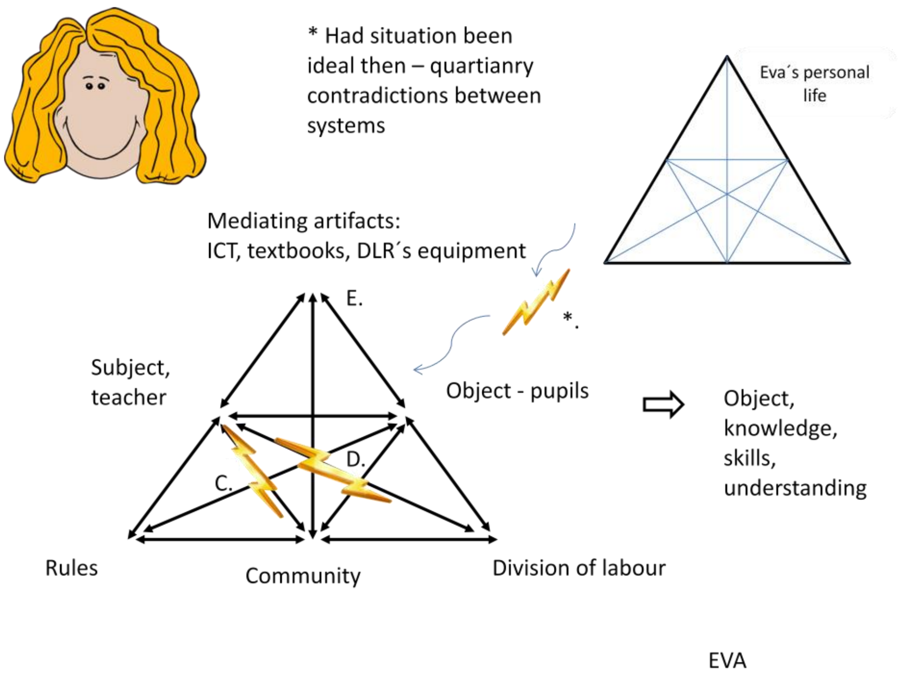

Figure 5-7 Eva, Type C, D, E and contradictions between professional role and personal life

Eva frequently mentioned difficulties of getting time in the computer cluster (Type C). On two separate occasions she talked about having to 'fight' with teachers of other subjects to get time and having put concrete suggestions to her headteacher about distributing access to the clusters more equally between teachers and subjects. From this is seems that she had started the learning cycle in terms of using ICT in her teaching and was facing secondary contradictions.

The problem that stood out when working with Eva was that she was obviously torn between two roles. There is tension between the central activity (teaching) and its interacting neighbouring activity system (home). The tension is between her roles as a young mother and a science teacher with little experience, the time needed to do something extra, and the time demands of being a young mother. This tension could be called a quaternary contradiction (Engeström, 2001) in the sense that they are between two activity systems, the school and the home where Eva is the subject in both of them. Strictly speaking, it is incorrect to talk about quaternary contradictions when the subject is in reality facing primary and secondary contradictions but this is a real problem nonetheless. This problem manifest itself in the fact that even though Eva is willing and able in a sense to experiment more with ICT in her teaching, the time needed to find and familiarise herself with new teaching materials is limited because of her role as a mother of young children.

5.3. Summary

A qualitative exploration including four cases saw teachers recite a number of factors affecting their technology use; the most prominent ones are access to technology and teacher knowledge. Other factors also prevalent are lack of training, a weak support system and policy. On the more positive side there are technically competent teachers with positive attitudes towards ICT in science teaching. Teachers are aware of their limited knowledge of the possibilities, their feelings can be summarised as feelings of frustration. Some of them have a weak science background and their energies are aimed at coping with teaching the content and managing practical work so there is little time or energy left to familiarise themselves with innovative teaching methods such as ICT.

6. Interventions

This chapter presents the findings from the three interventions. The data includes test results, attitudes of teachers and pupils plus a description of the characteristics of successful teachers and their lessons in the intervention. These are contrasted against the less successful. The chapter is in three sections, one for each intervention.

For all the tests a score was calculated on a scale from 0-10 as was explained in section 3.5.3. (p. 54). For each intervention results for the treatment conditions are presented and for the separate classes. A large variance is found among the classes in all the interventions. This is to be expected in a quasi-experiment. In subsequent analyses the classes are combined into conditions to look for general tendencies that may occur despite the variation between the classes. Table 6-1 recaps the classroom activities during the interventions.

Table 6-1 Classroom activities during intervention

	Intervention classes	**Comparison classes**
Textbook, lecturing, exercises, note taking	Yes	Yes
Digital learning resources with worksheets	Yes	No
Pre- and post-tests	Yes	Yes

The sections have tables with pupil views from a questionnaire with open questions on the resources used. The numbers are from the pupils that actually used the websites and gave an opinion. Examples are given of what pupils said about these resources both in the post-questionnaire and in group interviews.

6.1. Genetics

Five teachers teaching seven classes (see Table 3-5 p. 46) participated in the genetics intervention that involved reading from a website and answering questions from a worksheet for at least two lessons. The experimental classes, with one exception, also spent one lesson manipulating bugs in a simulation.

The website *Erfðavísir* covers more material than is in the curriculum so the worksheets were designed to lead pupils to the relevant sections and leave out the advanced ones. The intervention teachers were told to try to let the website replace the textbook as much as possible. Four classes used *Erfðavísir* and were all observed while doing so. The teachers were Eva, Anna and Olga and the comparison teachers were Tara and Tina.

6.1.1. Observed lessons

Anna took her class twice to the computer room to read through this resource. The second time around she also used the worksheet. Pupils either worked on their own or in pairs. All except three pupils worked well, (one checked *Facebook* regularly and two at the back doing various things). Most pupils managed to finish the worksheet and the teacher collected these with the intention of marking them. The intention In the next visit was to try *Bug Lab* but the computer room was busy. The third time she had reconsidered using *Bug Lab* and decided against it, saying she had not really looked at it and that it seemed to be complicated. Instead the class was to work on interactive quizzes. This time she had not booked the computer room expecting it to be vacant but another class was working there. Some computers could be used though. The rest of the class used computers in the library and worked on the quizzes in really large groups so only some pupils were actually active. The lessons observed in the classroom included lecturing, reviewing homework and worksheets accompanying the textbook. Pupils seemed moderately engaged with the tasks at hand. Anna had not prepared pupils for what they were supposed to do in the computer rooms and considerable time went into guiding pupils to start the tasks.

Eva used *Erfðavísir* twice. Where the second lesson was observed, considerable off task behaviour occurred, but no more than in a classroom lesson previously observed. In the beginning of the intervention Eva said she was going to try to replace the textbook completely but soon said she would use it and in the end she ended up relying on it. When asked if she would use the website again she said:

> *Yes in combination with the book, to connect them to the fact that this (the webpage) is something that matters, it is like they always need to have a book that tells them that it matters, but of course I could give them an outline to begin with, saying, we are going to learn genetics and you have to learn, this, this and that, this will be on the test*.

Her rationale was also that the pupils did not read the webpage well enough but only looked for the answers. However this happens with books as well, indeed the lesson had all the same characteristics of pupils answering questions from a book (they browse for the answers, ask each other and the teacher 'where can I find the answer to this question?') Eva also mentioned that the pupils did not take the website seriously enough.

Eva used *Bug Lab* in one lesson with pupils working in pairs. A good amount of chatter could be heard but this was related to what they were doing.

Both Olga's classes were observed using *Bug Lab* and *Erfðavísir. T*here was a marked difference in pupil activity where they paid little attention to lectures and discussions in the classroom with lots of off task behaviour, but worked very well the whole time on *Erfðavísir.* Pupils were again disengaged back in the classroom where the teacher reviewed the answers, expecting them to correct them if needed. In another period working with *Bug Lab*, pupils could be heard having fun and using genetic concepts when working together. Olga in both cases had prepared pupils for what they were supposed to do in the computer room, showing them both the DLRs and worksheets on the interactive white board.

Tina is a very efficient teacher and she used worksheets with questions developed over some years alongside the textbook that all the teachers used. Her lessons were very well prepared, organised and productive. Her grasp of the subject was excellent and the way she explained phenomena and gave realistic examples was highly effective. There was some note taking, practical exercises and answering questions both from the textbook and worksheets from the teacher, along with some extra exercises on *Punnett* squares.

Tara however used only the textbook. The lessons were relaxed with some lecturing, sometimes a bit chaotic, no note taking and then working on questions from the textbook. Her grasp of the subject was good but examples were few and poor. Pupils did not pay much attention to what was going on.

All groups were observed in the classrooms working without computers. In those lessons teaching was very traditional; a mixture of lecturing and note taking, discussions, written questions from the textbook and exercises with *Punnett* squares and family trees.

6.1.2. Genetics test scores

A mean score for each class is calculated. Scores are given for the intervention classes and comparison classes separately on the scale 0-10. The test scores show that the comparison group showed better gain, scoring lower on the pre-test and then passing the intervention group and scoring higher on the post-test (Table 6-2, Figure 6-1).

Table 6-2 Genetics test results

Class	N	Pre-test			Post-test		
		Mean	SD	Group	Mean	SD	Group
INT 110	18	4.97	1.31		5.47	1.32	
INT 210	22	3.01	1.36	M= 4.16	5.99	1.08	M=5.49
INT 410	13	4.58	1.03	SD=1.45	5.05	1.04	SD=1.17
INT 411	15	4.52	1.03		5.17	1.06	
Comp 710	22	4.19	1.51	M=3.87	5.22	0.84	M=6.20
Comp 810	15	3.93	1.37	SD=1.44	6.59	1.81	SD=1.77
Comp 811	17	3.41	1.38		7.11	2.05	
Total	122	4.03	1.45		5.80	1.50	
		Cohen's d = 0.20			Cohen's d = -0.48		

INT: intervention class; Comp: comparison class

Pre – test scores

On the pre-test the mean scores ranged from 3.01 to 4.97 with a total mean of 4.03. Two comparison classes and one intervention class scored under the total mean. A one-way ANOVA was used to test for score differences among the seven participating classes. The test scores differed significantly across the classes, *F* (6, 115) = 5.12, *p* = .000. A Games-Howell post-hoc comparisons of the classes however indicates that INT210 (*M* = 3.01) differed significantly from the other three intervention classes (*M*= 4.97; 4.58; 4.52) and Comp811 (*M* = 3.41). Comp811 also differed significantly from INT110 (*M* = 4.97, 95% CI [-2.99, -0.12]), *p* = .026.

An independent *t*-test showed no difference between conditions (comparison group (*M*= 3.87), intervention group (*M*= 4.16)), *t*(120) = 1.10, *p* = 0.273. All classes were therefore included in the statistical analysis. For the pre-test Cohen's *d,* the effect size is 0.20; a weak effect.

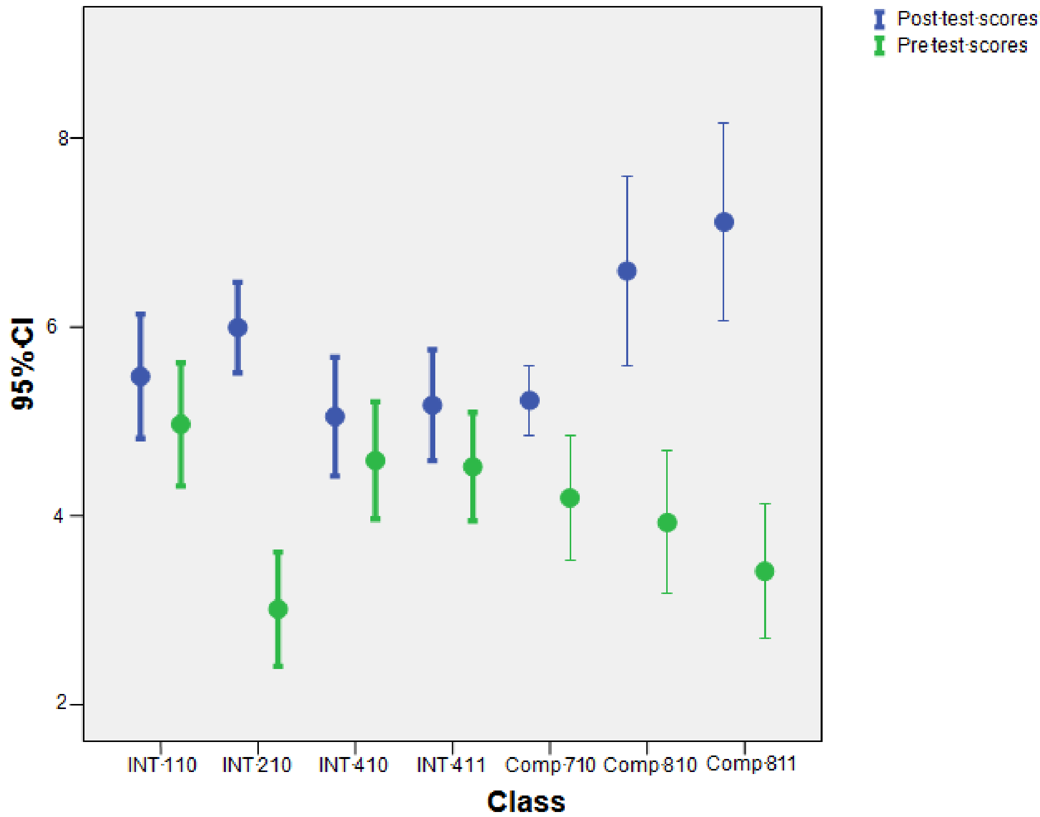

Figure 6-1 Genetics test results with error bars

Post test scores

On the post-test the scores ranged from 5.05 to 7.11. Of the four experimental classes only INT210 scored higher than the total mean of 5.80. In the comparison condition both of Tina´s classes scored higher than this. A one-way

ANOVA was used to test for score differences among the seven participating classes. The test scores did differ significantly across the classes, F (6, 115) = 5.65, p = .000. A Games-Howell post-hoc comparisons of the classes however indicates that Comp811 (M = 7.11) differed significantly from the three lowest scoring classes, (M = 5.05; 5.17; 5.22). Comparisons between the other classes were not statistically significant at p <.05.

An independent t-test between conditions did not show a statistically significant difference. The intervention group scored lower (M = 5.49) than the comparison classes (M = 6.20), t(85.38) = 0.78, p = 0.437. For the post-test Cohen's *d,* the effect size is -0.48, a modest negative effect.

All variables in one model

A one-way analysis of covariance (ANCOVA) was conducted, exploring differences in post-test scores by condition controlling for the pre-test scores. The independent variable, learning resource, involved two levels: intervention and comparison. The dependent variable was the post-test score and the covariate was the pre-test score. The assumptions for ANCOVA were not met so the outcomes have to be treated with caution. In particular, the homogeneity of the regression effect was not evident for the covariate, and the covariate was poorly linearly related to the dependent measure (see Appendix B).

When controlling for the pre-test scores, the results of the post-test were significantly affected by the condition F (1,119) = 10.761, p = .001. The strength of the relationship between learning resource and post-test was weak, as assessed by η^2, with learning resource accounting for 8.3% of the variance in dependent measure holding constant the pre-test scores. The intervention group had a lower adjusted mean (M = 5.44) and the comparison group had a larger adjusted mean (M = 6.26). In the ANCOVA, the adjusted R^2 was 0.181 indicating that 18% of the variation in post test scores was accounted for in the model (i.e. by pre-test + group).

6.1.3. What pupils thought of *Erfðavísir* and *Bug Lab*

Erfðavísir requires pupils to read and answer multiple choice questions and also fill out a worksheet with answers found on the website. As can be seen in Table 6-3, 60% of pupils found some positive aspects with this website.

Table 6-3 Pupils' views of websites used in genetics

Websites	Very negative	Rather negative	Mixed feelings	Positive	Very positive	Total
Erfðavísir	2	10	12	30	6	60
	3%	17%	20%	50%	10%	100%
Bug Lab	2	12	10	16	4	44
	5%	27%	23%	36%	9%	100%

For this website, there is no outstanding feature that pupils mention as an affordance. Four mention the visual aspects of the website, '*Quick and very informative especially the one with the graphics*'. They liked having a digital resource '*I found it fun because we do not often use computers*'. Six talk about it being nice to break from the routine. Pupils did not agree about the usefulness of the website. In the questionnaire there were four references to it being better than the textbook, but in focus groups some admitted to not reading it thoroughly.

> *Pupil 1: It was complicated to find the answers on the website*
> *Pupil 2: Yes it was...*
> *Researcher: Were you just then looking for the answers?*
> *Pupil 1: Yes, and skimming it quickly*
> *Researcher: So you did not read the whole text?*
> *Pupil 1: Yes I tried to and to find the answers but I never found them.*

I asked them so directly in the above abstract because this kind of behaviour was frequently observed with all the classes using the resource. They skimmed the pages, looking for replies to questions on the worksheet not bothering to read through the text as instructed. Pupils were seen clicking frequently on the options in a haphazard manner, without reading them until the next section opened. In this resource if you click a wrong option it only changes colour. The user is not given extra information or a further task to learn from the mistake. This is not to say that the resource is useless. A girl was heard saying while working on it '*Wow, the thing we did earlier [the pre-test], it was all wrong, I am lucky if I got my name correct!.*' She was clearly learning from the resource. Nine of the positive answers said pupils had learned from the DLRs. The feeling was that pupils liked to escape the routine and go to the computer room, but the website was not adding anything to their learning experience.

Another measure of pupils' views of the learning resources is what resource they chose to study for the test. Table 6-4 shows that only a small percentage of pupils used the resources when studying for the test.

Table 6-4 Resources used to study for the test in genetics

Genetics	**Text-book**	**Text-book tasks**	**My notes**	**Teache r notes**	**Erfða-vísir**	**Bug Lab**	**Inter-active tests**	**Other**
All N= 125	77%	55%	39%	44%	-	-	-	5%
Intervention group N= 65	69%	46%	35%	43%	12%	2%	9%	6%
Comparison group N= 60	85%	65%	43%	45%	-	-	-	3%

Table shows percentage of all those that answered the questionnaire

Of all the resources *Bug Lab* got the lowest proportion of positive views, only 45%, but the highest proportion of mixed reviews, 23% (Table 6-3). The positive views were mostly about fun, that they enjoyed the game-like feel of the resource, '*fun because it was like playing a computer game*'. Only four referred to learning in any way. An English speaking student put it well; '*Although the experiments were kind of "hands-on" it was kind of inefficient and undesirable because we weren´t really sure of all the effects of the present things*'. From observations it was clear that pupils really enjoyed manipulating the bugs with phrases such as '*I am playing God*' and '*they just keep dying*' being heard. In focus groups though they said that most did not understand the tasks nor all the controls: '*The most complicated thing I have done*', '*Hehe nobody understood anything!*'. The negative views from the questionnaire were of the same ilk, with three mentioning that they did not learning anything from it. So the bottom line is that *Bug Lab* is too complicated for pupils to learn from using it, at least for a single lesson with little preparation.

6.1.4. Summary of genetics intervention

Table 6-5 provides a summary of the genetics intervention. The main result is that the classes using the websites made less progress and scored lower than the classes not using the websites. Pupils had fairly negative views of the resource and were observed using them in a haphazard manner. These are tentative indications of negative effects that the websites may not have helped pupils learn basic genetics.

Table 6-5 Summary of genetics intervention

Summary of genetics intervention	
Intervention	Comparison
Teachers: Eva, Anna, Olga (2 classes)	Teachers: Tara and Tina (2 classes)
68 pupils in 4 classes	54 pupils in 3 classes
Pre-test	
M=4.16 SD =1.45	M= 3.87 SD = 1.44
T-test: *t*(120) = 1.10, *p* = 0.273 (no difference)	
Purpose of teaching sequence: **Learn and understand basic genetics concepts**	
Digital learning resources: *Erfðavísir,* *Bug Lab*	**Digital learning resource:** None
Other learning resources: Worksheet, teacher presentation **Observation:** Considerable off-task behaviour, unfocused work. **Teachers' views:** *Erfðavísir*: neutral views. *Bug Lab*: too complicated. **Pupils' views:** *Erfðavísir* mixed reviews, *Bug Lab*, fun but useless.	**Other learning resources:** Textbook, teacher presentation, worksheet (only Tina)
Role of pupil: receiver and reviser	**Role of pupil:** receiver and reviser
Post-test	
M = 5.49 SD = 1.17	M = 6.20 SD = 1.17
T test: *t*(85.38) = 0.78, p = 0.437 No difference	
ANCOVA *F* (1,119) = 10.761, *p* = .001	
Adjusted mean: *M* = 5.44	*M* = 6.26
Result: No difference between conditions was found, the resources did not live up to expectations.	

6.2. Chemistry

Six teachers with eight classes participated in the chemistry intervention: Eva, Inga (2 classes), Ellen as intervention teachers, Dora (one intervention class and one comparison), Tara and Tina in comparison (see also Table 3-5).

6.2.1. Observed lessons

Five classes used *Chembalancer,* all using the worksheet for one lesson. All lessons were observed here. In all of the schools, pupils took some time to realise how to use the website keeping the teachers quite busy going between them and explaining. Ellen, who had a large class of 27 stopped the pupils and used an overhead projector to explain again how the balancer worked. Hers was the only class that showed off task behaviour, being both a larger and younger class than the others. They also seemed to take advantage of them being too many for her to monitor. This was also the case in lessons observed with these classes in the classrooms. All pupils who stayed on task finished balancing the 13 equations on time, many with time to spare. Having worksheets when using this website did not seem to make much difference to their engagement or learning. In some instances pupils had not filled out the worksheet but when asked to repeat the task they found this quite easy and fast.

Teachers were also introduced to a very simple simulation of a chemical reaction[13] and encouraged to use it as a whole class discussion stimulant. Two of the teachers chose to do so.

In Anna's class pupils worked for one lesson on a selection of interactive multiple choice questions and matching exercises. The lesson was very disorganised with some pupils in the computer cluster and some next door in the library. Pupils worked in groups or pairs with varying levels of concentration.

The comparison classes learned to balance equations from a teacher demonstration and then balanced the equations in the textbook. Tina also used

[13] http://www.chem.uci.edu/undergrad/applets/sim/simulation.htm

a worksheet with similar equations as the intervention group. This lesson was observed and pupils needed help frequently when learning the method. Lots of pupil interaction was observed with them helping each other. The lesson Tara had planned to teach balancing equations was observed. She talked them through the method but no pupil work took place in that lesson.

All the classes used the same textbook *Efnisheimurinn*. Teaching in all groups was very traditional; a mixture of lecturing and note taking, discussions, written questions and practical work from the textbook.

6.2.2. Chemistry test scores

For the chemical intervention three sets of scores are presented: a score from the pre-test, post-test and balancing chemical equations (Table 6-6). All are on the scale 0-10. For the post-test a score was calculated for the whole test, that is, all questions that were comparable between classes. On the post-test there were four items specifically on balancing chemical equations. The ICT tool Chembalancer was designed to be used for that task so a separate score was calculated for those items. Pre- and post-test results can be seen in Figure 6-2 and pre-test and balancing chemical equation in Figure 6-3. Both show the intervention group to have made better gain than the comparison group.

Table 6-6 Chemistry test results

Class		Pre-test			Post-test			Balancing chemical equations		
		Mean	**SD**	**Group**	**Mean**	**SD**	**Group**	**Mean**	**SD**	**Group**
INT 120	16	3.67	1.81		4.95	2.41		5.13	2.73	
INT 321	10	1.94	0.75		5.72	1.97		7.00	3.30	
INT 322	13	2.26	1.01	M=3.12	5.85	2.40	M=5.74	5.38	3.78	M=6.33
INT 520	22	3.41	1.48	SD=1.53	6.65	1.70	SD=2.05	7.18	3.39	SD=2.96
INT 620	18	3.58	1.47		5.24	1.58		6.67	3.66	
Comp 621	15	3.83	2.06		5.33	2.59		5.87	3.50	
Comp 720	20	3.13	1.87	M=3.47	4.76	2.20	M=5.27	2.90	2.20	M=4.63
Comp 820	19	3.54	1.83	SD=1.90	5.75	1.92	SD=2.22	5.47	3.39	SD=3.27
Total	133	3.27	1.69		5.55	2.13		5.64	3.17	
		Cohen's *d* = 0.21			Cohen's *d* = 0.22			Cohen's *d* = 0.56		

INT: intervention class; Comp: comparison class

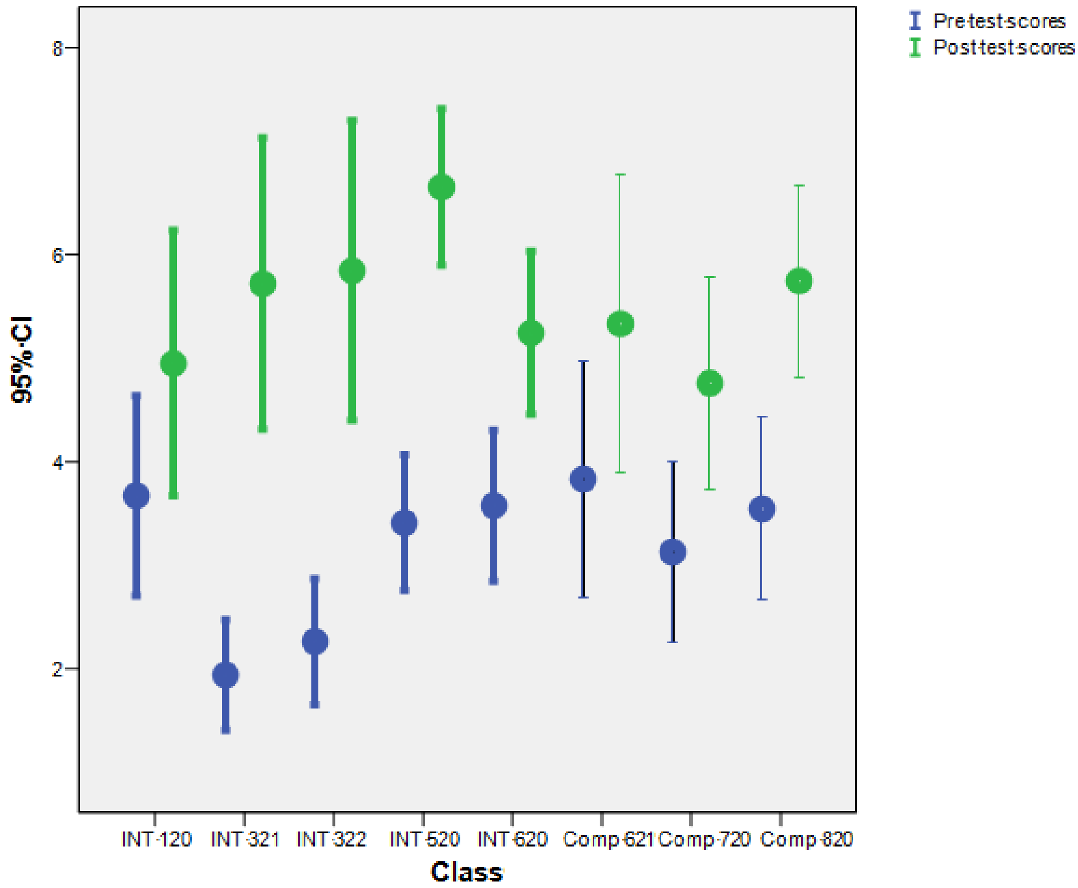

Figure 6-2 Chemistry test results with error bars

Pre – test scores

On the pre-test the mean scores ranged from 1.94 to 3.83 with a total mean of 3.27. A one-way ANOVA was used to test for score differences among the eight participating classes. The test scores differed significantly across the classes, F (7, 125) = 2.25, *p* = .035. A Games-Howell post-hoc comparison of the classes however indicates that only one of the classes INT321 (M = 1.94, 95% CI [1.40, 2.48]), *p* = .007 differed from the others. Comparisons between the other seven classes did not show a statistically significant difference at *p* < .05.

One class was statistically different from the others on the pre-test. It was decided to keep it in, as an independent t-test between conditions showed that the comparison classes (M = 3.47) did not score significantly higher than the experimental classes (M= 3.13), $t(97.56) = -1.11$, $p = 0.269$. For the pre-test Cohen's *d,* the effect size is 0.21; a borderline modest effect.

Post test scores

The post-test scores ranged from 4.76 to 6.65. A one-way ANOVA was used to test for score differences among the eight participating classes. The test scores did not differ significantly across the classes, F (7, 125) = 1.62, p = 0.135. A Games-Howell post-hoc comparison of the classes indicated the mean scores of all eight classes were not statistically significant at $p < .05$.

An independent t-test between conditions also did not show a statistically significant difference. The experimental group (M= 5.74) did not score significantly higher than the experimental classes (M= 5.27), $t(107.76) = 1.24$, p = 0.219.

Balancing chemical equations scores

The mean of the classes ranged from 2.9 – 7.18, with three of the experimental classes and one comparison class scoring higher than the total mean of 5.64 (see Table 6-6). When the two conditions are compared using an independent t-test, the experimental classes scored significantly higher (M= 6.32) than the comparison classes (M= 4.63), $t(105.42) = 3.07$, p = 0.003.

A one-way ANOVA was also used to test for score differences among the eight participating classes. The test scores differed significantly across the classes, F (7, 125) = 4.08, $p < .000$. A Games-Howell post-hoc comparisons of the classes indicated that only one of the classes, Comp720 ($M = 2.90$, 95% CI [1.87, 3.93]), differed significantly from two others INT520 $p = .007$ and INT620 $p = .001$. Comparisons between the other seven classes were not statistically significant at $p < .05$.

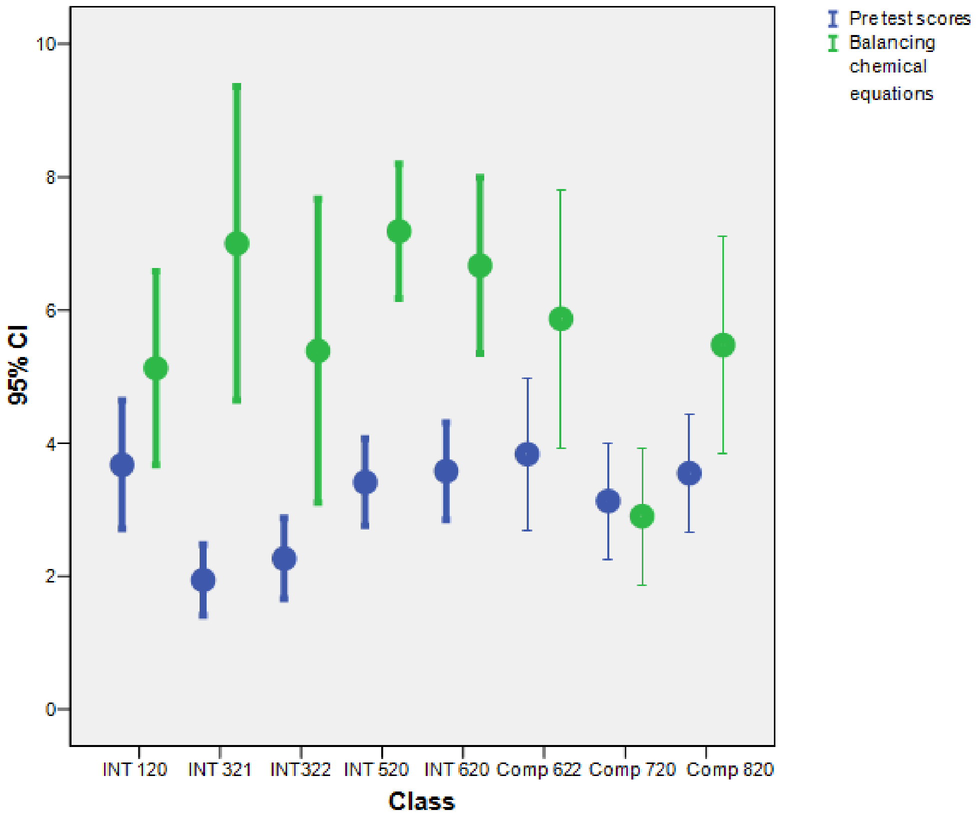

Figure 6-3 Balancing chemical equations - with error bars

All variables in one model

A one-way analysis of covariance (ANCOVA) was conducted exploring differences in the scores or balancing chemical equations by condition while controlling for the pre-test scores. The independent variable, learning resource, involved two levels: intervention and comparison. The dependent variable was the score for balancing chemical equations and the covariate was the pre-test score. The assumptions for ANCOVA were met. In particular, the homogeneity of the regression effect was evident for the covariate, and the covariate was linearly related to the dependent measure (see Appendix B).

There was a significant effect of using the website Chembalancer on pupil scores for balancing chemical equations, F (1,130) = 12.833, p = .001. The strength of the relationship between learning resource and post-test was weak, as assessed by η^2, with learning resource accounting for 9.0% of the variance in dependent measure holding constant the pre-test scores. The intervention group had the larger adjusted mean (*M* = 6.40) and the comparison group had a smaller adjusted mean (*M* = 4.52). In the ANCOVA, the adjusted R^2 was 0.132 indicating that 13% of the variation in post-test scores was accounted for in the model (i.e. by pre-test + group).

6.2.3. What pupils thought of *Chembalancer*

Pupils generally found this to be very helpful, especially middle ability pupils, The high attaining ones said '*I got it as soon as the teacher explained, so I just had to do it*'. What happens is that many pupils could not be bothered to count and just punched in numbers randomly and hit balanced repeatedly (11 hits were counted with one pupil). However they soon got tired of that and then either asked the teacher for help or just seemed to stop and think. Inga commented that she would have liked to get a log showing how often pupils tried for each equation before getting it right.

Chembalancer was the website pupils liked the most with a total of 79% giving positive feedback on its use. The tone of the responses was mostly the website helping them understand how to balance chemical equations.

Table 6-7 Pupils' views of websites used in intervention

Websites	**Very negative**	**Rather negative**	**Mixed feelings**	**Positive**	**Very positive**	**Total**
Chembalancer	5	13	4	56	27	105
	5%	12%	4%	53%	26%	100%
Interactive tests Chemistry	2	2	5	17	6	32
	6%	6%	16%	53%	19%	100%

The few negative responses referred to the task of balancing chemical equations itself being difficult. This can be contrasted to 21 responses that referred to the task being easy and 43 to the website helping with learning and understanding: '*fun because you finally understood how to balance it [the equations]*'. Pupils also mentioned liking the puzzle-like element of balancing equations using the website, and that it stretched their minds but not their handwriting. In the interviews pupils all agreed that the website drawing the diagrams for them made the task clearer and that they found it easier to solve equations later with pen and paper. Even though *Chembalancer* is a really simple website, or as one pupil said, '*it might have been considered modern before the invention of the computer*' it really helped the pupils learn an opinion that was seconded by everyone. Even though there are only 13 tasks, it seemed to be enough to help the pupils grasp the method. Those who had real difficulties seemed to be the ones that had low motivation to learn science and so did not really give it a try unless they received encouragement and help from the teachers.

Table 6-8 shows that almost a third of pupils chose to use Chembalancer to study for the test in chemistry. This is by far the highest number from all the resources.

Table 6-8 Resources used to study for the test in chemistry

Chemistry	Text-book	Text-book tasks	My notes	Notes from teacher	Chem-balancer	Inter-active tests	Other
All N = 172	83%	59%	44%	45%			10%
Intervention group N=124	84%	60%	44%	51%	29%	8%	9%
Comparison group N=62	63%	42%	32%	24%	-	-	10%

Table shows percentage of all those that answered the questionnaire

6.2.4. Summary of chemistry intervention

Table 6-9 provides a summary of the chemistry intervention. A significant difference cannot be found on the post-test scores for the whole test, neither between all the classes nor between conditions. However when only the tasks of balancing chemical equations is explored, there is a detectable difference between conditions with the experimental groups that used the website to help practicing balancing equations, scoring on average 0.85 points higher. Both pupils and teachers agreed that *Chembalancer* was very useful for both learning and practicing balancing chemical equations. *Chembalancer* was the simplest and the best website used, it worked flawlessly in all classes.

Table 6-9 Summary of chemistry intervention

Summary of chemistry intervention		
Intervention		Comparison
Teachers: Eva, Inga (2 classes), Ellen and Dora		Teachers: Dora, Tara and Tina
79 pupils in 5 classes		54 pupils in 3 classes
Pre-test		
M = 3.12 SD = 1.53		M = 3.47 SD = 1.90
T-test: *t*(97.56) = - 1.11, *p* = 0.269 (no difference)		
Purpose of teaching sequence: **Learn to balance chemical equations**		
Digital learning resource: Chembalancer		**Digital learning resource: None**
Other learning resources: Worksheet, teacher presentation	**Observation:** Pupils worked well, finished the task. Little off-task behaviour	**Other learning resources:** Textbook, worksheet, teacher presentation
Teachers' views: Chembalancer helped pupils learn, easy to use	**Pupils' views:** 'Chembalancer really helped us learn'	
Role of pupil: receiver and reviser		**Role of pupil:** receiver and reviser
Post-test balancing chemical equations		
M = 6.33 SD = 2.96		M = 4.63 SD = 3.27
T test: *t*(105.42) = 3.07, p = 0.003 Significant difference		
ANCOVA *F* (1,130) = 12.833, *p* = .001		
Adjusted mean: *M* = 6.40		*M* = 4.52
Result: Pupils using Chembalancer made better progress balancing chemical equations and all found Chembalancer helpful		

6.3. Ecology

Three classes in two schools participated in this part; Ellen with one experimental class, Olga with two experimental classes (one did not take the pre-test) and two comparison classes from Dora (see Table 3-5 p.46). Both intervention teachers said they had used all three suggested resources. *Sunny Meadows* was the main website used in this intervention. In it pupils decide how many foxes and rabbits and how much grass they start with and then run the simulation which simulates 50 years.

6.3.1. Observed lessons

It was only possible to observe one of Ellen’s lessons in the classroom, one in which pupils were working on laptops on a task from the teacher. Both Olga’s classes were observed in the computer room working with *Sunny Meadows* and a further lesson was observed in the classroom. She first demonstrated on an IWB before going to the computer room. Pupils stayed on task and really enjoyed it. Even when the teacher said they could have the last few minutes for free activities many continued running the simulation. A contributing factor to the fun they had was that the website gives out scores depending on how well the ecosystem does. The teacher took down the scores and wrote them on the blackboard so they had a competition trying to get the highest score. The game-like quality seemed to encourage pupils to really try their best. Both classes used worksheets where they were supposed to record the ratio between the species. Pupils in the observed class, especially the boys, soon found out that the simulation keeps track of their five highest scores and did not see the point in using the worksheet.

These classes were also observed watching the cartoon *Mysteries of life.* Both teachers wrote down the ecology concepts with Icelandic translations and then showed the cartoon, stopping to explain further and translate. It is difficult to determine, even when watching the video recording from the lesson, how well pupils were paying attention.

The lessons observed with the comparison classes consisted of note taking, class discussion and reading and answering questions from the textbook. From the post questionnaire it can be seen that the teaching in this chapter was all like this except they went for a walk to a nearby pond meaning to collect samples but it was frozen.

6.3.2. Test scores

For the ecology intervention two sets are presented, pre-test scores and post-test scores (see Table 6-10 and Figure 6-4). Here the intervention group made better gain than the comparison group.

Table 6-10 Ecology test results

Class	**N**	**Pre-test**			**Post-test**		
		Mean	**SD**	**Group**	**Mean**	**SD**	**Group**
INT 430	18	3.84	1.11	M= 4.06	5.27	2.19	M=5.89(5.92)
INT 431	(19)	*	*	SD=1.37	5.99	1.47	SD=1.87(1.75)
INT 530	28	4.20	1.51		6.30	1.54	
Comp 630	25	3.23	1.42	M=3.61	4.80	1.47	M=5.23
Comp 631	23	4.00	1.49	SD=1.48	5.70	1.52	SD=1.55
Total	94 (113)	3.83	1.44		5.63	1.69	
		Cohen's d = 0.32			Cohen's d = 0.42		

*no pre-test administered INT: intervention class; Comp: comparison class

Pre – test scores

On the pre test the mean scores ranged from 3.27 to 4.20 with a total mean of 3.83. A one-way ANOVA was used to test for score differences among four of the five participating classes. The test scores did not differ significantly across the classes, F (3, 90) = 2.05, p =.113. The teacher of the class with missing pre-test gave the information that both the classes were of similar ability. It was also apparent on the pre-test that pupils generally had very little understanding of what roles the different organism play in the food-chain. Only 3 of 94 pupils knew that plants are always at the bottom of a food-chain and no one wanted to add decomposers to the organism already chosen. Taking this into account it was considered right to include comparison INT431 in the post-test even though no statistical comparisons can be made on the class score.

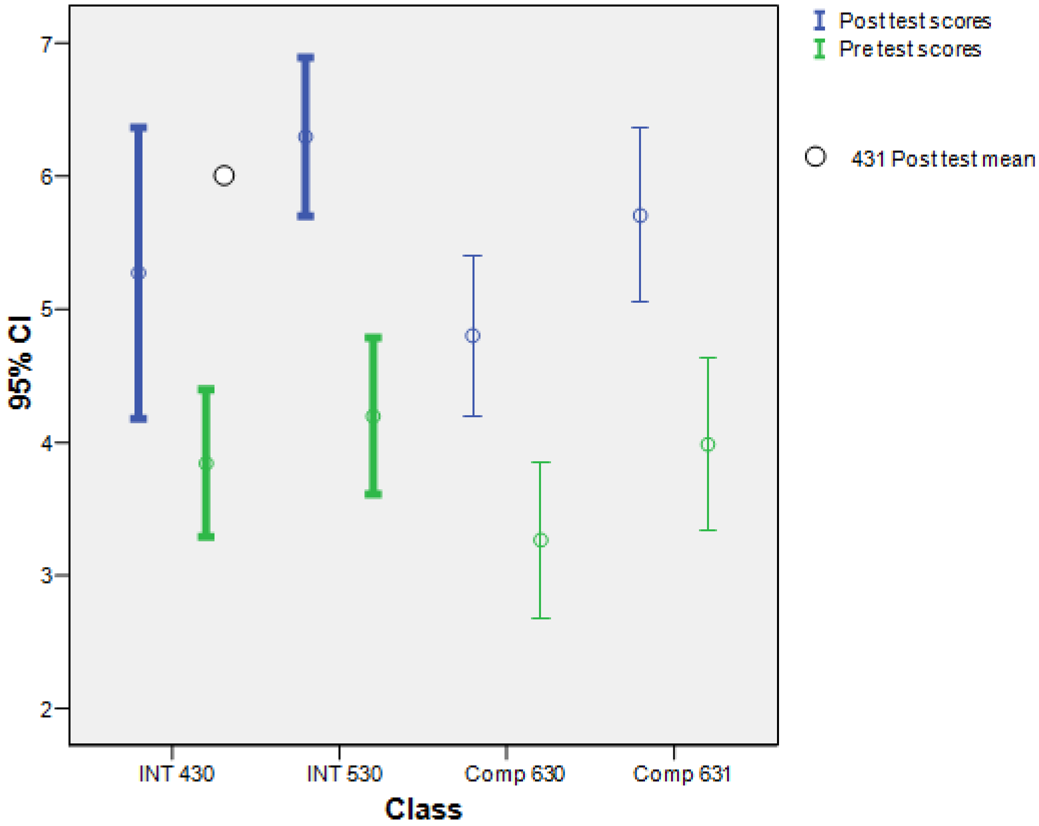

Figure 6-4 Ecology test results with error bars

An independent *t*-test between conditions did not show a significant difference between the comparison classes (M = 3.61) and the experimental classes (M= 4.06), *t*(91.87) = 1.52, p = 0.132. For the pre-test Cohen's *d,* the effect size is 0.32; a modest effect.

Post – test scores

On the post-test the scores ranged from 5.27 to 6.30 (see Table 6-10). Two of the experimental and one comparison class scored higher than the total mean of 5.63. A one-way ANOVA was used to test for score differences among the five participating classes. The test scores differed significantly across the classes, F (4, 108) = 3.24, p = .015. A Games-Howell post-hoc comparison of the classes however indicates that the difference was only statistically significant between experimental class 530 (M = 6.30, 95% CI [- 2.66, -0.33]), p = .006 and comparison class 60 (M=4.80). Comparisons between the other classes were not statistically significant at $p < .05$.

An independent *t*-test between conditions did show a statistically significant difference. The experimental group (M= 5.92) did score significantly higher than the comparison group (M= 5.23), $t(107.448) = 2.21$, p = 0.029.

All variables in one model

A one-way analysis of covariance (ANCOVA) was conducted exploring differences in the post-test by condition while controlling for the pre-test scores. The independent variable, learning resource, involved two levels: intervention and comparison. The dependent variable was the post-test score and the covariate was the pre-test score. The assumptions for ANCOVA were not met (Sig=0.22) so results have to be treated with caution. The homogeneity of the regression effect was not evident for the covariate, and the covariate was poorly linearly related to the dependent measure (see Appendix B for ANCOVA table).

The ANCOVA did not show a significant effect from using websites, F (1,91) = 1.69, p = .197. The strength of the relationship between learning resource and post-test was weak, as assessed by η2, with learning resource accounting for only 1.8% of the variance in dependent measure holding constant the pre-test scores. The intervention group had a larger adjusted mean (M = 5.77), than the comparison group (M = 5.35). In the ANCOVA, the adjusted R^2 was 0.227 indicating that 23% of the variation in post-test scores was accounted for in the model (i.e. by pre-test + group).

6.3.3. What pupils thought of *Sunny Meadows*

In the questionnaire the largest proportion of the pupils gave the website *Sunny Meadows* positive comments (see Table 6-11), saying it was fun whilst also recognising that they had learnt from using it. Typical positive answers included '*It was loads of fun and fascinating*' and '*I learned a lot about equilibrium in the environment and learned a lot about all of this*'.

This exchange from a group interview shows pupils both remembering what they were doing and why:

> *Researcher: What was this website all about, what were you really doing?*

Pupil 1: Keeping everything alive

other pupils nod and agree

Pupil 2: Increasing understanding and such things.

The negative comments ranged from the task being difficult to unnecessary as the respondent already knew this topic. Overall both pupils and teachers liked this website and thought it was useful. Both teachers planned to use it again.

Table 6-11 Pupils views of websites used in ecology intervention

Websites	Very negative	Rather negative	Mixed feelings	Positive	Very positive	Total
Sunny Meadows	5	5	7	18	24	59
	8%	8%	12%	31%	41%	100%
Mysteries of life	2	5	7	11	9	34
	6%	15%	21%	32%	26%	100%
Eco kids	3	3	7	20	16	49
	6%	6%	14%	41%	33%	100%

Another measure of pupils' views of the resource comes from where they were asked what they used to study for the test. Table 6-12 shows that pupils did not use the digital resources when studying for the test.

Table 6-12 Resources used to study for the test in ecology

	Text-book	Text-book tasks	My notes	Notes from teacher	***Sunny Meadows***	***Mysteries of life***	***Eco Kids***	Other
All N= 108	85%	69%	47%	47%	-	-	-	12%
Experimental group N= 62	79%	61%	55%	47%	2%	0%	2%	11%
Comparison group N= 47	91%	77%	36%	47%	-	-	-	13%

Table shows percentage of all those that answered the questionnaire

The *Mysteries of life*, the short cartoon explaining what food chains are all about, was shown by the teachers to the whole class (Olga showed it two times). The cartoon was chosen because it seemed fun and might explain food-chains in a more thought provoking manner than a teacher could. The pupils that remembered seeing the cartoon gave it mostly positive views, '*fun one shows more interest because it is new*', some of the negative comments were about the cartoon being about something they already knew and one thought it was too childish.

> *Pupil 1: See, it did not help me a lot.*
>
> *Pupil 2: No when, because it was so complicated to understand because science has difficult words and you do not understand completely, in you know, English.*
>
> *Pupil 3: Well he stopped to tell us what the words meant but is was still really difficult.*
>
> *Pupil 4: Bear? What bear? what cartoon was that?*
>
> *Pupil 5: I understood everything but decomposers.*

In the excerpt one pupil appears not to remember seeing the cartoon. This was the case for many of them, claiming in their responses that they had been sick or that the class had not seen it. In some cases it may be that they were not paying enough attention for the 2 minutes and 40 seconds that it lasted. The commentator in the cartoon speaks fast in English and some thought the words had been difficult and that it would have been better in Icelandic. Still Icelandic pupils are exposed to English quite a lot and one pupil knew all the concepts from playing the computer game *Spore.* Ideally, pupils should be able to use resources in their own language but as pupils could effectively use these resources in English this suggest that using low language intensive resources may be a better option than not.

6.3.4. Summary of ecology intervention

Table 6-13 provides a summary of the ecology intervention. The intervention classes scored higher than the comparison classes. A *t*- test showed that difference to be significant and an ANCOVA showed the same direction of effect, but this was not significant and very small. These findings do not give a clear answer to the usefulness of these resources, though they indicate that the websites used benefited the pupils. Teachers and pupils thought the main resource *Sunny Meadows* to be both interesting and engaging.

Table 6-13 Summary of ecology intervention

Summary of ecology intervention	
Intervention	Comparison
Teachers: Olga and Ellen	Teachers: Dora (2 classes)
46 pupils in 2 classes	48 pupils in 2 classes
Pre-test	
M = 4.06 SD = 1.37	M = 3.61 SD= 1.48
T-test: *t*(91.87) = 1.52, p = 0.132 (no difference)	
Purpose of teaching sequence: **Learn basic ecology concepts and how ecosystems work**	
Digital learning resource: *Sunny Meadows*, *Eco Kids*, *Mysteries of life*	**Digital learning resource:** None
Other learning resources: Worksheet, textbook, teacher presentation **Observation:** Pupils worked well, finished the task. Little off-task behaviour **Teachers' views:** Positive, planned to use them again **Pupils' views:** *Sunny Meadows*, fun and helpful. Others rather positive.	**Other learning resources:** Textbook, worksheet, teacher presentation
Role of pupil: Explorer, receiver and reviser	**Role of pupil:** Receiver and reviser
Post-test	
M = 5.89 SD = 1.87	M = 5.23 SD = 1.55
T test: *t*(107.448) = 2.21, p = 0.029 Significant difference	
ANCOVA F (1,91) = 1.69, p = .197	
Adjusted mean: M = 5.77	M = 5.35
Result: Pupils using DLRs made better progress, the resources were found to be helpful and fun.	

6.4. Effects of participation on teachers

Four of the teachers were interviewed towards the end of the intervention with the aim of accessing what effects, if any, their participation in the intervention had had.

Eva had not tried out any other ICT applications during the intervention. However she talked about an eye-opening experience and expressed a willingness to learn more and to use online videos more often. When asked if she thought if she has learned anything by participating she said:

> *Yes, yes. To me the possibility opened up how to connect science more to tasks in computers and to use technology better. Also to give more consideration to what content I should be teaching but not just what textbook*.

When Anna was asked about what she had learned, she talked about finding the resources fascinating and that pupils had learned from them. She had asked for resources to use while teaching electricity and used them but that was it regarding experimenting with ICT during that winter.

Olga said she had not tried out any other ICT applications or learning resources during that school year. When asked why she had volunteered to participate in the intervention she said:

> *I have always wanted to connect the two [science and ICT] but have not seen the angle, you have to be so organised for it to function completely, maybe I will feel confident enough to implement more ICT in teaching science next school year*.

Ellen had been using ICT to some extent before participating in the intervention and continued to do so, looking for new resources. When asked if she had learned anything during the intervention she said:

> *Well I do not know how to say precisely what I have learned, but I feel it has helped a lot, me just starting to teach, especially ecology, I thought when I was explaining food=chains to them, I thought it hard to understand what they [the pupils] found hard. It is complicated, because I think it is so simple, so I think it helped me understanding their understanding*.

To sum up, three of the intervention teachers had found the resources interesting and participation had stoked their intentions to try to integrate ICT into their teaching. Despite their increased interest to use more ICT it has not as yet influenced their practice. Ellen used a variety of resources both before and during participation in the intervention. Inga was not asked about her use or learning since she only participated in one part.

6.5. Summary

Introducing teachers to a selection of DLR´s in a series of small scale interventions resulted in varying results in terms of pupil learning. In balancing chemical equations and in the ecology intervention the intervention classes scored significantly higher than the comparison classes but in basic genetics this was not the case, the difference was slight and not statistically significant.

This variance could to some degree be traced to features of the DLR´s but teacher effects seemed to play a bigger part. Participation in the interventions did not change teachers’ practice but opened their minds to the possibilities that ICT holds for teaching and learning science.

7. Towards an understanding of ICT use in science education in Iceland

This chapter discusses the three main aspects of this study. First how ICT is used in science education in Iceland, secondly what factors affect teachers, thirdly what the interventions revealed. This study confirmed what was suspected that the extent of ICT use is not great as outlined in section 4 but the study gave an insight into how it is used, therefore more attention is paid in section 7.1 to how ICT is used rather than to what extent it is used. Section 7.2 then addresses the conditions that impact upon ICT use or rather the factors that affect teachers' technology integration. Concerning the interventions the question was if there would be measureable differences between groups using DLR's and not. The three interventions all gave different results and section 7.3 discusses those and the lessons learned from them. Finally the last question was if participation in the interventions would impact upon science teachers' practice. That did by and large not turn out to be the case as presented in section 6.4 and does not merit a separate discussion other than to stress that changing teacher practice is not a simple thing.

7.1. How Icelandic teachers are using ICT in science education

Regarding the availability of equipment the survey confirmed what previous studies had shown, that generic equipment is readily available with, on average one computer per classroom and an internet connection (Vilji og veruleiki, 2008; Pelgrum, 2001). Equipment for pupils however, especially for whole class use, is limited and pupils stated they seldom use computers in school.

What we know now is how this equipment is used and the small effect ICT is having on teaching and learning science. How ICT is used in science teaching is described in chapter 4.2. This is summed up in Figure 7-1 along with the associated roles (Newton and Rogers, 2003) these uses put pupils in. The uses found in the study (see section 4 and Table 4-6) are labelled either as activities done ‘often’ those are the ones that all teachers seem to practice to some extent. The ‘seldom’ are those activities that only limited evidence was found of and the of the ‘close to never’ activities almost no evidence was found of.

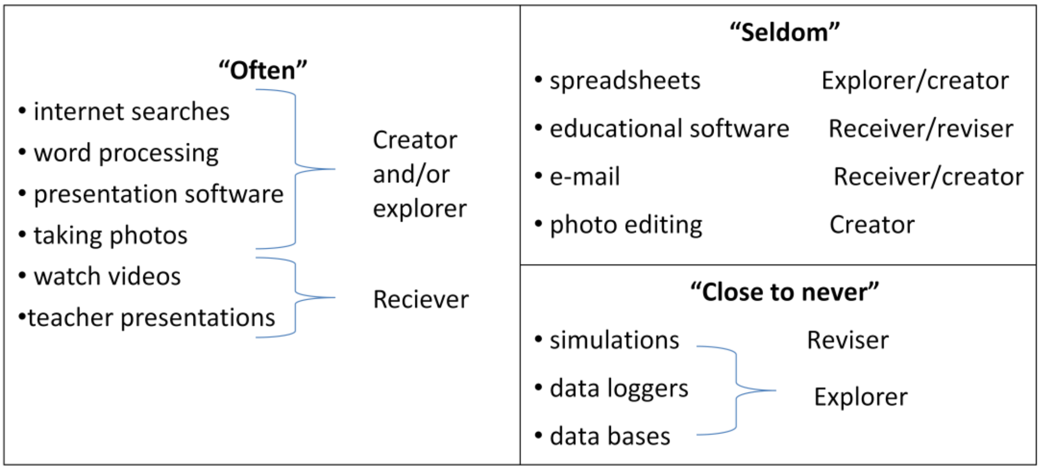

Figure 7-1 Frequency of different uses of ICT

Rodrigues (2007) found that teachers first integrate ICT into their current practice which is teacher oriented before trying out other modes of pedagogy. Teacher presentations and watching videos put pupils in the role of receiver which has been the prevalent role of pupils so this kind of ICT use has done little to change teaching practices. The ‘often’ chosen ICT activities are the ones that fit with teachers’ current pedagogy. The contradiction analysis showed that one possible reason for this is that bringing technology into the classroom requires managing the class around the technology. Instead of disrupting the comfortable way of practice, teachers are trying to use the technology in a way that fits their usual way of teaching.

Writing papers, giving presentations and photo taking put pupils in the role of *explorer* and *creator* (Newton and Rogers, 2003). Drent and Meelissen (2008) considered such uses innovative but not word processing. In the current study word processing, finding information and presenting it, go hand in hand. Such activities are innovative in the sense that pupils adapt the work to their own needs and interests, usually choose the topic and have a large influence over how extensively they explore the topic. They also have some say over presentation. In that sense these projects are emphasising and enhancing pupil centred pedagogy. However at the same time the topics tend not to be around the central ideas of science, but around less important matters. Teachers stated as a reason to use ICT that they want to add variety to their teaching and do so with papers and presentations that can also be done with other learning resources, the use value is in extending practice but not transforming it (Twining, 2002). Jakobsdóttir (2001) has found that schools using more non-traditional teaching methods the internet was used more than in schools with traditional teaching methods. This indicates that increased use of ICT may lead to less reliance on textbooks and more on other learning resources and perhaps other modes of learning transforming teaching and learning.

7.2. A model of the factors that affect teachers

In this section I will discuss the conditions that affect teachers in their technology integration into science teaching. It is a little disturbing that the factors and issues that teachers in Iceland are bothered with are factors that were prominent in the discussion elsewhere over a decade ago (Cox et al., 1999). When analysing the data I could well relate the Icelandic situation to Ertmer's observation from 12 years ago:

> Having to deal with numerous first-order barriers simultaneously may frustrate teachers who feel pressured to overcome every barrier before beginning the integration process. When asked to describe the barriers that most significantly impacts integration they may quickly recite a whole range of problems, apparently regarding every barrier as significant. These "laundry lists" of concerns illustrate the frustration teachers feel, often at the start of the process, when the existence of so many first-order barriers seems overwhelming. In addition, these types of responses may suggest that underlying second-order barriers are also at work (Ertmer 1999, p.51).

Such 'laundry lists' emerged from this study, however Ertmer suggests that beneath the first-order barriers there are second-order barriers that seem to have a stronger effect which seems to be the case in the Icelandic context. It could be seen that there was not always a correspondence between how teachers described their access and how their observed circumstances were. One even went so far as to say first order barriers such as time and equipment were an excuse. The centrality of second-order factors is evident in a model presented throughout the section, (see Figure 7-2). Teacher knowledge, attitudes and beliefs are central, influenced by first order barriers including support, resources and policy. This model is compared to the model devised by Hew and Brush (2007) (HBmodel see Figure 2-1) and amendments suggested to fit the Icelandic context. Several changes are made to the factors the most prominent being:

- assessment is exchanged for policy related factors;
- pupils influence is added as that proved to be an active factor;
- relevance of resources is added;
- support is set as a separate factor, including peer support;
- factors placed in the model to reflect where actions can be taken.

The original model was in the context of barriers however this is a narrow view to take. It is just as influential to change to emphasise factors that do encourage teachers as it is to reduce the barriers. In the amended model both facilitating and hindering factors may be seen. In fact some of the factors identified in this study acted as both a facilitator and a hindrance, i.e. having equipment encourages teachers but not having it acts as a barrier.

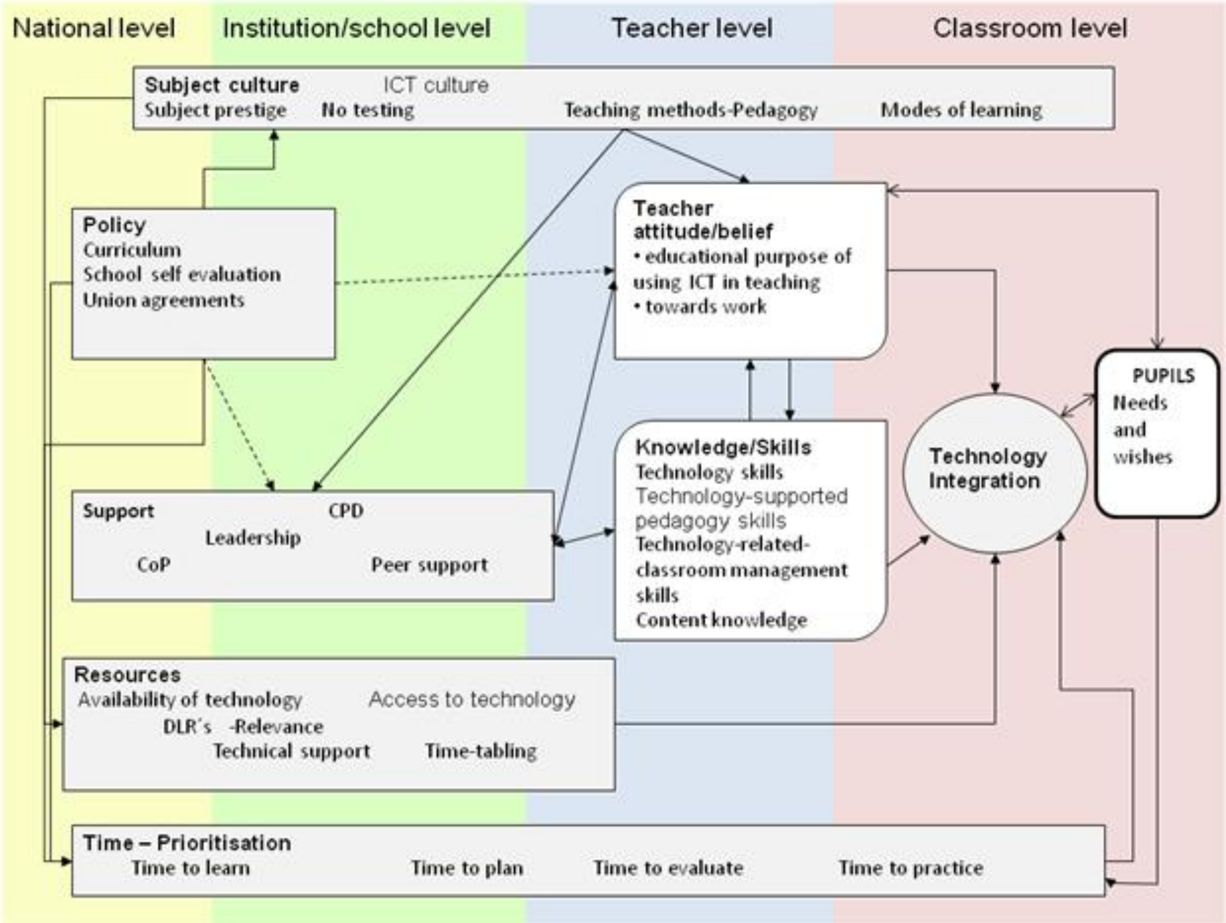

Figure 7-2 Adapted model, factors that affect technology integration

The levels indicate where actions could be taken for improved or increased technology integration.

Reciprocal relationship

Weak relationship

In the amended model the factors are placed to reflect where in the school system each of them is most noticeable, and where actions and strategies could possibly be taken against the barriers, or to support facilitating factors. This change is influenced by the global conceptual framework of the *Comped* study (Pelgrum and Plomp, 1988; ten Brummelhuis, 1995) where the factors are outlined at micro-meso-macro level and the work of a research group on collective teacher efficacy (Macdonald A. (project leader), May 2011; Macdonald et al., 2010). The levels presented are 'National level' i.e. laws, regulations, curriculum and union agreements. 'Institutional/school level'; which depending on management structure in the municipality, would be individual schools or schools within the same district office. 'Teacher level' are the teachers, as individuals or groups, and classroom level is what happens in the classrooms. As a result the aspect 'institution' and 'resources' as presented in HB model are split into 'resources', 'support' and 'time', but the HB model presented 'institution' as a factor providing support, time and resources.

Resources are an important factor affecting teachers as it was seen in this study that, in one way or another, it affected all the participating teachers. For successful use of ICT, there needs to be adequate equipment and access to it. The same goes for DLRs, especially considering their relevance to the curriculum (Rodrigues, 2006). This study showed that the availability of DLRs for science in schools is scarce and their direct relevance to the curriculum is weak (contradiction C section 5.2.2). There was little mention of teachers using the websites from NCEM but as mentioned in the introduction (section 1.2) most of the resources have a weak relevance to the curriculum as they focused mostly on biology and Icelandic nature. Relevance is not present in the HB model but is added to the amended model as an important aspect of DLRs.

Though lack of support does not rank high in this study, I maintain that teachers need more support than they realise. ICT use in schools is not supported in a systematic way. Support, in the form of CPD and training teachers in using ICT, has been very limited (see 5.1.3). This is worrying because relevant training, providing knowledge and skills that can instantly be implemented in the classroom, is one of the more important aspects of successful ICT implementation (Rodrigues, 2006).

It was striking how little the teachers talked about support from management. The teachers did not seem to consider such support to be important, either as a barrier or a facilitating factor, and it can even be said that they did not seem to expect much support or guidance at all. The cases indicate that not having active support is a hindrance to teachers (see contradiction D. Section 5.2.2.) This was mostly seen in the way teachers did not talk about headteachers in the context of factors that affected them. This is quite different from other studies where support is considered a highly important factor for development of ICT use(Ertmer, 2001). Professional isolation and lack of peer support seems to be holding teachers back (see 5.1.4). In the studies reviewed by Hew and Brush (2007) peer support is nowhere to be found but is suggested as a strategy to overcome barriers. Rodrigues (2006)on the other hand listed recognition of peer expertise as an influencing factor. In the amended model peer support is added as a sub-factor of CPD, with a connecting arrow going both ways. This indicates that not only does the support affect the teachers but teachers may, and preferably should also contribute to their community of practice. It is important for teachers to feel that they belong to a community (Charalambous et al., 2011) and that they share their worries about different issues such as ICT integration.

Time for experimentation and collaboration with peers is essential (Haydn and Barton, 2008; Rodrigues, 2006). If teachers had more support from management, training and peers, it is likely that the task of implementing ICT into their teaching would not seem as overwhelming. The main recommendations from this study therefore are regarding support.

Research carried out during the years that standardised tests were held showed that science teachers felt time restrictions in covering the material (Sigþórsson, 2008). However in the current study this was not an issue. In fact this was found to be quite the contrary as many felt they had time to really explore topics as the pressure from standardized tests had been lifted.

Most often, not having time means that teachers need time for themselves outside the classroom to learn, experiment, plan and prepare. Time issues are thus more connected to knowledge issues and organisation than the curriculum. Ertmer (1999) categorises time as an extrinsic factor but in this study time might be considered an intrinsic factor, or at least highly influenced by intrinsic factors (such as teacher beliefs on what is most important and pressing at any given time). In the amended model time is stretched across the continuum as issues related to time and prioritisation can be addressed at all levels.

Working hours and time for professional development of teachers are decided through work agreements at the national level and implemented at institutional level. Providing time for training and planning in schools is essential. Even if pioneering teachers prioritize time to learn, experiment and plan ICT into their lessons, this does not apply to all teachers. However as Bennett has pointed out;

> It is clear that in-service training for teachers will not, in itself, lead to a significant increase in the purposeful use of ICT in science lessons: creating time for planning is essential if ICT is to be used appropriately and effectively as part of good teaching. (Bennett, 2003, p. 143).

This means that generally the impetus has to come from policy and management.

Through the analysis, time came to mean prioritisation at the teacher level. When the teacher said ‘I do not have time’ or ‘I have not taken the time’ it invariably meant that they prioritised some other task or activity either in their work or personal lives higher. For the majority of teachers not having time meant that other demands of the job were more imperative and when they were done, time and energy for studying new things was limited. To recap the cases, Eva talked about not having time. In her case it meant she used the time at school to do her usual tasks that come with being a diligent good teacher, but did not place any of the day to day jobs aside to explore using ICT more in her teaching. She also did not have time at home being the mother of young children. For Anna not having time meant prioritising tasks regarding teaching two demanding subjects higher than learning new skills. For Olga it meant prioritising learning and brushing up on content knowledge. No energy was left to develop pedagogy involving ICT and she relied on teaching in traditional ways, despite having good technology skills. For Ellen time was not an issue. She was developing her teaching practices for the first time and incorporating ICT as much as she could. This was mostly because of her own interest and the knowledge that ICT could be beneficial to pupil learning.

These time issues are bound to be strongly linked to teacher beliefs about what is important because they inevitably affect choices and priorities.

The HBmodel includes teachers' beliefs about the educational purpose of ICT in education. Attitudes of teachers towards ICT were outlined in section 4.3 which drew a very positive picture, with a large majority agreeing to all statements in the survey. These positive beliefs do not correspond to the limited use reported as not all beliefs are reflected in practice (Mansour, 2009; Ertmer, 2000).

My study did not reveal strong beliefs about why or how ICT should be used. Fishbein and Ajzen (1975) argue that attitude formation needs to be looked at in conjunction with its informational base. Teachers beliefs that computers are supposed to be helpful for learning and motivating probably comes from other sources. In all likelihood teachers have not bought the discourse though they can speak it. An exception to this might be the younger teachers who have information from more trustworthy sources, as seen in Ellen who spoke about reading research showing the affordances and benefits of ICT.

Cavas et al. (2009) found in a survey of 1,071 science teachers that computer ownership and experience affected attitudes towards ICT use in schools. This may begin to explain the professed positive attitudes of Icelandic teachers which were seen in this study. All teachers in Iceland use computers in their work, and Icelandic homes have one of the highest ratio of high speed connections in the world. These positive attitudes are still not sufficient to drive technology integration. Other factors at work seem to have a stronger influence.

Though there is currently a discrepancy between the stated beliefs of science teachers and their actions, these beliefs are the first steps towards future actions (Fishbein and Ajzen, 1975). There is still a lot left here to explore. Research has shown that readiness for change and the willingness to go outside your comfort zone and try out new things, is a factor in teachers' CPD in regard to ICT implementation (Rodrigues, 2006). Early in this study two quotes showed two completely different attitudes towards exploring new things (see p. 97). These statements raised questions like: what is it that influences teachers' attitudes towards work and change? These questions drew my attention to literature about the attitude of teachers, however such research was too vast for this study. It seems that teacher attitudes are important and have a central place in technology integration. However, how and why that is, is outside the scope of this study and will need further exploration in the Icelandic context.

There were several indications that pupils' needs and opinions affect teachers in their technology integration. Teachers talked about engaging pupils with a variety of teaching methods. ICT was prevalent in that discourse (see section 4.3) where the use of ICT was believed to be a reason unto itself because technology appeals to pupils. This opinion of the teachers is supported in research where varying learning tasks and learning activities is suggested as a means to increase pupils´ interest and motivation (Pintrich, 2003). The belief that computers can affect pupil learning has led some governments to pour money into integration schemes (eg. Singapore, the first Master plan for Information Technology in Educationwas launched in April 1997.) In Icelandic policy documents ICT is perceived as a way to meet pupils current and future needs 'The Internet will play a key role in enabling students to engage in studies in many schools at once and shape the curriculum to their own needs' (Ministry of Education Science and Culture, 2001). As a result of this pupils have been added to the model. Their absence was noticeable in the HB model, where pupils and their views did not seem to play any role in affecting technology integration. Drent and Meelissen (2008) found links between innovative ICT use and teachers' pedagogical approaches. They argue that experiences with the use of ICT support student oriented approaches. This relationship seems to be reciprocal, teachers use ICT with pupils which again puts more emphasis on pupil centred learning.

Indications of subject culture as barriers in the Icelandic context were not obvious at first glance. Extrinsic factors were much more noticeable. Subject culture incorporates expectations of all stakeholders and traditions about how and why we teach science. In the model the subject culture is stretched across the continuum involving several aspects. Cuban (2001) suggested that the actual reasons for little technology integration are teachers' core values and beliefs about teaching. Core beliefs about teaching and learning could be seen in this study. Science is supposed to be about experiments and nature. Even the word in Icelandic *náttúrufræði* means ´the study of nature'. This understanding of science could be seen in teacher responses where they were more concerned with lack of practical work and field trips, than their limited use of ICT. In the interviews, when asked about ICT, teachers started talking about practical work, showing they perceived that as a much more pressing problem. The culture of science teaching dictated that the subject should be taught through practical work. The case of Anna also pointed to the low prestige of science versus other schools subjects.

I removed testing as separate factor from the amended model. However it is part of the subject culture of science that there are no standardised tests. Previous research had shown that during the years standardised tests were given teachers felt pressured by them (Þórólfsson et al., 2007; Sigþórsson, 2008). Having no tests is a double edged sword. Without that pressure teachers are not pushed on in developing more efficient ways of teaching. At the same time not having tests gives time and leeway for those that want to do develop their pedagogy. The TALIS study showed that more value is placed on good relations with pupils, parents and colleagues than on high test scores (Ólafsson and Björnsson, 2009). That kind of stance obviously encouraged some of the teachers to use ICT as doing so pleased pupils.

From the cases one can see how the whole culture of the school is rigid. Though the teachers verbalize their interest in new teaching methods, they revert and stick to the methods they know and are comfortable with. There has been evidence from other sources that teachers hold on to the methods they are used to and when faced with new technology use it only use it to support their current practice. Saye (1997) found that a majority of both pupils and teachers wanted to use ICT to support traditional ways of practice. However a minority valued the fact that it opened ways to more individualised learning. This minority had a higher tolerance for uncertainty. Teachers are themselves also conservative and teaching is a 'conservative practice' (Tobin and McRobbie, 1996). This 'conservative practice' applies to science teaching just as to any other subject where the accepted culture is that pupils sit quietly, facing the front, learning from the teacher. Computers change that. The teacher is no longer the focus of the pupil as pupils will have to move to the computers focusing their attentions on the screen. Most often they will move to another space in the school, perhaps to many different spaces. There were some indications that this was hindering teachers (see section 6.1.2, pedagogical factors). It bothered them to ´lose control´, not being able to see all students at the same time. It is clear that bringing technology into the classroom has some effect. It has been said that the first priority for a majority of teachers is to maintain order in the classroom and to have a controlled learning environment (Cox et al., 1999). Changing the environment is a threat to the teachers' control.

Another tradition that is hindering teachers seems to be an overreliance on textbooks. A seminal study (Sigurgeirsson, 1992) illustrated that teaching in Iceland is more governed by the textbooks than the curriculum. Science is no exception here. Talk among teachers about what they were teaching generally revolves around what book to cover for each year group, rather than what the curriculum guide suggests and certainly not to give the textbooks a break and use DLRs as a main learning resource. There also seemed to be a big difference there between teachers. Those that are confident generally could organise all kinds of different activities, but those less confident seemed more hesitant to let go.

The ICT culture within the school also affects teachers in their decisions. It is daunting when the culture is so that a teacher always has to start from the beginning; bringing pupils and technology together, the computers are turned off, pupils use them seldom, and there are often no set ways of saving and retrieving work. Issues such as these stemming from school and subject culture push technology integration far down the list of priorities.

A large spectrum of knowledge issues turned out to be a major barrier for teachers (see 5.1.6). Even active users of computers assign their reluctance to use computers to lack of knowledge.

The TPCK model reminds us that a different set of knowledge is needed to teach with computers than just knowing how to use them. TPCK includes 'knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings' (Mishra and Koehler, 2006, p.1028). These were all weak for a large majority of participants in this study. Lacking knowledge on how to use ICT in teaching is not a problem isolated to science; 58.6% of Icelandic lower secondary teachers say they need more training in using ICT in teaching (Ólafsson and Björnsson, 2009).

The survey indicates that teacher knowledge of equipment and applications is hardly a limiting factor. Teachers use applications more in other situations than in the classroom. A similar trend could be seen when teachers' competence in ICT use did not affect their innovative uses of technology (Drent and Meelissen, 2008). This suggests that teachers are more lacking in technological **pedagogical** knowledge than technical knowledge. A frequent complaint was not knowing where to look for DLRs and not knowing about science specific applications. Knowledge of the science curriculum and educational aims are considered part of science teachers' PCK (Abell, 2007). Teachers realised what the curriculum guide expected but not how to get there.

Content knowledge seems to be a barrier to technology integration as could be seen from the case of Olga. Previous evidence of teachers' content knowledge come from the TALIS study (Ólafsson and Björnsson, 2009) where teachers are said to have positive efficacy beliefs in terms of knowing the content, and 45,4% claim they need training in their teaching subject. This might be higher for science teachers since only 46% of them are qualified science teachers

(Ministry of Education Science and Culture, 2005). Not having solid knowledge of the subject you are teaching must mean that first of all that your time which should be spent organising ways for successful teaching must go into familiarising yourself with the topic. This leads to overreliance on textbooks and teaching by the book, not recognising the main big ideas and getting caught up in details because you do not know better. In this situation it is unlikely that teachers will really try much innovation in their teaching.

In the HB model assessment is a separate factor. In the amended model I removed assessment as there are no standardised tests in science. No evidence was seen of internal assessment in schools playing any part. One would assume though that curriculum and policy should affect practice. The teachers in the current study were not asked to articulate their views on external pressures. Nevertheless the views they expressed have similar characteristics as the expressed in Sugar, Crawley and Fine (2004) that “everyone” would approve of ICT use in schools, and “No one” would disapprove. That social support of ICT use had not been explicitly communicated, but rather felt as an indirect assumption. Still it is noticeable in this study how little mention there is of external pressure or expectations that teachers should use ICT in their teaching. Despite policy papers and a curriculum that states in several places that ICT should be used teachers did not mention this as a reason to do so. It is a long running thread in school development that the impetus should come from the ‘grass-root’ or from ‘above’. The research team at Kennisnet (see e.g. (ten Brummelhuis and van Amerongen, 2011; ten Brummelhuis, 1995) argue that a movement that starts with leadership and vision all under the umbrella of cooperation is way forward. Still, too much pressure from ‘above’ may have the opposite effect. Hennessy et al. (2005), for example, reported teachers that felt they had to use technology just for the sake of it and not because of its usefulness. This caused them feelings of disempowerment.

Seeing the world as black or white can never be fruitful and saying innovation has to come from above or from the grassroots is not a helpful distinction. This is followed up later in the recommendations.

7.2.1. Summary

Not one factor can be said to be the main cause for limited technology integration. Looking at the factors separately isolates them when in fact they in most instances are interwoven and connected in intricate ways. The working of the factors has been compared to a cog wheel that in a complex manner affect each other (Drent and Meelissen, 2008). Practical and technical factors such as equipment and support seem the most obvious barriers, but with them out of the way teachers must still find impetus and ways to integrate the technology into their teaching. Hew and Brush (2007) argue from their review that knowledge and skills are more important than tools or support from peers, but also recommend that further work is needed to examine that claim. This recommendation is repeated here as in the context of the current study all those factors appear to be weak so determining their rank of importance is not possible here though lack of knowledge and peer support seems most pressing.

7.3. Factors that influenced the impact of the interventions

The intervention part of this study was meant to answer the question would pupils using a selection of DLRs show more progress than pupils being taught using only textbooks. In all the interventions the impact from using digital learning resources was small, often borderline significant and in one case negative. The views of pupils and teachers on the resource effectiveness though largely correspond to the statistical results. Results from comparing the conditions give tentative grounds to assume that the differences found may be due to effects from the treatment. However other aspects are suspected to have influenced the impact of the interventions.

Three of these aspects are worth discussing. First, the results indicate that benefits from using DLRs vary between resources, drawing attention to different affordances or properties they may hold, and possible benefits that may accompany them.

Secondly, the influence of the relevance of the resources to the perceived importance of the learning aims and testing.

Lastly, the results from the classes indicate that the biggest effect was not from the resources themselves but from the teachers. The differences between classes across conditions are in some instances rather large and a pattern emerged putting the focus on the teachers more than the learning resources.

7.3.1. Resources and roles

Twining (2002) points out that a clear distinction needs to be made between intentions and what is actually achieved by computer use in education. Twining's computer practice framework and the four learning modes listed by Newton and Rogers (2003) (receiver, reviser, explorer and creator), introduced in section 2.1 are used here to reflect on the properties and benefits of the DLRs. Data from pupil progress in the interventions and their responses along with teacher opinions were used to determine whether the potential that the resources were believed to have during the design phase of this study seemed to have been realised (see below).

When choosing the learning resources an effort was made to find ones that could possibly extend or transform learning activities by putting learners in the role of explorer and/or reviser. This section discusses to what extent these goals and the goals of effective learning were achieved.

The resource *Erfðavísir* puts pupils in the role of receiver as pupils read and receive information from the website. It seemed to have the potential to put pupils in the role of explorer and reviser, by having non-linear navigation and interactive questions. This practice is in many ways similar to learning from a textbook and in that way supports current practice. The main issue was whether reading subject material from a website with some interactive material was in any way better than lecturing and reading from a book.

The results were that the comparison groups scored slightly lower than the intervention groups. Pupils did not engage with the opportunities to revise the knowledge and explore ideas. The animations did not seem to add enough to be said to extend the activity of reading. These results seem to support the criticism of DLRs that mostly contain reading material that they have little to offer beyond books. It still has to be taken into account that this website is not designed specifically for use in schools and pupils only used the resource at school and not at home unlike how a textbook would be expected to be used.

The question was also concerned with if using the website was different to listening to the teacher. Pupils for the most part agreed that lecturing is better, saying they understood better if the teacher explained well and it was better to be able to ask questions.

The conclusion seems to be that *Erfðavísir* puts pupils in the role of receiver which, in the way it was used in the intervention, supports current practice with little chance of transforming or extending science learning. The lesson to be learnt is that care has to be taken how such resources are designed and used. The big issue is not to replace books but to develop teaching methods and pedagogy that incorporates the best of both worlds, making learning science an engaging activity, whether at home or in schools.

The teachers did not believe that DLRs would replace books any time soon because schools are not sufficiently equipped for such a change. Recently e-books for other appliances other than desktop computers have emerged and other reasons than effective learning for using them. Those reasons include easy access, portability, low cost and that they are easy to make. Those reasons refer more to the static nature of books but new formats of digital textbooks aim to maximize the effectiveness of learning by adding search and navigation, audiovisuals, animations, 3D graphics and other state-of-the-art multimedia functions (Kim et al., 2010). Such pupil-centred textbooks allow pupils to work at different levels according to their needs. Whatever resource comes along teachers will need to integrate them into the work of pupils focusing their tasks and giving them purpose.

The website *Chembalancer* was the simplest and the best website in all the interventions (see 6.2.3). *Chembalancer* is basically a drill and practice resource, which puts pupils in the role of reviser. *Chembalancer* extends the task of balancing chemical equations in the sense that the task is still the same and could have been achieved without a computer. The task is extended though because the process of giving pupils feedback is changed. Every pupil gets instant feedback on their work instead of other slower and or less individualised methods. The property of the website of giving visual aid in building the molecules, may also be said to extend the task. These two features seem to have been responsible for the intervention classes scoring higher than the comparison classes.

The interactive tests used in this intervention are designed so that they only tell the user whether the answer is correct or wrong but give no further advice. This activity can also be done without a computer so the activity of revision is extended, but not transformed.

One interpretation of the findings is that DLRs will produce better learning results the more interactive features they contain. Two interactive simulations were supposed to be used in the intervention. *Sunny Meadows* in ecology and *Bug Lab* in genetics. They were believed to hold the potential to transform the activity of exploring on one hand the development of an ecosystem, and on the other, inheritance in bugs by modelling these phenomena in a simulation. Observing the development of an ecosystem could hardly have been observed otherwise in a classroom but exploring inheritance laws may to some extent be done in pen and paper based tasks.

It seemed from the observations that the more interactive the DLR, the more pupils engaged with them. This tendency seems to be reflected in the test results, in the sense that those DLRs that had pupils scoring higher, seen with *Sunny Meadows* and *Chembalancer*, which are highly interactive. *Erfðavísir* where intervention pupils scored lower, is only interactive to a limited degree. In the same way pupils had more positive views of those resources with more interactive features, as long as there were not too many complicated features.

Bug Lab seemed to have the properties needed to transform the task of understanding genetics laws, giving pupils an opportunity to observe and manipulate a population of bugs. Though highly interactive and therefore should have positive connotations, *Bug Lab* was deemed too complicated by one teacher. When observing pupils it was clear that it had too many features for them to navigate and partake in meaningful learning at the same time. It is known that when technical applications get too complicated they interrupt the purpose of using them, for example. Waycott (2004) found when looking at the use of personal digital assistants that the focus shifted away from the intended one when faced with novel interfaces and technical difficulties.

Sunny Meadows is also very interactive but much simpler than *Bug Lab* and more suited to the pupils' age. Both Ardac and Sezen (2002) and Steinberg (2000) suggest that the groups using simulations in their study did not show better progress due to the level of interaction with the simulation. Pupils using *Sunny Meadows* were highly active and the simulations helped them infer how ecosystems work, thus transforming the teaching and allowing them to explore phenomena they would otherwise not have been able to do. Though the positive effect was only medium sized, the pupil interviews revealed a stronger conceptual understanding than perhaps traditional knowledge tests reflected.

The types of resources that proved useful in the intervention are not available in Icelandic. The resources in English used in the interventions did not prove to be a big hindrance to pupils but they were chosen because of low language demands. Resources in pupils' mother tongue are needed to study complicated concepts and ideas.

The characteristics of successful DLRs as suggested from these interventions are that they are highly interactive without being too complicated. They put pupils in the role of explorer or reviser. That is not to say that resources that put pupils in other roles do not have a place in science teaching just that the ones used here did not prove successful. The resources used in the intervention mostly support or extend pupil learning. Only one of the resources selected did transform pupil learning in anyway.

7.3.2. Effects of testing and relevance

Teachers during the interventions were encouraged to make the URLs to the websites available to pupils. As it turned out, pupils did not seem to regard computers primarily as tools for learning. Pupils were asked what resource they had used to study for the test (see section 6). DLRs were in all cases used by less than 30% of pupils to study for the test. In comparison textbooks were used by over 63% to up to 91%. Pupils stated both in the questionnaire and focus groups that they realised that test questions would be based on the textbook so that was the resource they more or less all used. Still the nature of the resource seems to matter. There were some examples of pupils going back to interactive quizzes and Chembalancer but not to reading material or simulations.

The effect of using *Chembalancer* is larger than effects in the other two interventions. This may be in some part due to the nature of the task. In balancing chemical equations the task is exactly the same as in the test. The simulation *Sunny Meadows* is meant to increase understanding of a complex phenomenon but in that intervention the test tasks were quite different from the simulation. Another interpretation might then be that that the more alike the DLRs are to the tests the more likely one is to find a difference.

Testing may also have influenced difference between classes. In the genetic intervention it is quite striking that both Tina's classes raised their score well over 3 points or close to doubled their score, whereas others gained 25% or less. This may have many explanations, possibly that teachers made different use of the pre-test. It seems from responses that questions that were both on the pre-test and the post-test were discussed or taught specifically between the tests by Tina. An example is a question where pupils are asked to order by size, a body, a cell, a chromosome, a gene and DNA. The difference is striking, 44% of Tina's classes order correctly but 0-18% of the other classes. This may either have been knowingly or something that would have been done by Tina anyway since all her observed lessons seemed to indicate her being a highly efficient teacher.

7.3.3. Effect of teachers' pedagogical content knowledge

That teachers are important is well known from educational research. From a meta-analysis of over 800 studies one of the main conclusions was 'Teachers are a major influence on student learning' (Hattie, 2009 p.238). Educational change is dependent on 'what teachers do and think – it's as simple and as complex as that' (Fullan, 2007 p. 129).

Figure 7-3 gives an overview of all the post-test scores. When they are explored side by side a pattern can be seen. It shows that pupils of the same teachers tend to score similarly, though in most cases they are from different year groups. For example, classes taught by Tara and Olga tend to score low where classes taught by Ellen and Tina tend to score higher.

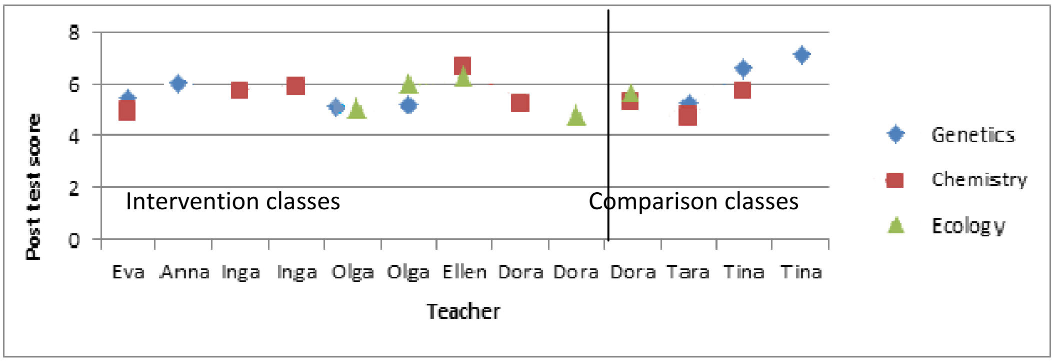

Figure 7-3 Overview of all test scores

This difference across conditions indicates that the resources used are not the deciding factor in pupil achievement but the teachers are. The observations of the participating teachers point to certain characteristics in their practice and preparation to have more say in how well pupils did. Observations showed these two sets of teachers being markedly different; on the one hand Tina highly efficient and enthusiastic, and Ellen, willing and able; and on the other hand, Olga struggling with preparation and content, and Tara's teaching methods lacking, among other things, in pace and preparation.

The lessons that had a successful sense to them had certain characteristics

- the teachers were well prepared;
- the lessons had a certain pace to them, with a range of activities in one lesson, a well thought out beginning and sometimes a defined end, with fairly quick transitions between activities

With these observations in mind and the fact that classes of some of the comparison teachers made better progress than intervention classes, it seems that the pedagogical content knowledge of science teachers may be a more important factor on pupil learning than the learning resources being used. Being a good teacher, having good PCK is more important than having DLRs.

7.4. Limitations and methodological comments

This study gives indications but not clear answers about the usefulness of the resources. By having many different resources insights were gained as to what features contributed to effectiveness. After this experience the attractiveness of studies with an iterative research design is understandable, for example studies such as those reported by Linn, Clark et al. (2003) which also includes the design of the resource along with the associated pedagogy. When the research reveals what parts were useful and which could use improvement, it is tempting to change the design but a onetime only quasi-experimental design does not allow that. The chosen quasi-experimental design is though the most appropriate though when effectiveness is the main issue concerned.

The good thing about this intervention is the ‘natural setting’ as the classes are taught by their teacher, in their regular lessons. Some interventions showing large effects of the treatment have involved a significant manipulation of the teaching situation, and so results have little transferability onto regular classroom teaching. Taking for example interventions where the researcher works with a small group of pupils (see e.g. Barton, 1997), in those studies it can be said that the learning environment becomes yet another variable to consider. Of course interventions such as this study require some manipulation of the learning environment like taking pupils to a computer room. However, this manipulation can quite easily become part of the regular practice for those wanting to capitalise on the effect reported in studies. Manipulation of teaching must be within reach for the everyday practitioner if studies are to be successfully replicated in practice.

Aspects of the methods in this study that give room for improvement are first of all the test design. As the resources in most cases covered only a small part of the curriculum, a short test on precisely that part may have been more appropriate. Using the regular assessment was chosen for sake of authenticity and to increase the likelihood of pupils taking the tests seriously.

The quasi-experimental design limited the guidance that teachers could be given because then the guidance would have become another variable to consider. In working with the teachers, what happened was that the proficiency of the teachers in dealing with new educational technology and resources became a variable. However this variable seems to be the same one that actually mattered more in the interventions; that is their TPCK and confidence.

7.5. Summary

This chapter discussed how the current uses of ICT in support and sometimes extend science teaching but have not have had the transformative effect on teachers and pupil roles that was suspected with the introduction of computers to schools. Furthermore it discussed the way the resources chosen for the interventions are all very different. What stands out is that none of them really transform pupil learning though many have the potential to extend classroom activities. Still the lessons learned are that visual elements and interactive features seem to facilitate learning and engagement.

Furthermore it argued that the use of DLRs do not provide a ‘dream ticket’ to science teaching and learning. The effective use of DLRs is dependent upon the strength of the teacher’s pedagogical content knowledge and can be seen as a potential area of development for the competent science teacher.

8. Conclusions and recommendations

I started this work intent on exploring why ICT had such a limited profile in science education and to provide evidence that it may be used for the benefit of pupils. My study showed the factors that affected teachers (see chapter 5 and section 7.2) and gave evidence on the effectiveness of a selection of DLRs (chapter 6) and discussed what did affect the outcomes (see section 7.3.) This last chapter sets out to tie this information into a set of suggestions relating to the findings. First some recommendations for the school system are presented, secondly for further research and lastly some final thoughts.

8.1. Recommendations for practice

During the data collection the focus of this thesis shifted from **why are teachers not using ICT** to **how can teachers' use of ICT be facilitated.** My study visibly indicates that teachers and their knowledge base was more important than the resources used, highlighted what has long been suggested that the best way to school development and technology integration is through supporting teachers (Cuban, 2001; Fullan, 2007). In the Icelandic context there are three interlinked recommendations arising from this thesis on how technology integration might be supported. Firstly, on the provision of physical tools together with the development of relevant DLRs and other resources, as a foundation for the successful integration of ICT into science teaching; secondly, concerning the need for CPD of science teachers, including the need for support and a collaborative community; and thirdly around the conceptual tools focused around a shared vision and a collective understanding of what role the educational community sees ICT playing in schools.

Even though ICT was first introduced to schools in the 1980s, schools have still not changed. This problem of teachers not using ICT extensively is therefore still relevant and maybe even more relevant now than in earlier years. Cavas et al (2009) suggest that:

> Being the prime actors in implementing ICT in learning and teaching, teachers should be in the centre of attention. They should be involved in all stages of the implementation and meanwhile be assured that this approach is advantageous over the previous one, is compatible with their teaching practices and they will be given any technical help and training. (p.29)

Specifically in the Icelandic context my recommendations are:

- schools need more resources, physical equipment and DLRs to meet the requirements that are made of them
- teachers need more support including:
  - increased CPD opportunities
  - communities of science teachers
  - active support from management.

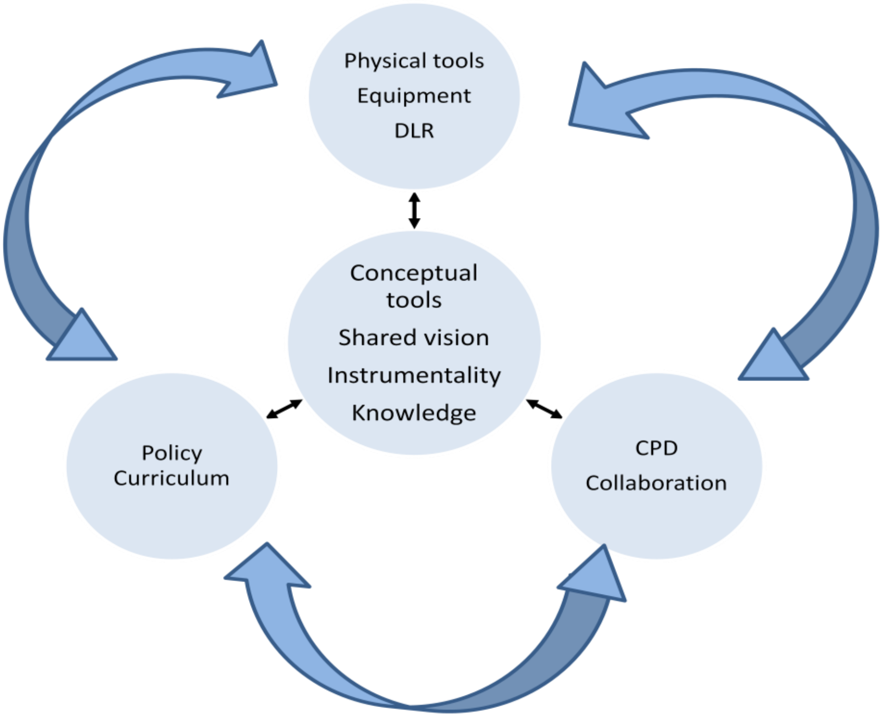

Figure 8-1 Development of conceptual tools

These recommendations are intertwined and centre around the notion that the Icelandic school system needs to develop conceptual tools, and a common understanding of how and to what purpose ICT should be employed in teaching and learning. The above diagram shows a suggested relationship between the components. It suggests that with policy and curriculum that leads to sufficient resources, supported collaboration and CPD there may develop knowledge of and understanding of ICT and teaching methods, perhaps inspiration for design of DLRs. These recommendations are further outlined in the next sections.

8.1.1. Physical tools – resources and DLRs

This thesis started out with the assumption that there were enough physical resources. In some ways that proved to be the case (see contradiction C section5.2.2), there are enough resources for the current mode of practice. However if there is a will to develop further to include a more varied use of ICT, that will mean that more or even different kinds of resources are needed. In order for pupils to use computers on a regular basis, the provision of one computer for classroom and one computer room per school is not enough. It has to be said here that since the start of this work that the available tools have changed considerably, that is to say on the market but not in schools. With the arrival of tablets and smart-phones initiatives have started in two schools one with the *Kindle* and one with the *iPad. A*t first glance it seems that especially with the *ipad* the teachers are experimenting with quite new ways of practice.

I suggest that the scarcity of relevant DLRs is not exactly an incentive for teachers to demand more computers, so an effort needs to be put into developing a selection of relevant resources in Icelandic. The interventions gave some indication about what features and characteristics successful resources need (as summarised in section 7.3.1). The experience from the interventions also suggests that DLRs need to have to be highly relevant to the intended learning aims. As it is, the availability is poor. This study showed that DLRs may be used for pupil benefit, but a greater variety of digital learning materials is needed, including learning resources relevant to all fields of science.

The last consideration I put forward is about resources is that the choice and provision needs to take notice of how and why they are to be used. The general school policy in Iceland is very much centred on individualised learning. The new general National Curriculum is built up around the *Key Competences for Lifelong Learning* (OECD). Emphasis is placed on skills, creativity, literacy, sustainability and pupil choice and autonomy. ICT can no longer be considered in isolation (Watson, 2006). A shift of focus from technology to learner is in order, where equipment is chosen and supplied because of learning and educational benefits and affordances rather than techno-centric enthusiasm.

8.1.2. Conceptual tools

Bringing in new technology needs new ways of thinking about teaching, namely what role ICT should play in schools. Ways of thinking may be referred to as an instrumentality, and if we want to take advantage of the whole potential of ICT for teaching and learning an instrumentality needs to be developed. Developing this instrumentality is a task facing the whole system: learners, teachers and other stakeholders; '*the learners construct a new object and concept for their collective activity, and implement this new object and concept*' (Engeström and Sannino, 2010 p. 2). The learners in this instance would be the teachers, who need support and collaboration in order to learn together guided goals set out by themselves, the curriculum and policy documents.

8.1.3. Collaboration and CPD

The last set of recommendations is about the need to build a set of conceptual tools, through collaboration and CPD. The isolation and lack of knowledge prevalent in the study was not expected. I had not anticipated how little knowledge teachers have of the possibilities of employing ICT in their teaching. The need to provide opportunities for collaboration, to facilitate flow and construction of knowledge of ICT relevant practises for teachers is clear. The interventions indicated that teachers need more than participating in small scale interventions to change their practice. This underlined that change is a gradual process.

Watson (2006) asks 'Is the teacher a catalyst or inhibitor, an innovator or conservator of the status quo?' (p. 203). The conclusion that can be drawn from this study is that teachers do differ in that regard. However, on the whole Icelandic teachers seem to be ready for change. They have positive views towards ICT, and they use what they have, but the system as a whole lacks the common vision and infrastructure to take the next steps. Donnelly et al. (2011) identified in their research that teachers differ in terms of technology integration, from creative adapters with a strong sense of empowerment in their teaching and wide PCK, to contented traditionalist with weak PCK, resisting change, and in between selective adopters and inadvertent users. They point out that different teachers dealing with different issues need different approaches. There are indeed teachers who take it upon themselves to learn and implement, but change on a systematic level needs official support. In a small country like Iceland it should be easy to identify the pioneers and support them in their endeavours and in inseminating their expertise for more widespread school development.

Official initiatives to increase the use of ICT have only made it past the policy papers to a limited extent. Younie (2006) reviewed official initiatives in the UK and found them to be problematic:

> Policy aims can be achieved if an awareness of the complexity of the implementation process is maintained, (by those implementing policy at the local level). This necessitates an understanding of the fact that it is a fluid, non-linear, reiterative process in which key factors are dynamically inter-related: namely, ICT needs to be implemented on multiple fronts, both materially in terms of an ICT infrastructure and culturally in terms of generating an ethos that values ICT for classroom practice (p. 399).

The initial provision of equipment had the characteristics of a movement from the right (top-down) in the *Four in Balance model* (ten Brummelhuis and van Amerongen, 2011) starting with ICT infrastructure and ending with leadership. ten Brummelhuis and colleagues (2011) argue that the movement needs to be from the left starting with a common vision and ending with the then recommended provision of appropriate equipment. This corresponds with the stepwise progress toward designing and implementing an instrumentality.

> The notion of an instrumentality refers to the entire toolkit used in an activity, understood as a multi-layered constellation, which includes both material and conceptual elements (Engeström and Toiviainen, 2011, p. 36).

Here the activity would be using ICT for teaching and learning and the instrumentality would include vision, expertise and skills in integrating digital tools successfully into the learning process, most likely redesigning it at the same time.

The learning process of developing an instrumentality will not happen by itself nor with individual teachers. Though teachers are willing and able this is not enough. Research has suggested that one characteristic of management in high ICT using countries is a bottom up change-orientation, where teachers and/or students instigate change (Pelgrum and Voogt, 2009). Similarly Fullan (2007) suggests that the initiative for successful change needs to come from both the bottom and the top.

This was also the approach used in the OECD DLR study. Country coordinators were asked to find examples of both policy and practice and see whether together they have some sort of systemic effect on education (Macdonald, 2008a). One of the weakest links in Iceland was the provision of grants, particularly follow-up support, to projects that had shown themselves to be successful. A financial basis for maintaining innovate ICT work and the production of DLRs was not available. Figure 8-1 in that spirit does not show a linear process but an interwoven circular motion where the initiative may come from any direction and all elements have effect upon each other.

The question is then whose responsibility it should be to initiate collaboration and CPD overall. A recent report from Ministry of Science, Education and Culture (2010) states that it is the responsibility of almost all stakeholders to be responsible for CPD and school development including the ministry and the individual teacher. Though in practice, it is the headteacher in each school that is responsible for the school curriculum and CPD.

There are many overlapping reforms such as anti-bullying, restitution, inclusion, individualised learning and fewer initiatives from authorities on ICT implementation. Previous ministers seem to have placed more emphasis on technology with numerous policy documents (see introduction). Now ICT has not even made it as a ‘pillar’ in the new curriculum, though it is separate in the original OECD documents. Still ICT, cloaked as technology literacy, has found its way there, and there is an emphasis on applied and integrative science and there is a great emphasis on creativity and sustainability.

As a result of this thesis steps have already been taken to build a community of teachers with the help of online environments and two grants. An ongoing series of workshops was started around different themes with presentations from both practicing teachers and lecturers from the University of Iceland. A *Facebook* group was started in spring 2011 and in August 2012 had around 100 members, who share ideas and resources, debate, ask for and give advice.

Fullan (2007) states that communities of practice have not really taken off with any depth or spread. In the few years since he stated that social media has flourished exponentially, making it far easier at least to grow but to what depths the learning and interactions an online community of science teachers may reach is yet to be seen. I believe that as teachers become used to going to an online community for advice and reflection social media may greatly support CPD by providing opportunities and resources for learning and cooperation when, and if, needed.

8.2. Recommendations for further research

This study did not give clear indications as to how or to what extent teacher beliefs and attitudes affect their ICT use. One of the side roads that this thesis could have gone towards is exploring further teachers' attitudes towards work, including 'going the extra mile' and why we prioritise so differently (see section 5.1.5). Issues around efficacy, ambition, incentives and why some are willing to put in a little effort to implement changes and innovation but not all are of interest. Others have also suggested that more work is needed in that area (Ertmer, 2005; Mansour, 2009). This recommendation is repeated here but also emphasising the need to explore to what extent those beliefs may be influenced.

The intervention part of this study showed that existing DLRs may be used in science teaching with some positive outcomes. Evaluation of usefulness of the most common uses found in this study has not been carried out. It would be beneficial for future practice to have an inkling as to whether these uses are benefitting pupils in the way intended. Especially since the new National Curriculum seems to expect further independent pupil work. It is clear however that the resources and the vast array of digital tools are expanding exponentially. After my experience with the quasi-experimental interventions it is my contention that getting teachers involved in research with a design based (see for example Juuti and Lavonen, 2006) element would be more sensible . Working with a community of teachers may give opportunities for short research informed studies promoting discussion and reflection with action research elements. This would at the same time facilitate a development of a common vision for ICT use in teaching with teachers collaboratively trying out innovative ICT uses reflect on them and report to colleagues. This would provide a more systematic recording of elements of the resources and the way they are employed in teaching and what needs amendment.

8.3. Contributions

This thesis has provided a comprehensive overview in regard to ICT use in lower secondary science teaching in Iceland, from the availability of resources and how they are used to teacher and pupil attitudes towards the current practices. Such a comprehensive overview was not available before and will prove a valuable addition to existing literature on ICT implementation and school development.

This study highlighted the factors that affect Icelandic teachers in their technology integration. This work has established that implementing technology is a complicated process and that the conditions that affect teachers are numerous. There is rich potential for using ICT in science teaching but also barriers that need to be overcome. Not one actor can be held responsible for low technology integration, all stakeholders need to take an invested interest and commit to further development.

In this thesis I used cultural historical activity theory to analyse and reflect on aspects of teachers' lives and their own practice. This use of activity theory shed light on aspects that otherwise might have been overlooked or misinterpreted. Methodologically, this study shows the value of collecting different kinds of data to be able to compare and contrast qualitative and quantitative data to give a rich description of a complex reality.

Last but not least the importance of teachers was emphasised as they proved to be just as important and in some cases more important than the resources used. This is important evidence that this is still the case. ICT implementation has often been characterised by bringing in equipment and expecting teachers to just take to it like fish to water (Cuban, 2001). That has not happened and my study is a timely reminder in times of rapid technology influx that a sound TPKC does not emerge by itself for majority of teachers.

8.4. Concluding remarks

Böhm (2004) said 'Frequently investigators experience difficulties in sticking to the central proposition of the investigation because of the 'surfeit of important details'' (p. 274). At the beginning of analysing the interviews, I found that teachers had spoken about all different kind of things other than those I had asked about. For example, I asked about what resources they needed and they would start talking about practical work and outdoor education. Being a novice interviewer, I found this all really interesting and got side-tracked. Now at the end of this road, I wonder whether this was not also a sign of the urgency or better yet lack of urgency that teachers view ICT use. Maybe other matters are far more urgent? Maybe teachers are more concerned with practical work, assessment, classroom management and other things they started talking about. Or maybe this is also a sign of the lack of knowledge that I found, that by teachers not knowing about the affordances and benefits of ICT in teaching science they do not realise the urgency of the matter!

My study has shown that ICT and DLRs may be used for pupil benefit but that it also takes skills and knowledge on the teachers' part. The effect that teacher expertise has on learning may not be underestimated. In the coming years I will do my best to implement the recommendations put forth in this thesis to nurture my own and my colleagues expert TPKC so we may bring Icelandic schools into the 21st century with innovative technology rich science teaching and learning.

"Computers are not magic, teachers are magic."

~Craig R. Barrett, Intel Chief Executive Officer (Barrett, 2005)

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List of abbreviations

CPD – continuous professional development

DLR – digital learning resources

ICT – information and communication technology

IWB - interactive whiteboard

OECD - Organisation for Economic Co-operation and Development

NCEM – National Centre for educational materials

MSEC – Ministry of science, education and culture

Menntamálaráðuneytið

Mennta- og menningarmálaráðuneytið

TPCK - technological pedagogical content knowledge

Appendices

There are two appendices

All resources used in this study may be found at:

http://svavap.wordpress.com/edd-thesis/

A. Questionnaire

This is the Microsoft Word version of the questionnaire in English, the online version in Icelandic can be seen at:
http://www.surveymonkey.com/s.aspx?sm=nXb7z_2ft9Ok6uBECS8e_2fU5A_3d_3d

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The uses of ICT in Science Education in Iceland

1. Introduction

I kindly ask science teachers of grades 7 – 10 (ages 12 – 16) in Iceland are to answer this questionnaire. It is part of my doctoral degree at the University of Leeds. In my thesis I will be exploring the uses of ICT in teaching Science. In this part of my study I am interested in exploring what factors influence whether and how Icelandic science teachers use ICT in their teaching also their attitudes towards its use.

The information you give will be treated as completely confidential. I have obtained a permit from the personal data protection agency. If you have any queries about the purpose of this questionnaire, or would be interested in the results, please feel free to contact me at: ed07sp@leeds.ac.uk or svavap@hotmail.com

Regards Svava Pétursdóttir

2. Background information

1. Age

☐ 30 or under
☐ 31 – 40
☐ 41 – 50
☐ 51 60
☐ 60 +

2. Gender

☐ Female
☐ Male

3. Background information- continued

1. What is your level of education? Please tick the highest relevant degree.

Degree | field or specification

- ☐ B. Ed degree from Icelandic teaching university __________
- ☐ B. Ed degree from Akureyri University __________
- ☐ Teacher degree from Icelandic Teachers school __________
- ☐ B.S/B.A. degree with teacher certificate __________
- ☐ B.S/B.A. degree without teacher certificate __________
- ☐ Other, what ?________________________ _______________

2. Do you have postgraduate education?

- ☐ Yes, what? ________________________
- ☐ No
- ☐ I am currently studying, what? ________________________

3. Teaching experience in years _______ thereof science teaching ___________

Drop down menu		
	0 - 5 years	0 - 5 years
	6 - 10 years	6 - 10 years
	11 - 15 years	11 - 15 years
	16 - 20 years	16 - 20 years
	More than 20 years	More than 20 years

4. Size of school

- ☐ under 50 pupils
- ☐ 50 – 100
- ☐ 100 – 200
- ☐ 200 – 500
- ☐ 500 +

4. *Use of ICT in science teaching*

This section is about what kind of ICT resources are available in the school and whether you use them.

1. **Hardware and facilities** please tick the one best applicable. If you teach in many rooms answer for the one you use most.

N=123	Yes and I use it often	Yes and I use it occasionally	Yes but I never use it	No it is not available
There is a computer in my classroom	45%	19%	1%	36%
The school has provided me with a laptop	36%	17%	2%	45%
There are 2 or more computers in my classroom	10%	10%	0%	79%
There is an internet connection in my classroom	57%	35%	2%	7%
There is a projector in my classroom	42%	18%	1%	39%
There is an interactive whiteboard in my classroom	11%	1%	1%	87%
Students have access to computers in the school in library or other common areas	29%	49%	10%	12%
My school has a laptop trolley available	16%	18%	9%	58%
There is a computer room/cluster with enough computers for each student in a whole class	21%	41%	10%	27%
Web based learning environments eg. WebCT or http://moodle.org/	5%	4%	10%	81%

Other available computer hardware___________________

2. What kind of data loggers and other digital science equipment is available in your school?

5. Your computer usage

Please tick all that you use

Here you may tick as many options in each line as applies.

N=121	Use it for personal purposes	Use it for planning and jobs within the school other than teaching (work without students)	For teaching purposes (work with students)	Never use it	Do not know what this is
Internet	83%	95%	83%	0%	0%
E-mail	83%	79%	24%	2%	0%
Word-processing software e.g. Word	71%	88%	70%	1%	0%
Spreadsheets e.g. Excel	57%	62%	35%	16%	2%
Databases e.g. Access	8%	7%	5%	41%	29%
Presentation software e.g. PowerPoint	49%	78%	75%	3%	0%
Photo editing software	32%	37%	26%	34%	4%
Making web pages	19%	11%	12%	55%	9%
Publishing software	31%	31%	36%	36%	7%
Forums	25%	6%	4%	56%	10%
Chats,	31%	4%	3%	51%	10%
Mind-mapping software	17%	23%	11%	41%	21%
Mp3 players	27%	10%	18%	46%	8%
Digital cameras	51%	50%	57%	17%	1%
Data loggers	4%	8%	12%	50%	23%
Educational software on CD ROM	14%	26%	45%	33%	6%

Other please specify ______________________________

6. Internet use in science education

Please tick all that apply

(At the end of this questionnaire all these links and more will be available for you)

Students in my class use the internet to:

N= 112	Used often	Used some-times	Never used	Not available	Do not know what this is
Research for essays and other projects	35%	59%	5%	0%	35%
Read information from learning websites e.g. http://www.namsgagnastofnun.is/lotukerfi/Lotan.htm or http://www.gen.is/	22%	57%	20%	1%	22%
Do exercises an quizzes e.g. http://www.ismennt.is/not/einarjo/sjalfsprof/rafmagn1.htm or http://funbasedlearning.com/chemistry/chembalancer/default.htm	8%	29%	55%	8%	8%
Use interactive simulations eg. http://www.scienceyear.com/wired/index.html?page=/planet10/	2%	7%	63%	28%	2%
Do interactive experiments http://resources.schoolscience.co.uk/BritishEnergy/11-14/circh3pg1.html	3%	17%	50%	30%	3%
Watch video e.g. experiments http://www.nams.is/efnisheimurinn/index.htm	24%	55%	18%	3%	24%
Make simulations using e.g. Phun http://www.phunland.com/wiki/Home	2%	1%	58%	39%	2%
Publish their work e.g. texts or photos on web-pages	7%	26%	62%	5%	7%
Publish their videos e.g. on http://teachertube.com/	4%	9%	69%	19%	4%

Please add other if applicable_______________________

7. Recent use of ICT

Please describe a recent science lesson or set of lessons using ICT. Please include as many details as you can.

Read through all the questions before you begin answering this page

1. Did the pupils work by themselves or in pairs or groups?

2. What was the students' task?

3. What science content was being covered?

4. What hardware was being used?

5. What software was being used?

6. What was your role in the lesson?

7. Do you think the students learned much from the lesson?

8. Where the students engaged and worked well during the lesson?

8. Factors that influence my use of ICT

1. What factors do you think make it easy for you and encourage you to employ ICT with pupils?

2. What factors do you think stop you or discourage you from employing ICT with pupils?

9. Support and assistance

Please tick everything you have access to

- ☐ Science head of department/coordinator
- ☐ Support of colleagues within the school
- ☐ A supportive management team
- ☐ ICT coordinator- consultant within the school
- ☐ ICT coordinator outside the school
- ☐ Support in setting up computer equipment
- ☐ Support in using software
- ☐ Support for preparation of practical work that includes computers
- ☐ Support, assistance during practical work
- ☐ Other ____

10. Training and courses in using ICT in Science education

1. Have you had any training in using ICT in teaching generally?

   Yes ☐ no ☐

   If people answer yes> go to question 2, if no > question 3

2. Please give more information about the training you have had

3. Have you had any training in using ICT in teaching Science?

   Yes ☐ no ☐

If people answer no > next section if Yes > question 4

4. Please give more information about the training you have had

11. My approach towards ICT use in science education

Please tick the one that applies to you

N=47 *	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
I use ICT often in my science teaching	34%	45%	9%	11%	2%
I trust that the ICT equipment will work during the lesson	40%	40%	6%	6%	6%
I only use ICT when student can work individually on a computer	2%	6%	26%	45%	21%
Most of my pupils can use software in English	19%	40%	23%	11%	4%
I am not afraid to make mistakes in front of a class	45%	38%	4%	6%	6%
I feel confident using ICT in front of students	40%	47%	6%	2%	4%
I feel confident managing a class using ICT	43%	43%	4%	6%	4%

*There was a mistake with skip logic and first 47 did not see this question

12. My attitudes towards ICT use in science education

N=93	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
I think ICT is a valuable resource in science education	60%	35%	5%	0%	0%
I believe ICT is a great tool for learning	60%	35%	4%	1%	0%
I think ICT can make teaching easier	53%	32%	10%	4%	1%
I think ICT use can be very motivating for students	57%	36%	5%	1%	0%
I think students learning can benefit from ICT use	53%	38%	7%	1%	0%
I feel ICT can have a positive impact on the way we teach	50%	39%	9%	2%	0%
I am aware of what role ICT should play according to the National Curriculum	19%	47%	26%	7%	0%
I think that ICT is relevant to the science curriculum	27%	37%	31%	5%	0%

13. Science content and ICT

In this section I want to find out what science content you think might benefit from a different approach using ICT, both concepts that you feel that students perceive as difficult and/or you find it difficult to teach, please be as SPECIFIC as you can

1. Science that I find difficult to teach, please be as specific as you can.

2. Science that students find hard to learn, please be as specific as you can

Thank you very much for taking the time to answer this questionnaire

—o—o—o—o—o—o—o—o—o—o—o—o—o—o—o—o—o—o—o—o—

I am looking for teachers to work with, in the next phase of my research which would involve interviews and/or a teaching intervention. I am both looking for experienced and inexperienced teachers and users of ICT in teaching.

If you are interested can you please submit you contact details, this information will be detached from your answers during data analysis.

Name:

Email:

Phone number:

School:

B.ANCOVA tables

ANCOVA - genetics

Tests of Between-Subjects Effects

Dependent Variable: Post test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	53.137	2	26.568	14.414	.000	.195
Intercept	252.505	1	252.505	136.989	.000	.535
pre-test	38.284	1	38.284	20.770	.000	.149
Condition	19.835	1	19.835	10.761	.001	.083
Error	219.347	119	1.843			
Total	4382.249	122				
Corrected Total	272.483	121				

a. R Squared = .195 (Adjusted R Squared = .181)

Parameter Estimates

Dependent Variable: Post test

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	4.685	.379	12.348	.000	3.934	5.436	.562
pre-test	.390	.086	4.557	.000	.221	.560	.149
[condition=Intervention]	-.816	.249	-3.280	.001	-1.308	-.323	.083
[condition=Comparison]	0	.	.	.	.	.	.

ANCOVA- balancing chemical equations

Tests of Between-Subjects Effects

Dependent Variable: Balancing chemical equation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	192.489	2	96.244	11.031	.000	.145
Intercept	385.414	1	385.414	44.176	.000	.254
pre-test	99.848	1	99.848	11.445	.001	.081
Condition	111.964	1	111.964	12.833	.000	.090
Error	1134.188	130	8.725			
Total	5556.000	133				
Corrected Total	1326.677	132				

a. R Squared = .145 (Adjusted R Squared = .132)

Parameter Estimates

Dependent Variable: Balancing chemical equation

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	2.834	.666	4.258	.000	1.517	4.151	.122
pre-test	.517	.153	3.383	.001	.215	.820	.081
[condition=Intervention]	1.878	.524	3.582	.000	.841	2.915	.090
[condition=Comparison]	0	.	.	.	.	.	.

ANCOVA -ecology

Tests of Between-Subjects Effects

Dependent Variable: Post test scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	68.075	2	34.037	14.640	.000	.243
Intercept	132.311	1	132.311	56.907	.000	.385
pre-test	57.785	1	57.785	24.854	.000	.215
condition	3.920	1	3.920	1.686	.197	.018
Error	211.577	91	2.325			
Total	3181.823	94				
Corrected Total	279.652	93				

a. R Squared = .243 (Adjusted R Squared = .227)

Parameter Estimates

Dependent Variable: Post test scores

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	3.227	.459	7.038	.000	2.316	4.138	.352
pre-test	.555	.111	4.985	.000	.334	.777	.215
[condition=Intervention]	.414	.319	1.298	.197	-.219	1.046	.018
[condition=Comparison]	0	.	.	.	.	.	.