LiFE: Learning in Future Education

Evaluation of innovation in learning using emerging technologies

-by-

Professor Anne Bamford

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Executive summary

Known as the “Learning in Future Education” or “LiFE” project, a team of researchers led by Professor Dr Anne Bamford, Director of the International Research Agency and Director of Education undertook a detailed research investigation of the impact of 3D on pupils’ learning. The goal of the LiFE 1 project was to determine the most effective type of 3D experiences and to measure the value and impact of these experiences on pupil learning and achievement. The pilot research also examined learning strategies and teaching processes and measured the meaningful impact on educational outcomes.

The research took place between October 2010 and May 2011 across seven countries in Europe. The study focused on pupils between the ages of 10-13 years learning science-related content.

The research project involved 740 students, 47 teachers and 15 schools across France, Germany, Italy, Netherlands, Turkey, United Kingdom and Sweden and took place October 2010 – May 2011. Equality of access is the law in Europe so the schools included children from different backgrounds and with learning or behavioral challenges integrated into the general classes. The 15 schools in the study were selected on the basis of direct contact as well as from recommendations by local education authorities. All schools voluntarily agreed to participate. The study involved: private and public schools; single sex schools; city schools and rural schools; high and low academic achieving schools; technology-rich and technology-poor schools; large schools and small schools; primary, middle and secondary schools; and experienced and less experienced teachers.

Results were gathered on how pupils understood the concepts being presented and the differences noted between 2D and 3D presentation. The research also examined classroom pedagogy and the way teachers worked with the 3D technology. Researchers collected both quantitative and qualitative data based on multiple interactions within each classroom. For the quantitative portion, pupils were tested before and after the lessons with a “control” group learning in 2D only and the other group receiving the same instruction plus 3D. Pupils were also tested on their ability to retain and reinterpret the information through an open-ended task.

Researchers collected observational data on the engagement level of students. Records were made in relation to communication (e.g. how many pupils were talking, asking or answering questions), attention (how many pupils were watching and not distracted), and behavior (how many pupils were disrupting others or off task).

The results of the study showed consistent reporting of improved test scores. On average, 86% of pupils improved from the pre-test to the post-test in the 3D classes, compared to 52% who improved in the 2D classes. Individuals improved test scores on average 17% in the 3D classes, compared to an 8% improvement in the 2D classes between pre-test and post-test.

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1 Eight countries were included in the trial, including Finland, but Finland has been excluded from the research report as their data was collected internally and therefore not verifiable for inclusion in the research report.
There were also behavioral and communication changes and improved classroom interaction. For example, **92% of pupils on average were attentive during the 3D part of the lesson** while only 46% were actively paying attention during the non-3D part of the lessons. The rate of ‘on-task’ conversation and questions from pupils increased after the 3D part of the lesson. Pupils were highly motivated and keen to learn through a 3D approach. The teachers found that the use of the DLP 3D technology led to a deepening of pupils’ understanding, increased attention spans, more motivation and engagement.

The pupils in the 3D class were more likely to recall detail and sequence of processes in recall testing than the 2D group. The 3D pupils were also more likely to perform better in open-ended and modeling tasks.

Teachers within the LiFE project found it easy to integrate 3D technology into their regular lessons with six out of the 15 schools also modifying teaching and learning pedagogy in response to the introduction of 3D. Teachers felt that 3D animations allowed them to teach topics in more depth and less time than conventional teaching methods. The teachers and pupils proposed ways that 3D could be successfully integrated across the curriculum.

Parents indicated strong support for the introduction of 3D into the classroom. There was acknowledgement that 3D offered enormous potential to enhance pupils learning and retention and that it should be available at home as well as at school.

While the overall results of this initial research study indicate strong evidence of a positive impact on 3D animations on pupils’ learning and classroom interactions, further research is needed on reported health experiences on first use and on the design and usability of the interactive glasses. As with all new technology, models of innovative pedagogy and learning examples are also needed to continue to reflect on its effectiveness on learning now and into the future. The report draws attention to key aspects of 3D technology and makes recommendations for the future integration of 3D into learning.

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2 **Digital Light Processing (DLP)** is a trademark owned by Texas Instruments. DLP 3D is a form of interactive 3D based on digital light projection. Unlike other forms of 3D it enables a ‘solid’ object to appear to be projected directly in front of the child. The single-chip version of DLP is used in modern colour digital projectors, with the two technologies being used in over 95% of the projectors currently sold. DLP is the form of 3D used in digital cinema projections.
Chapter 1: Background to the study

1.1 Introduction

LiFE is an acronym standing for “Learning in Future Education”. LiFE 1 was the first phase of an on-going research process and evaluated the implementation of 3D projection technology in seven European countries. The project involved 15 classes testing 3D and 15, 2D ‘control’ classes across the seven countries. There were 740 pupils, 47 teachers and 15 schools directly and indirectly involved in the 3D pilot. There were six IT coordinators and 12 researchers, including two doctoral students across the various countries assisting with the research. The project began in October 2010 and was completed in May 2011, with interim findings and presentation in January 2011 and final reporting in June 2011. The LiFE 1 project was conducted with pupils aged between 10-13 years of age and focused on the science curriculum area, in particular, a theme of work around ‘the body and the senses’. Most schools conducted the project for 6-8 weeks and had three lessons per week, though this pattern varied to meet the needs and restrictions within each school and school system.

1.2 Aim

The goal of the LiFE 1 project was to determine the most effective type of 3D experiences in the classroom and to measure the value and impact of these experiences on pupil learning and achievement. The research also examined learning strategies and teaching processes and measured the meaningful impact of 3D on educational outcomes. Within this broadly stated goal, the research aimed specifically to:

1. Conduct an empirical review and evaluation of eight weeks of implementation of the use of 3D projection technology known as Digital Light Processing (DLP) in 15 classrooms.

2. To identify, document and analyze case studies of the use of DLP in two classes (pupils aged between 10-13 years) in each of the following European countries: England, Germany, France, Italy, Finland, The Netherlands, Sweden and Turkey.

3. To formulate a set of quality examples and recommendations of strategies to strengthen the use of DLP in the classroom.

4. To advise the key political decision-makers in each of the participating countries of the use of DLP in innovative education.

5. To develop a set of best practice indicators that can be used internationally as part of the future application of DLP.

1.3 Method

The sample schools were chosen based on targeted sampling, with the aim of including a range of possible school types. Within the sample schools there were private, semi-private and public schools; single sex schools; city schools and rural schools; high and low academic achieving schools; technology-rich and technology poor schools; large schools and small
schools; primary, middle and secondary schools; and, experienced and less-experienced teachers. Some schools were selected on the basis of direct contact while others were recommended by local education authorities. All schools volunteered to participate and were free to withdraw from the project at any point. Two of the initial schools did not complete the full research program.

European law requires equality of access for all children, so the schools included children from different backgrounds and with learning or behavioral challenges integrated into the general classes. In half of the research countries involved, permission to conduct the research was granted from the Ministry of Education with the ministries taking a keen interest in the results and impact of the project. In these instances, the Ministry (and sometimes local education departments) have sought a copy of the report and details of the impact of 3D. The general opinion was very favorable to the research, praising its independence and cooperation between different technology companies to support classroom research. In all but one country, all the pilot tests were undertaken in 'normal classroom' situation. In one country a special ‘experimental classroom’ was used that enabled detailed recording of the children's responses.

In each school there was a ‘control’ class and a 3D class. Both classes had the same instruction but the 3D class also had the 3D resources. The content was the same for each class and all classes had content based on science – specifically, the senses and the body. As conducting educational research requires a naturalistic setting, all schools were free to organize learning in their usual manner and adhering to their required curriculum as long as both the 2D and 3D classes followed the same content and had the same instruction methods, except for the inclusion of the 3D. In some cases, the same teacher taught the 2D and 3D lessons and in other cases a ‘team’ of teachers worked on the project. In each of the pilot classes, the pupils did not use 3D in every lesson, but rather 3D was inserted where relevant into the lessons where it was deemed applicable. For example, in Turkey, they had on average five science lessons per week and generally 3D was used in some way in 2.5 of these lessons. It was also recommended that the 3D should only be used for about 15 minutes in each lesson. The longest example observed used 3D for 26 minutes and the shortest for 4 minutes. The average length of use of 3D was 12 minutes per lesson observed. As one teacher in the English pilot school stated, “The 3D comes in to the lesson... Makes an infinite difference and then goes back again. It really makes a phenomenal difference.”

Pupils and teachers completed online pre- and post-research surveys. In some schools, completing the survey was compulsory, and in other classes it was optional (depending on school policy). The first survey was completed by both the 2D and the 3D classes, while the second survey was completed only by the 3D classes. The survey was available in all the participating languages. The survey questions were translated by research participants or coordinators in each country to ensure accuracy and appropriateness.

Both 2D and 3D classes were pre-tested and post-tested. Each school arranged their own pre- and post-test and the same test or task was administered before and after the project.

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1 Or the relevant nominated local authority.
Results were not compared across schools, but rather each individual pupil was compared against their own pre-test performance to determine the extent and nature of changes that occurred. An open-ended recall exercise (task) was also administered after four weeks. This task asked pupils to recall anything they remembered about what they had learnt in the unit. Teachers reported qualitative and quantitative changes they noticed.

We used a multiple choice pre-test for both the 2D class and the 3D class. We are doing a unit on the five senses. It fits very well with our curriculum. Each week we have .... Lesson time and it is usual for us to do one week for each sense, so a week on smell, one week on hearing and so on. The eye and the ear usually take the longest for the children to understand. The pupils are age 13.

In one school, the pre- and post- tests were done using the SMART electronic questionnaire.

Conducting the pilot as part of the regular day-to-day business proved to be quite a logistical challenge. Firstly, each country involved had differing levels of regulation regarding conducting research in the classroom. For example, in Finland it was not possible at all for external, independent researchers to enter the classrooms. This restriction meant that the Finnish example had to be treated as a 'one off' case study and the data excluded from the general comparisons made.

In each country, two or three schools were a part of the research and in each school there were at least two participating classes. While you would expect that this would give some consistency, at least within the country, this was not the case. Increasingly in Europe, schools are becoming quite autonomous, especially those schools operating in the private sector. In each school, there were timetable issues and the difficulties of fitting the demands
of the research around these constraints. The issue of 'timing' was exacerbated in schools with a fixed projector as not only was the class timetable juggled but also room booking and movement of pupils had to be factored in.

While initially the intention was that the age of pupils in the pilot would be 10-12 years, slightly older pupils (up to 14) were included as their ages matched the content available in terms of demands of the curriculum. This did not affect the validity of the data collected as each participating sample group were pre- and post-tested, and thus like was compared with like.

Additionally, there was an ethical challenge, in that in each school, one class learned the content using 3D while the other class learned the same content but did not have the 3D. Given the nature of the school playground, pupils in the 3D class would tell the other pupils and over time demand became strong from the pupils 'missing out' to also get the 3D experience. In many case, the schools allowed this to happen following the end of the official 6-8 weeks of the pilot phase. This meant that in some instances, pupils in the 'non 3D group' were also exposed 3D after the research period. This impacted upon the veracity of the results in the testing of retention that followed one month after the conclusion of the research phase.

The teachers were generally very enthusiastic and positive to participate in the research project as the following comment from a teacher suggests:

I was a bit afraid. I have only been teaching for four years. I felt a bit nervous. I thought, be careful and I can do this. I told my father that I am trying 3D as a teacher and he was very interested and excited for me. It is a wonderful opportunity doing this pilot. He was saying, why don't you go to London and to Paris! Everyone has been supporting me in this pilot and I realized I could do it. I like the project and that is important. I think the project will be important for the future of education. I want to do my best in the project. I am not a closed-minded person. I am open and flexible. Flexibility is important. The principal told me I was coming to England to talk about the project. I jumped and screamed. I was so excited. It is my first time to England!

The survey results also indicate that the pupils were generally very happy to be part of the research process with only 3% of pupils not liking being part of the research process (see Figure 1.3.1).

Figure 1.3.1 Pupils' attitude to researchers and visitors coming to the class
More generally, 88% of pupils felt that the 3D project was good or very good with only a % dissatisfaction result 3% (see Figure 1.3.2).

**Figure 1.3.2 The 3D project was...**

![Pie chart showing pupil satisfaction with the 3D project]

Two observational visits were competed with each class. During the visits, 3D classes were observed and principals, parents, teachers and pupils were interviewed. During the observations, interval tracking was used to determine patterns in children’s behavior, communication and attention. The researcher adopted a ‘fly on the wall approach’ and did not interfere in the lessons. During the visits, were permissible, photographs and video images were gathered.

The process of gathering permissions for the research was coordinated by the researcher but the responsibility for ethical assurance rested with each school as each school has specific policies and procedures in place to cover research and sharing permissions. As an added precaution, the draft report was sent to each school for them to check that all images and text included did not breach any privacy or data protocols within each school or system. While all parents were happy for their children to use the 3D, some parents were not happy for their children to be filmed and so these children watched the lesson from an adjoining room. Interestingly, after the first lesson, the motivation of these children to join the lesson was so strong that many of them convinced their parent to let them join the remainder of the lessons.

The research process followed four clear stages:

**Stage one:** Small scale pre-testing in two schools in the United Kingdom commenced in April 2010 and concluded June 2010. In April 2010, the first set of the DLP/3D was provided to two schools in England. By May 2010, pupils in Year 8 science (12 years of age) began two modules using the 3D technology. The first was on the eye and the second on the ear. At the

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4 Interval tracking is a research methodology where specific observations are made in a systematic way every five minutes across the duration of the lesson. In this case, records were made in relation to communication (e.g. how many children were talking, asking or answering questions), attention (how many children were watching and not distracted), and behavior (how many children were disrupting others or off task). These form a pattern of the flow of a lesson and can be used to map the impact of the 3D on classroom interactions.
end of the unit, the same test was applied to assess the understanding of the pupils. Concurrently, small ‘class’ tests were administered during the unit of work to assess ongoing understanding. At the completion of the unit, interviews were conducted with teachers to determine any initial responses to the technology and to pre-test the research methodology. While it is always hard to separate learning outcomes from the experimentation phase, the primary aim of the pre-test was to assure that the technology and software was suitable for use in the full pilot.

Stage two: Selection of schools to be involved in the full pilot. The scope of the study was limited to a sample of schools in England, Sweden, Italy, France, Germany, The Netherland and Turkey. In each country there were two or three schools with two or more classes in each school. The focus was on pupils between the ages of 10-13 years of age. Schools were selected on the basis of interest to be involved, suitable technical expertise and accessible geographic location within each country. The schools were chosen broadly to be reflective of various types of schools and with pupils of differing ability levels.

England, France and The Netherlands started in November 2010, with the other countries commencing at the beginning of the 2011, in January. Each school received a laptop (preloaded with 3D ‘Body’ content), 35-100 pairs of 3D glasses, and a DLP projector. Technical representatives from the various partner companies assisted with the delivery and installation of the equipment and provided brief instructions to the teachers involved in the pilot. Sweden and Germany were the last countries to join and started research in February 2011.

Stage three: The Live phase of the research commenced as soon as the equipment was in the school. Teachers and pupils (and parents) completed research permissions and a pre-pilot survey. Children were pre-tested on their understanding of content. Schools were free to choose the particular focus of their investigations from the available, pre-loaded content. Each school received two or three research visits during the course of the unit. Regular email contact was also made between the researcher and the teachers involved. A local area coordinator also played an important role in mediating the process and translating key aspects of the research. The live phase of the research ran for eight weeks. The amount of time dedicated by each school to the experiment varied depending on the context in each school and the available time to commit to the project. As is generally true of educational action research, it is not possible to control all variables as the experimentation must be conducted in a naturalistic class setting and it is not valid to intervene too directly within this setting. The research did not impose specific instructional methods or content sequences. Similarly, while various pupil pre- and post-tests were suggested and provided, as assessment is generally a school-based matter, teachers were also encouraged to choose their own methods and to be active in constructing a suitable research method that was appropriate to their class. Additionally, some teachers were provided with 3D enabled video cameras and encouraged to keep a visual record of learning and a written or email journal (blog).
During the live phase the research used a range of methodologies including:

- Document and media analysis
- Survey and data tracking of baseline data
- Interviews
- School visits
- Focus groups
- Observations
- Provisions for electronic submissions

Research was conducted in line with European research protocols involving research with children, including the highest level of child protection. All data was subject to European data protection laws. All participants in the research gave permission to participate and for recording and presenting of research findings. Participants were free to choose to withdraw from the research at any point.

Stage four: The **analysis and reporting phase** occurred throughout the research implementation. Both quantitative and qualitative methods were used. The data was analyzed according to statistical and thematic frameworks. Themes were derived from international quality indicators and inductively from the data collected. The detailed evidence-based empirical review and analysis lead to:

1. The production of this published report in English
2. A succinct executive summary
3. A clear and concise list of recommendations
4. A ‘public’ style content presentation of the findings using visuals and sound
5. Participation in public and media discussions and in meeting with senior educational decision makers

Throughout the research there were regular interim reports, both verbal and written to all the participants in the research and the broader stakeholder community.
Chapter 2: Making it happen

2.1 The technology

- The technology was easily adapted into the classroom and teachers did not need any specific training or professional development to be able to use 3D in their teaching.

The package of technology provided to the pilot schools was easy to use for the participating teachers and required no particular technical knowledge. In order to undertake 3D learning in the classroom, schools needed:

1. A DLP 3D enabled projector

Schools found that it was possible to implement 3D learning with only one DLP projector per school. Many projectors are already 3D capable and future purchases of DLP projectors are generally no more expensive than those that are not 3D capable. DLP projectors are capable of working successfully with existing electronic ‘smart’, whiteboards or other screens but also worked just as well when projected onto a wall, or in one case even projected onto the front of the teacher’s white T-shirt.

2. A PC or laptop with a special graphics card

Most standard PCs and laptops can be fitted with the necessary upgraded graphics card for only a small cost. More recent laptops tend to have adequate graphics cards.

3. 3D software relevant to the curriculum

There are a number of 3D software manufacturers. Many have emerged from the non-educational sector and even those from education have often come from adult education or training programs. There are emerging software developers that are developing content specific to schools. The schools in the pilot project were provided with a software set suitable for use with children aged 10-14 years. The software was only available in English which posed some limitation (see section 2.2 on content and section 2.3 on language for more details).

4. 3D active glasses

Each school was given between 35-100 pairs of active 3D glasses, depending on the number of pupils involved in the research (see section 2.1.4 on glasses for details). At the commencement of the pilot, some legal and import regulations held up the distribution of the equipment to schools.

In most of the research schools, the teacher required some low level technical support to set-up the equipment and to ensure it was running effectively. In about half of the schools, the technical capacities within the school were sufficient but for the other half of schools, additional technical support was provided from the various suppliers to ensure that the technology was working appropriately. At the beginning of the project 70% of teachers thought that they might experience some technical difficulties. In practice though, there
were some minor technical problems in the early stages but these were easily resolved. The teachers found the technical support from the partner companies to generally be efficient and effective. For example:

*The activation codes did not work and we had to email several times, but our problems were responded to quickly and we were able to resolve the problem.*

*At first it took technical support to get the 3D to synchronize.*

*We needed the help of the technician to start with, but now there are not any problems really.*

In the following example, the teacher felt less confident with the technology but quickly the pupils were able to take over the task of setting up the equipment and the lesson ran smoothly.

*At first we had problems. We don’t have a space where we can leave the 3D set up all the time so we have to set it up each time we want to use it. That took ten minutes and the children would get distracted. But now the pupils have taken control of setting it all up. They are great and now we have no problems. The only problem is the batteries in the glasses.*

The larger schools or schools within a larger network of schools tended to have a technical assistant in the schools and these people were able to help with the initial set-up within the schools.

*I like technology and I feel confident to try new technology, but other teachers are not like me. I have had no problems using it and don’t need any support, but I think if there was not a technical guy, other teachers would struggle. Even for me, I was less afraid of the technology because I have the technical guy to help. If there is a problem, he can help me and I can go on with the lesson.*

*The PC needed a special graphics card and needed to be configured. The technology team helped us.*

In general, the implementation into the schools occurred in a straightforward manner. Apart from the kit of equipment provided as part of the pilot project, schools needed only minor additional adjustments. For example, in Turkey, all of the pilot schools were supported in the introduction and implementation of the technology by technical support staff, though this was not considered to be a major burden. The few problems noted were more likely to be connected to either the computer or cabling or to practical issues associated with the downloading of ‘codes’ for the 3D software. For example, two out of the three schools in the Turkish pilot needed better cabling, a better graphics card and enhanced operating system to enable the 3D to run, even though the majority of the projectors in the school were currently 3D ready. Similarly, some schools reported delays in the software code (code not working) though this problem was resolved quickly and the pilot started.

Within the classroom, teachers all appeared very comfortable and confident using the technology with them moving the images around, rotating and zooming in. They talked
comfortably over the 3D images and seemed to have no problem maintaining the flow of the lesson while operating the 3D.

*It really took no time at all to get familiar with the buttons for using the 3D. I like the depth, the zooming and the movement.*

*It was really quite easy. Once you get to know it you just turn it on. No problems.*

Some schools shared portable equipment and while this was satisfactory, the teachers generally preferred fixed equipment as it was ‘ready to go’ and did not require being set-up each time before the lesson. Teachers were more likely to make frequent use of 3D in lessons if the equipment was permanently set-up (i.e. ‘ready to go’) in their classes.

*While it would be good to have portable equipment, this is not practical as it take quite some fine tuning to get the 3D to work. For example, some pupils were seeing it going in instead of coming out. This took time to set up, but now it is set up there are no problems. We can just go into the room and turn it on and everything is ready to go. But if we had portable equipment, we would need to be setting it up all the time and this would take time away from the lesson.*

*I would prefer a fixed projector as I find the moveable projector is a bit of a problem. It takes too long to set it up.*

One teacher experienced a technical problem with the speed the content loaded: “It is OK for me but it takes a long time when the children are there and it takes time.” There appeared to be only two technical problems that were observed across more than a single school. One persistent problem that encountered in the Swedish and German cases was a horizontal line passed through the images. The line would begin at the top of the image and travel slowly down the screen. While several suggestions were made to overcome the problem, each time the projector was restarted the problem would re-occur. In classrooms with this problem, pupils were more likely to also report higher levels of eye discomfort. It was suggested that the problem was due to the need to change the hertz settings, though this did not appear to fully resolve the problem.

The other repeated problem was that some teachers did not realize that the 3D image could come ‘out’ from the screen and were watching it with the image going in. Once the switch was made, teachers were amazed by the 3D effect they saw. In one example the image was going in instead of coming out and the teacher was not wearing 3D glasses so did not know. Children responded with “wow” when the image then came out!

The following section contains specific details about particular technical aspects associated with the implementation of the LiFE 1 project.

### 2.1.1 Lighting

- **Low level natural lighting was the most suitable for 3D in the classroom**

In general it appeared that ‘low’ natural lighting gave the best 3D results (such as a ‘normal classroom with blinds drawn and lights turned off). If the classrooms was too dark (i.e. NEC projector)
‘blacked out’) more pupils reported eye strain or headaches. The research showed that there were the least complaints about eye strain or headache if the 3D was used in slightly less than normal classroom light (e.g. with no artificial light and dull rather than dark classroom conditions). If the classroom was too light or had fluorescent lights on the 3D effect was less effective and pupils also reported that the 3D glasses flickered on and off, or had ‘back reflections’. For example, in one of the pilot classrooms, quite dark blinds were pulled during the 3D. While this made the 3D image sharper, a higher percentage (40%) reported some negative reaction (pain in eyes, slight headache). This seemed to be the most pronounced as the lights were turned back on and the eyes had to rapidly adjust to accommodate the change in light levels. Any florescent lighting (especially from behind) gave reflections and some flickering sensation in the glasses.

> We have to turn the lights off and we need both the curtains pulled.

> We had a little bit of a problem if the classroom was very light. You need to pull the blinds down and turn off the lights, but then you can see things clearly.

The 3D images were clear from all the corners of the room and equally clear from the back and the front of the class. Some classes reported that the pupils at the back of the class could actually see better clarity than pupils towards the front. Both the teachers and pupils reported having difficulty seeing where the arrows were pointing and reading the labels on the images. The labels were too small and the yellow color meant that they did not stand out from the background.

### 2.1.2 Control and interactivity

- The teachers would like to be able to point, rewind and pause the content
- Both teachers and pupils want more interactivity and more activities in the content
- Some of the labels are hard to read

The teachers wanted to be able to “point” things out within the images and to be able to move around the class as they were talking and working with 3D. The pupils frequently commented that their teachers still tried to point, even though inevitably they were pointing at the wrong part of the image, as these comments from pupils suggest:

> It would be better if the software had some way of pointing.

> We see to the left but the teacher sees to the right.

> The teacher was funny. They were pointing at the shape but we were all seeing it in different ways.

> The teacher is funny with 3D she points and her finger is there but she is not pointing at the thing and she doesn't understand.

Both the pupils and the teachers wanted more interactivity and more flexibility in the way they controlled images.

> The system would be easier to use if there was a Wi-Fi fi controller and you could focus it as you move around the classroom.
It would be great if we could just move our bodies and the shapes would rotate too.

In four of the pilot schools, the teachers let the pupils control the 3D. The pupils appeared to like a mix of both the teacher controlling the system and the pupils controlling it themselves, as you see in these comments from pupils. In this aspect, the findings were quite divided with opinion equally divided between those pupils wanting whole class lessons, controlled by the teacher, and the pupils wanting to be able to work in smaller groups and have some control over the technology.

I would like to control it as that way if I did not understand something I could turn it around and look again.

I like it better when the teacher controls it as it is sort of whole class things and we can all share and the teacher makes good explanations so we understand.

The pupils like the 3D the best when the images were more animated and where the 3D was exaggerated, as these pupil comments, suggest: “It is best when things shoot out and also when you can travel inside things.”

2.1.3 Projector

➢ The teachers satisfaction with the projectors was generally very high

DLP® Link technology, developed by Texas Instruments, allows 3D images to be projected with the aid of a single projector and active LCD shutter glasses. The projector generates consecutive, alternating images for the left and the right eye at a rate of 60 frames per second. The liquid crystals in the shutter of ‘active’ glasses are synchronized with the
projector and are switched between transparent and dark to match the projector. The difference in perspective that results from this creates the 3D effect.

The projectors appeared to be deployed quickly and easily. It did not require special screens and seemed to work very successfully in all the classrooms in the pilot study (except where the black line appeared, as mentioned in section 2.1). The teachers generally favored installation of a permanent projector, though some teachers felt that more portable options would be preferred. This would enable more flexible teaching and greater group work.

2.1.4 Glasses

- The design of the glasses needs to be changed to suit children
- The glasses are too big and too heavy for the pupils
- Poor synchronization of the glasses can cause unpleasant sensations for the pupils

The glasses were the only major problem in the pilot research. Only 50% of the pupils felt the glasses were good or very good, with the other 50% giving a negative or neutral response to the glasses. Despite a number of different brands being tested there were numerous problems reported. As can be seen in Figures 2.1.4.1a, the pupils’ satisfaction with the glasses was low in a number of areas.

*Figure 2.1.4.1a The glasses fitted me*

*Figure 2.1.4.1b The glasses looked good*
2.5 Health and safety

- Mild to moderate short-term discomfort was experienced by 49% of pupils using 3D for the first time
- Headaches and sore eyes were the most commonly described, but the symptoms stopped once the glasses were removed
- Pupils want more 3D and for a longer duration than their teachers

During the pilot study, there was consistent reporting of discomfort caused mainly from the glasses or the visual sensation of 3D. The symptoms were reported consistently across the countries and classes in terms of type of symptoms described, frequency of symptoms and pattern of disappearance. In response to the survey question about ‘negative’ feelings experienced when viewing 3D in class, only 41% of pupils said “everything was OK” (see Figure 2.5.1).

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It is important to note, I am not a medical doctor and the research has not focused on health and safety issues. The findings in this section are based on the self-reporting of the pupils and teachers, not any medical examination. At the time of publication of this report, recent research findings from the American Association of Optometrists presents a more detailed overview of the medical aspect of 3D glasses.

Note: This graph represents numbers of pupils NOT percentages as a pupil can report more than one symptom.
Figure 2.5.1 Pupil reporting of discomfort during 3D

The symptoms most commonly reported were mild headaches (that would disappear within 10-15 minutes once the glasses were removed), mild nausea, sore eyes, dizziness and what pupils reported as being a “weird” feeling. In all cases, the discomfort appeared to subside quite quickly once the glasses were removed. Interestingly, the highest level of reporting was the first time the pupils saw 3D (28% of pupils reported some negative effect) while this figure fell to 22.7% on the second viewing and 13.6% on the third viewing, with below 4% on the subsequent viewing.

The severity ranged from 3-7 (with 0 being no negative effect and 10 being very strong negative effect). The average for rating for the pupil experiencing some negative effect was said by the pupils interviewed to be a ‘6’ rating. Based on the survey results, 23% of pupils indicating that they experienced any negative impact said it was “not a problem” and a further 65% of pupils experiencing some discomfort indicated that it was “a little problem”. Slightly less than 3% of the pupils reporting discomfort felt that it was “a big problem”. Despite these problems, 89% of pupils reporting problems still wanted to continue to learn with 3D. The following comments are indicative of the sorts of symptoms described by pupils:

I feel a little bit dizzy and miserable. The first time it lasted for 10 minutes and last time [she saw 3D in class] about 3 minutes but this time it is OK.

I got a bit of an eye headache the first time. The glasses went on and off and I moved my head and I saw purple and blue.

I don’t think 3D is very nice. I get dizzy so I stop looking.

My eyes were a bit painful.

My eyes are hurting [After using the glasses for 3 minutes, she removed her glasses and rubbed her eyes, before putting the glasses back on]

Only 5% of pupils reporting any negative symptoms said that these feelings were still there 10 minutes after stopping to view 3D.

Usually only one pupil or no pupils in a class reported any discomfort on the fourth or subsequent sessions.
My eyes are really hurting

They give me a headache

It is funny - we are learning about the eye and my eyes are hurting

The glasses were changing color and this gave me a headache

When I first wore the glasses I got a little dizzy. When I took the glasses off it went away after about 15 minutes. It only happened the first few times and now I am fine.

I felt dizzy for a few minutes and had a headache. It is kind of confusing and makes you feel kind of weird. But that was only the first time.

I don’t like the flipping on and off. It made me feel weird.

During classroom visits, my observations were consistent with the pupils self-reporting of discomfort with an average of 26% of pupils being observed to remove glasses or rub their eyes during the first research visit session. Pupils seemed most likely to rub their eyes when the light came on if the room had been dark and/or if the glasses were ‘flickering’ (turning on and off\(^\text{10}\)). In the classes where this occurred, the reporting of discomfort increased to 34.7%. For example, one class had 8/23 pupils reporting headache, mild dizziness or sore eyes after the first use of 3D. The same class reported 5/23 on the second use and 2/23 on the third use. No one was still experiencing any negative effects by the fourth lesson. The teachers also reported similar observations:

The first two times we did 3D some, the children complained of headaches and a little bit of nausea and a few children had to take the glasses off or go outside. But now there don’t seem to be any problems any more.

On average I would say in a lesson we might use 3D for around 15 minutes. Some children get tired eyes and then they take the glasses off every few minutes. I think pupils with some eye disorder have had a few more problems. At first it was a problem for pupils with glasses, then we realized, that they should put the 3D glasses over their spectacles and now that seems fine. Every child can see the 3D.

The pupils also did not like having the 3D for too long:

I don’t think you should watch it for too long. It makes our eyes tired.

There were very mixed responses from the pupils to the survey question regarding how much 3D pupils would like in a schools day, with some pupils wanting it only once a week or less but others wanting it very frequently. Generally, between once a week and once a day seemed the ‘right amount’ for the majority of pupils, 15% wanted 3D at least three times per day. Only 3% of pupils said they never wanted 3D (see Figure 2.5.2a). Despite this very low

\(^{10}\) This was most likely to occur if there was a light source behind the pupils such as a fluorescent light of bright light from a window.
'never’ rating, in classroom practice, a teacher would need to monitor\textsuperscript{11} these children carefully and provide alternative learning strategies if 3D was to be adopted in the class.

\textit{Figure 2.5.2a How often would you like 3D in the class (pupils)?}

The responses from the teachers (Figure 2.5.2b) were very similar to those of the pupils, but in general, the pupils wanted more 3D than their teachers.

\textit{Figure 2.5.2b How often would you like 3D in the class (teachers)?}

Similarly, while in the LiFE research we recommended that the children watch approximately 10 minutes of 3D (although the actual time varied from class to class and appeared to have no bearing on discomfort with actually a slight indication that the longer you viewed 3D the less negative complaints were recorded\textsuperscript{12}), most pupils actually wanted a longer duration of 3D viewing as suggested in the survey findings.

\textsuperscript{11} As it may be possible that pupils who say ‘never’ to 3D learning might change their mind or those happy to have 3D now might also change their mind.

\textsuperscript{12} Though it should be cautioned against any assumptions being drawn from this data as clearly classes where there were less reported negative reactions to 3D would be likely to incorporate more 3D whereas teachers receiving more complaints from pupils would be most likely to reduce the amount of time pupils in the class view 3D.
Figure 2.5.3a How long should you watch 3D in the class? (Pupils)

The majority of pupils felt that longer than 10 minutes was the best amount of time with 28% of pupils suggesting longer than 30 minutes or with no limits was the best. A consistently small number of pupils (4%) wanted less than five minutes.

The results for the teachers were similar.

Figure 2.5.3a How long should you watch 3D in the class? (Teachers)

A smaller proportion of children (approximately 5%) reported a sharp 'pain in the eyes' after the first use. Interestingly by the second use, children experiencing either the 'pain in the eyes' had reduced by around 50% and by the third session there were no children that noted this problem.

Confusingly, there appeared to be very little discernible pattern in the pupils who reported discomfort. For example, pupils who wore spectacles were no more or less likely to report problems than other children. Similarly, some children who did not like watching 3D movies

Consistent with the qualitative findings of pupils reporting problems with 3D
The exact figure was hard to obtain here as it had to be based on the pupil’s description so this figure is taken from those pupils who used the phases “eye pain”, “eye hurt” or “sting” but excluded those who just said “sore eyes” or “funny eyes” or similar mild descriptors.
because of headaches, nausea or dizziness, were quite happy with 3D in the classroom and did not experience any symptoms. Position in the classroom (i.e. front, back or side of the room) did not seem to be a variable in pupils reporting discomfort based on the observations or the pupils comment, though several teachers thought it may have an effect. One school commented that 'closeness' might be a factor in headaches as the teacher had noticed that pupils sitting closer to the screen were more likely to report eye pain or headaches, but that is not clearly evidenced in other data. There appears to be a slight link with children who experienced some problem with the glasses also being a child who feels car or motion sick. There did not appear to be any correlation with pupils that felt some negative effect and cross effects (i.e. with 3D cinema or 3D TV). Some children only felt a negative effect with the 3D in class, while others did not feel it in class, but had felt nausea or headaches in the cinema or watching 3D TV. The pupils often made the comment that the 3D was 'different' in the classroom environment. Several teachers reported similar experiences, such as this example from a teacher with a 3D television at home:

I have a 3D television at home and we watch movies on it and it does not hurt my eyes. It seems like a different type of 3D. It is definitely different the one we use in class and it does seem to strain your eyes more. On the TV even in 3D things are quite flat. It is sort of depth rather than things popping out at you.

Some of the pupils who experienced negative sensations said that these had also concerned their parents:

[Pupil comment] My mum thought it might damage my eyes.

[Pupil comment] My mum was worried about the permission form. She thought, 'this is a very serious project' and 'maybe the 3D damages you', but now she is very happy.

[Teacher comment] The parents were concerned that the 3D might damage the children's eyes in the longer term, though they reported no negative effects of the short term exposure.

Several teachers raised the concern about whether the content was actually 'too real' and might be disturbing for some children. For example, in one class in The Netherlands, several pupils chose to leave the room as they did not like the content, and one pupil had to be warned as she is particularly sensitive to the sight of blood.

Concerns were also raised about size and weight of the glasses. For example during an observation visit in one of the Dutch classrooms, a child had repeated problems with the glasses falling off because they were too big. He tried to hold the glasses with his hand then ended up taking the glasses off after a few minutes and not wearing them again in the lesson. Other children turned the glasses upside down to wear as they were heavy and hurt their noses and the top of their ears.
While the reporting of eye reactions or headaches quickly disappeared after three times of using the 3D in lessons, complaints about the weight of the glasses tended to become more pronounced after subsequent uses. The most widely reported complaint was that the glasses were heavy and hurt the children’s nose and top of the ears. In Turkey, 28% of all the children felt some level of physical discomfort with the weight and fit of the glasses. Even within this group, they still wanted to continue to use the 3D but tended to 'lift' the glasses off their faces or place their hands under the frame to avoid the discomfort.

Parents were also worried about the weight of the glasses as this comment demonstrates: 

*The glasses are far too heavy and hurt the children's faces. My daughter got red marks on her nose. Can't they be made out of something soft? They hurt the children's noses. Can they also hurt eyes?*

During parent interviews, while the overall response from parents was very positive, health and safety concerns were often expressed by parents. Those parents who allowed their children to engage in considerable amounts of recreational exposure to 3D (such as films, 3D TV and 3D games) showed greater levels of concern for their child’s safety when it came to...
3D in the classroom. It would be reasonable to say that parents expect schools to show considerable additional diligence when it comes to a pupil’s well-being and health.

The major concern parents had with the greater use of 3D in the classroom was the impact more frequent exposure may have on their children’s eye sight. Some parents reported that their children had slight headaches, nauseas or slight giddiness the first time they had 3D in the classes. While far more isolated remarks, two parents expressed concern about possible radiation omitted from the glasses or the system and one (other) parent was concerned that the glasses might actually produce a slightly hypnotic effect on the children.

As stated at the outset, it is beyond the scope of this research and my capacity as a researcher to determine the medical veracity of the comments made, but their consistency and frequency would tend to suggest this is an area that requires further investigation.

From the point of view of the pupils the glasses were “uncool”, heavy and uncomfortable and did not fit their faces. The children preferred to take the glasses off between the 3D sessions and the glasses were clearly not very comfortable for the pupils as this sample of the numerous comments received exemplify.

*The glasses are not comfortable. They are too heavy.*

*They fall forward if I lean over and I have to hold them on.*

*They should be made out of softer material. They hurt my nose.*

*They should be better looking. They are too big.*

*They should be made lighter. They are too heavy.*

*3D is cool but the glasses hurt my ears.*

*I wished the glasses fitted my head better. I do not like the blinking. The glasses are also too heavy.*

*The glasses are heavy and uncomfortable.*

*The glasses are not cool. They are too heavy and they hurt our face and our ears.*

*The glasses are too big. They slip down and hurt my nose.*

*The glasses are too big. When I lean forward they fall off.*

One pilot group tested new glasses. These glasses\textsuperscript{15} produced a 'sharper' image but the pupils found that they were not as easy to synchronize to 3D and a higher than usual percentage of pupils reported eye pain and headache. Several pupils changed glasses claiming they could not see 3D. The glasses were too heavy on the pupils' faces. The bridge of the pupils' noses hurt and also around the ears. Around 10% of children found this so

\textsuperscript{15}XpanD A102ELP1
uncomfortable that they needed to keep lifting the glasses from their faces or rested their hands between the glasses and their faces.

A 12-year old pupil of average size was asked to try two different glasses styles. The XpanD glasses were considered to be more comfortable due to the nose shape and the wrap around style. These glasses were reported to be more comfortable on the top of the ears. The glasses fall down if the child looked down but did not fall off. The child needed to push the glasses back up the bridge of the nose if he looked down and then looked up. The addition of the nose guard made the glasses slightly more comfortable. The look of the Nestri glasses was perceived to be ‘ugly’. It was reported that the nose was uncomfortable, being too tight on the top of the nose bone. These glasses did not move down if the pupils looked up and down. The manufacturers of the 3D glasses should explore materials that are more light weight and durable to ensure both fit and comfort for pupils.

In the Dutch classrooms, the teacher found an innovative way to deal with the problem of the glasses being too big and hurting the pupils' noses. She placed a cotton wool make-up pad over each child's nose to solve the problem.
An IT expert in a school suggested that Quantum Tunneling\(^{16}\) and other fabric technologies could be employed to make glasses in the future that more readily adjust to a child’s face size. For example, perhaps 3D active crystals could be embedded in fabric or another pliable material.

The teachers also reported problems with the usability of the glasses. There were problems reported with the batteries, with cleaning the glasses, with storing the glasses and durability. Throughout the pilot and pre-pilot, the manufacturers tried to work through the problems reported and develop alternative solutions. The following comments from teachers mirror the negative comments received from the pupils:

*The glasses are not good. They do not fit the children. They fall off. The glasses flick on and off and change color. I think all this is what is giving the children discomfort.*

*The glasses should be just 5-10 euros. Not too much.*

The teachers were also concerned about the potential to have to do time-consuming maintenance of the glasses.

*The glasses are too hard to keep clean*

*The glasses are heavy and uncomfortable and the cleaning is time consuming.*

*The only problem we have had with the implementation of 3D is the glasses. They are badly designed for children.*

*It was uncomfortable on the children’s noses. I took the rubber thing off to make it feel better.*

*The glasses need to be much more reliable. They flicker on and off and the batteries need replacing and this is difficult. The glasses need to be rechargeable.*

The earlier models of the glasses had batteries that often went flat and were difficult to change, as the following comments from teachers demonstrate:

*We had a problem with replacing the batteries. It was time consuming and difficult.*

*Could the glasses be charged with solar (like calculators?)*

Several teachers reported that the glasses were not durable in general class and broke – or broke down – very easily. This also appeared to affect the likelihood that a school would invest in 3D.

*As the principal, I am concerned about the durability of the glasses if we went down the path of having these in all the classrooms. One broke during one of the lessons and the child did not do anything.*

\(^{16}\)Quantum tunnelling composites (or QTCs) are composite materials of metals and non-conducting elastomeric binder. They utilise quantum tunnelling: i.e. without pressure, the conductive elements are too far apart to conduct electricity; when pressure is applied, they move closer and electrons can tunnel through the insulator. [http://en.wikipedia.org/wiki/Quantum_tunneling_composite](http://en.wikipedia.org/wiki/Quantum_tunneling_composite) Accessed June 2011.
The overall intention of the pilot project was to provide a pair of glasses for each child in the class. In practice, some classes were larger than the 30 pairs allocated (especially when you included the teacher and other staff). Also, the technical problems with some pairs of glasses meant in practice that often children had to share glasses. In terms of classroom practice, the sharing of glasses did not work at all effectively. All pupils and the teacher needed to wear the glasses for the lesson to be successful. The attention span of pupils was reduced markedly (by more than 52%) if pupils had to share as those children without the glasses tended to disturb other pupils and the process of swapping glasses negatively impacted on the 'flow' of the lesson. Also, if the teacher gave his/her glasses to pupils in the class, they tended to then once more teach from the front of the room and the changed classroom dynamics was also negatively affected. The implications of this finding is that all pupils need the glasses and that to be successfully operational in an average European class, class sets should contain 40 pairs of glasses, with simple ways to check all glasses are functioning before the teaching episode begins.

There have been a number of problems with the glasses in terms of synchronization and light reflection. It appeared that if sources of light came from behind the glasses (such as light through a classroom window or from a fluorescent light), the glasses would turn on and off and take some time to synchronize, causing a ‘flickering’ sensation or quick flashes of other colors. Some children found this synchronizing sensation to be “weird” and a little disturbing, producing a reaction that they described as being similar to car sickness or mild nausea, as these pupils’ comments exemplify:

- I see light coming in from behind.
- The glasses are very annoying. They keep coming on and off during the lesson.
- The glasses flicker and take too long to synchronize with the screen.
- There are problems with the glasses. The glasses are full of dots and change colors
- I am sitting at the side of the room and every time I turn my head it goes fuzzy.

To conclude, the overall finding of the pilot research is that the glasses need to be more robust in all for general classroom usage and need to be more adaptable in design to meet the needs of children.
One possible solution suggested for the future could be that pupils increasingly purchase their own glasses. Parents would generally prefer to buy glasses specifically for their child (children) as they are not happy with the children sharing glasses\(^\text{17}\). A survey across the participating countries showed that a price between 30-60 euros was deemed to be suitable with the overall average being 43 euro (or equivalent) in the survey countries. The parent group felt strongly that the pupils should have their own glasses. The price was not a major concern for the parents interviewed. The parents interviewed were happy to purchase 3D glasses for their child rather than having them share class glasses.

While both parents and pupils felt it was a better idea for pupils to purchase their own glasses, some parents wanted confirmation that the glasses were safe for their children’s eyes before making such a purchase.

[Comment from a father] I want to know that the glasses are safe for children’s eyes. This is important. Until the safety of the glasses is proven, I would not buy the glasses for my child.

There did not seem to be in particular problem for pupils who normally wore spectacles.

I thought there would be a problem for kids who wore glasses but this was not the case. They just put the 3D glasses over the top.

\(^{17}\) The parents were concerned about fit of the glasses and hygiene. As the glasses were worn over the head and eyes, glasses needed to be regularly washed and wiped with disinfectant cloths to prevent any possibility of cross-infection.
2.2 The Content

- The content was well suited to the curriculum
- More 3D content is needed
- User-developed content is an aspiration but at this stage, cloud-based content was preferred
- Teachers want high quality, accurate and realistic 3D objects

Most schools involved in the pilot felt that the best way to access content would be via an online 'cloud system', whereby teachers could download 3D visual and animated resources to complement their teaching units. In some countries (e.g. The Netherlands) similar 'subscription based' systems for other content were already available and it was felt that these provisions could easily be expanded to accommodate 3D. In some countries though, the school internet access was low bandwidth or intermittent meaning that an internet based system may not provide a reliable way to access online content, as this comment outlines:

> Content that 'sat' on the internet <cloud content> would not be a good idea. In this school we do not have good broadband. I prefer to rely on a CD, but only because of the broadband speed. CDs actually stop innovation as they are fixed and can’t move. In that way internet is better, but just not practical at the moment in this school.

It was generally felt that content could be shared 'internationally' and providing it was possible for teachers to add the labels and 'voice over' in the mother tongue language, and that resources were widely useable. Teachers expressed a strong preference for 'generic' content. They defined these as being high quality, accurate and realistic 3D objects. It was felt that generic learning objects could be used across a wide range of ages, making them highly valuable to the schools sector. It was also suggested that collaborations with textbook publishers and other educational publishers could be a useful way to provide the 3D content. For example, most currently available text books provide interactive CD-ROM content to accompany the books and this in future could contain 3D content. One teacher suggested that labeling was a useful feature as it could be used both as an introduction to the topic for pupils but also as a way of assessing and review during a unit or at the end of a unit of work. Another teacher suggested that it would be useful to have a blank text boxes, rather than labels so that the teacher could add their own ‘tagging’.

> It is very easy to move back and forward between 3D and the textbook. It fits very well.

> It fitted or program very well. ‘Senses’ are in the curriculum and we could very easily fit it into our program. We did not use the text book in the 3D unit.

> We have general guidelines we must follow and content that needs to be covered to match the exams. We had to change the timing a little bit to work with this pilot. ‘Touch’ was the only part of the content that did not match what is in the text book, but it was interesting.

Teachers gave a preference for a 'one stop site' where all teaching resources could be placed and accessed easily via an index system including the topics and age of the pupils. During the pilot, one third of teachers reported that while the content pre-loaded onto the laptop was
good, that lack of indexing meant that teachers had to spend some time before the start of the pilot investigating available content before starting the unit. While they felt that this was OK for the pilot, they would prefer a more clearly indexed system for the longer term application of 3D in the classroom to save time.

It would be great to have an index with all the content that is available like on You Tube. We need more content that is for sure, but we also need a good index system so you can choose the things to use in your subjects. Time is a valuable thing for teachers so the system must be quick and easy to use.

It was also felt that the index system could be more closely aligned to pupils’ levels thereby ensuring an effective match between the pupils and the content and to enable individual instruction.

The level of the content is important. Some of the content is far too easy for these pupils but then some is far too hard. It would be good if we were able to select different levels of the content.

Several teachers suggested that the text book ('methods') companies could provide more of the 3D content, though as one teacher commented "I don't think the publishers know how far 3D has gone". It was felt that the content was generally well suited to the curriculum and that the teachers were able to very effectively integrate 3D into their lessons. Most of the teachers observed during the research created their own hand-outs and resource material to accompany the 3D so that the 3D became part of the overall teaching and learning package. The majority of the teachers observed combined the 3D as part of their overall pedagogy. They were able to move seamlessly between 3D and other learning methods including drama, 2D images, diagrams and verbal description.

Several teachers spoke about the 3D not only ‘fitting’ the curriculum, but also enhancing it.

The content does much more than actually "fit the curriculum". Yes it does that but it also covers more detail and the children fully understand the concepts in a deeper way.

The content suits the curriculum very well.

The content is very relevant for our curriculum. If it wasn't I wouldn't use it.

The content was very relevant to our curriculum. Maybe we spent a little less time with the 3D as we could cover more material but also something we did in more
detail. For example, the skin and nose we spent longer because we all learnt more. So I think in general we spent less time than we would normally.

Can this spread to other courses? I also want to use this with other children and other classes.

I can see 3D being really useful for learning history and mathematics. Can this project spread to other courses?

One limitation identified that prevented wider ‘spread’ and distribution of 3D content were the different 3D formats currently available. These were viewed as adding unnecessarily to the complexity of implementing 3D and confusing for teachers new to 3D. The general view expressed was that there simply was not enough content in 3D\textsuperscript{18}, as these comments from teachers suggest:

\textit{We need more content!}

\textit{There is not enough content.}

\textit{It is important that we get 3D content for more subjects. We need more material.}

It was also felt from the majority of teachers that the content needed to be as rich and deep as possible (in other words they did not want simplified or ‘dumbed down’ content).

\textit{I have looked at some of the 3D content. The best so far is Amazing Interactive because it has more depth. Tell the content designers not to make it too simple. We want really good 3D content. You don’t need to make it simple. If we have good images, then a good teacher can easily adapt what he or she says to suit the different ages. So you take the ear, you could use this in a simple way even with very young children, but they should see the real thing and then the same thing could also be used with the oldest pupils but the teacher would just change what they said.}

\textit{I would like content that I could personalize to the level of the pupils. Sound is not important. I would not use the sound, but I do want to point and to be able to pause and rewind the content when the pupils need more input. It is not about converting all content to 3D but selectively using 3D when and where it is most relevant to learning.}

While the software supplied could be used to positive effect in the pilot classrooms, more software needs to be developed. The point was made by the teachers that it is not always possible to adapt software from the industrial or entertainment sectors for ready use in the classroom. Educational authorities and educational textbook and resource suppliers could consider funding the development of generic content that could be widely used at all levels of education. The teachers in the research project began to suggest more adventurous future uses of 3D technology:

\textit{I would really like to see the dissolving of the interface. With the web we could have 3D content delivered into the classroom at any point. It would not be on a screen, but}

\textsuperscript{18} At the time of writing this report, a quick search revealed that there were around 5,000 pieces of freely available 3D objects currently available on the internet.
rather like the 3D projection is in the classroom with you. I like the idea that the whole classroom could be transformed. That we could stream in content from all over the world...Cloud-based, centrally-hosted. The children get it! They really understand this stuff. We need good quality, professional research. Quality content will come from the teachers.

The teachers (and pupils) acknowledged that in most cases the pupils were in fact more advanced with 3D than most teachers. They spoke about the pupils being very knowledgeable and skilled in the use and consumption of 3D.

While there was evidence in the research of at least the aspiration among teachers and pupils to develop their own content, at present the software is not available to make this a feasible option. The use of 3D cameras means that pupils and teachers could gather their own content, but even in this domain, the applicability appears limited as the teachers saw the main benefit of 3D was to be able to show things that are not easily observed in the world around their pupils. So for example, the workings of the heart was a particular popular piece of 3D content as seeing the heart in action was not something that could otherwise be captured.

It may be possible in the future for user-generated content, but at this stage, the time and skill needed to develop 3D content would not make user generation feasible in most educational settings. The 3D video camera means that it is possible for schools to film and include that content quite easily. There is also scope for teachers and pupils to generate learning material to accompany 3D learning artifacts. So for example, while it would be difficult for pupils or teachers to develop a functioning 3D eye model, they could certainly develop teaching notes, lesson guides, resource material, assessment tasks and so on that could be used in conjunction with the 3D artifact.

[Teacher comment] Development of 3D content will be a long term goal

[Teacher comment] I would really like a 3D camera and we could start to add 3D content.

[Teacher comment] I think it is too difficult to make content that is good enough for the children. They are used to the block buster 3D movies and they are highly attuned consumers of technology. They want the best, and I have not got the time or the skills to make it good enough.

The pupils were generally very happy with the content (see Figure 2.2.1). In a general questions to pupils about ‘How good is the content?’, 88% of pupils felt it was good or very good. That is consistent with the 89% (in another survey question) who responded that the content was good or very good (as shown in Figure 2.2.1).
The pupils made some suggestions to improve the content and these included wanting more activities and games in the 3D experience. The pupils particularly liked activities and game sequences in the 3D content. During these activities there were even greater levels of pupil engagement, as these comments from pupils show:

*It would be good if the content was more fun... maybe get some games into the content... fun ways to learn about the heart.*

*The content would be better if it contained more exercises and activities.*

*Maybe in the future, when I grow up I will make 3D content.*

The pupils are high end users of technology. They expect good quality graphics. They want accuracy, and clarity and they expect zoom and animation and movement. The pupils were most attentive during animated sequences or during activities.

*Teacher comment* Before it was just pictures and diagrams. And now we watch the real thing in motion. The pupils reach out and try to touch it. They can really feel it in action. They are watching the real action and this makes such a difference in their understanding.

*Pupil comment* I really like it when the image does something sudden. It is cool. I like the nose when it blows.

*Teacher Comment* The pupils were particularly attracted to movement in 3D and wanted images to go 'inside' for example, to follow blood through the heart as if they were blood.

*Comment from a school principal* From a pedagogical point of view, 3D has very quickly and easily fitted into what we do in the school. It has turned our classrooms into cinemas. In some ways this is exciting, but I don’t want the children to be passive. The teacher should be able to interact more with the image. For example, could they have a special glove that allows them to point at the image or something?
There were two complaints in relation to the content and these were the lack of a pointer and the difficulty in reading the labels (as previously mentioned). The teachers also wanted far more control over the content with a scroll bar or other way to pause, rewind and repeat sections of the software, as these comments from teachers suggest:

I really wish you could pause the content. I often want to dig deeper and point things out or ask the pupil questions. It should have a pause button.

I would like a search engine and also a bar like you have on videos so you can get exactly to the part you want to focus on. The way it is now it is a bit annoying because if I want to focus on something you have to go right to the beginning again.

The content really needs a rewind button. I often want to pause it or go back but then you have to replay the whole section.

The only problem is that the system lacks a pointer. You cannot show kids the stuff you want them to look at.

The label colors are hard to see. We need a slider - fast forward and rewind. It would be good if there is basic content and then extension content so you can take the talented pupils further. The teachers need 3D tools as well [3D pointer].

The color on the screen is not good. The yellow labels are hard to read.

The yellow text labeling was small and difficult to read.

I would like to be able to have hypertext so I could change the language and add the language at the right level for the pupils. The content needs to adapt to the teacher. The teacher should not have to adapt to the content. I would rather be able to create learning that was more interdisciplinary. I also want a pause and a rewind button. For me innovation is important, but only innovation that helps pupils learn.

The pupils also agreed, “It would be really good if it had review and rewind so I could look back on something if I did not understand it.”

In summary, the majority of the pilot schools were very impressed by the quality of the content:

[IT coordinator] The amazing interactive content is better and the pupils are really amazed.

[School principal] I watched it and I was very impressed. I like the content very much.

However, as this teacher pointed out, “some content is very, very good, but others are not so good.” Adoption of 3D in the classroom will be largely dependent on the availability of good quality content. Some teachers in the pilot study felt that while the content was sufficient for a pilot test, it lacked the quality and depth to be more widely used, as the following teacher comments outline:

Some of the content is not good. I don’t think the ‘cell’ is explained very well.
The content is currently quite 'flaky' but then it is assumed that it is not project perfect as this is a pilot test and the content is really only prototype content. Content is likely to be in the experimental stage for at least 12 months.

For this age group (12-13 years) I don’t think the content is good enough. It has mistakes in it, but then again text books have mistakes too! The topics are right. We have to study the body but to me the content is too simple, especially we need to go to deeper levels in understanding the heart. It would be good if the content could tackle the topic at different levels.

I think the 3D content is a bit superficial. It needs to be more detailed. We need deeper level content.

I think there is too much detail in the content. There is a lot for pupils to take on board and you can’t stop the content and talk in more detail about particular things.

I wish you could go into the 3D even more. When I was teaching sound, I really wanted the software to be able to go into the ear, like a sound wave. And with the heart, I wanted the 3D to follow the blood. I want to go right into the organs. That would be great.

2.3 Language

➢ The teachers want the content in the mother tongue of the pupils but the pupils were generally quite familiar with and happy to have the English

➢ Most teachers played the 3D with the sound turned down and spoke over the images

One of the limitations of the pilot study was that the content used was only available in English and - in all but England - English was a second or even third language for the pupils. Despite this, there was surprisingly little negative effect. Some teachers even commented that it helped improve language competencies. Also it was suggested that “voice overs” were not a good idea as the majority of teacher in the pilot turned the sound down and chose instead to add their own commentary to the images.

I don’t need the sound. I don’t need anyone talking. As the teacher, I can do that. The words should be in Turkish. It would be best if I could type the labels on the images.

The first time we listened with the sound and watched it. Because it was in English not all pupils understood it but the images helped. The next time, I turned the sound down and just talked. It was much better then. I think if we left the sound on the pupils might get bored.

The pupils have high expectations. We need surround sound. They are used to this in the theatre.

Several teachers used both the sound on the 3D and their own commentary. For example, while the sound is played softly in the back ground, the teacher talks over the images in the mother tongue. At times the teacher pauses and allows the pupils to listen to the English voice over.
At first we watched the 3D with the English. It was OK as we want the children to learn English, but then next time, I turned the sound down and spoke in Turkish. It would be good if we could type our own labels.

In some innovative examples, teachers adopted integrated or ‘team teaching’ approaches where the children were learning both science and English at the same time.

I wanted the pupils to listen to the English. The language is quite hard. It is technical language. The English teacher and I worked together and we introduced the words first. We try to integrate English learning and biology so the 3D worked very well for this cross-curricula teaching.

The 3D has helped. We are doing the lessons in English - combining science and language learning.

But for other teachers, the language issue (only being English) was perceived to be a problem:

It would be much better if the program was in the mother tongue.

The language is a difficulty. I have to watch everything first and then work on translations.

We turned the sound off. It would be better if I could leave the sound on but the language is a problem.

However, the pupils liked the sound and wanted to hear the English:

I like the English man because I am also becoming better in English and learning hard words.

The teacher speaks a lot and she gets tired. In 3D the man is speaking. The problem with the man is that he speaks English. It would be better if he spoke Turkish, but even in the English, I don’t understand all the words but it still makes sense.

In some ways I think it is better that he speaks English [voice on the software] as we learn new words in English and now know quite hard words. Most games we play on the computer are in English so it is fine really. I want to get this content into my home, so I can use it whenever I want and be able to do revision.

The talking is good because then the teacher doesn’t have to talk so much. It helps us, even if we don’t understand English.

It doesn’t matter if the man talks English or Turkish. I like to listen.

As can be seen in the results from the survey, most children (from the seven research countries) felt that they could understand the language (see Figure 2.3.1), with 79% of all children agreeing or strongly agreeing. This provides further evidence to suggest that while teachers and school systems want content in the ‘mother tongue’ this is less of a concern to the pupils.
2.4 Implementation

- The schools and teachers found 3D to be very easy to implement within the school and as part of lessons
- There was considerable professional interest expressed in the potential of 3D from the various educational authorities involved

This section outlines the main findings of the research in terms of the way\(^\text{19}\) the 3D was used in the schools and classrooms. It looks at the ease of implementation from the school/managerial level, the classroom/teacher level and then the level of the lesson.

The 3D research project has resulted in a lot of interest from the Ministry of Education or educational decision makers in four of the research countries. They are keen to receive copies of the research report and want to be kept informed about the experiment. There has also been high level interest from researchers and school systems and several emails requesting the opportunity to participate in a possible LiFE 2 project. For example, this comment was made by an Education Department planner:

*It is our duty in the educational department to ensure that the educational institutions that we are responsible for are always provided with the best possible range of teaching materials and equipment. We believe that 3D technology will bring significant benefits and are therefore more than willing to give our pupils the advantage of this new method of teaching that may well characterize the classroom of the future.*

There was some initial concern that 3D might be difficult to implement in the school. As indicated in the pre-survey data, 77% of teachers were ‘a bit concerned’ about implementing 3D in the classroom, while 8% described themselves as being very concerned. In terms of being able to use the DLP, at the beginning of the project 63% were concerned or very concerned about their lack of confidence, though 85% of teachers in the research schools described themselves as generally feeling confident with technology and 100% of the pilot teachers said they “liked to try new things”. At the school/managerial level there

\(^{19}\) During the pilot research many variables were controlled but the selection of implementation method was left open so it was possible to record differences observed in the adoption of the new technology.
was support for the research and a realization that 3D was likely to become quickly embedded in schools.

I could see the time when ever school would have a 3D area - the “salon de 3D!” That would be great!

With 3D the implementation has been very easy. Everything has been fine and good. No problems.

In this school we are very committed to ICT integration. I trust my staff. If they see something new and they think it is something we should follow, then I will try to follow it. The classes were very keen to try. The one I chose really said "I want this." It is a class with a lot of problems [pupils with special learning needs] and the 3D has really worked for them.

The point was made that perhaps when 3D was totally integrated at the school level, then perhaps some of the ‘halo’ effect on learning of the novelty of 3D may wear off, as this teacher’s comment suggests:

When computers first came in, they were exclusive and then all children were excited and the same thing happened with the Smart board. Now these things are just part of learning. 3D is useful for learning so in no time it will become embedded and we won’t know how we taught before 3D!

I like the system [IT coordinator] as it [3D pilot] does not need much by way of technology.

The cost is high with the glasses and the computer, but soon I could imagine that the pupils will have their own glasses and all laptops and projectors will be 3D ready and then the price will come down and 3D will be affordable.

School principals could see that it was possible to implement 3D in the school with only minimum investment, but that content for 3D would be the major issue. While several countries favored 'cloud' based distribution, this was not widely available in 75% of test schools. Methods of content distribution to schools vary considerably from one country to the next (and even one region to the next) and more detailed consideration would need to be given to the best model for content distribution and sharing.

We would definitely use 3D in the future, but there is an urgent need for more content to be developed... and better glasses of course!"

For most of the schools in the pilot study, the implementation of the 3D was quite straight forward and could be easily introduced with their existing projectors, Smart board and general classroom arrangement.

The real cost is only the content. I [school principal] would start with a subscription model where you pay for the content you have, like the Apps. I don’t think it is good to have a full subscription for a school as some teachers would not use it. Maybe per class rather than per pupil? We only have 2,000 Euro for discretionary spending, and that is only 80 Euro per class. The investment needs to be cost effective.
[School principal] I want to get this for the school, but I think we will wait a year and then the cost will go down. Also then there will be more content.

[Teacher comment] I think the 3D fits in very easily to the classroom. It is flexible and easy to adapt to the classroom. I would certainly like to continue using 3D in my teaching. I would like the content to keep developing. We need more and more content.

[School principal] It is a great thing [3D] but for us the issue is always economics, value for money, upgrades.

The teachers were asked to suggest the suitable price for a complete set of 3D capable resources for the school (glasses, content, computer and projector). Figure 2.4.1 shows the responses from the teachers to the cost of the 3D equipment. Judging from these results, it would appear that a cost band of less than 3,000 Euro is likely to be affordable for most school situations.

**Figure 2.4.1 How much would you expect to pay for a complete set to implement 3D?**

The overall response from school leaders (principals and executive officers charged with IT strategy and purchase in the school) were very positive towards the implementation and potential of 3D, as these comments outline:

*In this school we find that theoretical retention is a problem. As I see it, the 3D increases visual retention and this boosts learning. Schools have to keep pace with where the pupils are. As you know from your survey, many of these pupils have 3D at home and they have certainly seen 3D in the cinema. We need to ensure that school learning is just as rich. I can see a lot of applicability of this technology. For example it could be used in art and architecture, in mathematics, even in language leaning and history. It was very easy to bring into the school. There was only very basic training needed. It is not complicated. We do need the content in French. We should take the lead. Learning is about being able to show the pupils lots of examples. Very little is needed to operate the system. The projector and computer are easy and you can project on the wall. The glasses the pupils could buy themselves, so the real cost for the school is the content. How much would this be? We have very little money to spend... Maybe only 1500 euro per year so the cost needs to be low.*
It [3D] is very good. The pupils asked a lot of questions. I was impressed that pupils wanted to stay behind at the end of class and they continued to talk about the topic. They were dealing with a very complex topic, but they all understood it. Tres bon! Very good. The pupils get a very good understanding because they are seeing things for real.

There is not a single system that works for all teaching and 3D is the same, but the 3D does help them learn better. It makes the kids visualize more effectively.

We are sure that the system should be in every schools and be available for every teacher. At the moment, it is only in our school. And this sort of gives the Wow effect in our school that you don’t see in other schools. Of course this is good for us, but I also think it helps the children to visualize content and helps their retention of concepts.

We would definitely keep it in the school and would like to invest more in 3D in education. We would have to upgrade the graphics card. These can cost nearly as much as a whole new computer. But technology is developing rapidly and things always get cheaper. But maybe there will be other technologies in the future. Keeping up with it all is always the problem for principals.

The implementation at the level of the ‘lesson’ seemed to be very straight forward. All the teachers observed used 3D intermittently during the lesson and seemed quite comfortable to turn the 3D on and off as the content and flow of the lesson dictates. The teachers in the pilot research consistently found that the 3D was very easy to implement into the classroom environment. The teachers did not need any special preparation or training and all the teachers observed were able to comfortably use the 3D and integrate it effectively into their lessons. The teachers felt that one advantage of the system was that all pupils, regardless of where they sat in the class could see the 3D models very clearly and that the 3D could be projected onto any surface (i.e. did not need a special screen) and so the image could also be projected into all corners of the classroom. The pupils also appreciated how easy it was to see the 3D no matter where they sat.

[Teacher comment] No matter where you sit in the classroom the model is right in front of your eyes.

[Teacher comment] The children are arranged in desks looking to the front. One advantage is that 3D made it easier for all children to see as the model appeared close to them, whereas normally children at the front are advantaged over children at the back.

[Pupil comment] When the teacher shows a model if it is small you can’t see it, but with 3D even if the teacher moves around or a big kid is in front of you the 3D will always move in front so you can always see things clearly.

It was also felt that the 3D content was ‘value for money’ as it could easily be accessible and appropriate across a range of disciplines and at different age levels.
I think you could use this in all classes. You can keep the same images, but then the teacher would just say different things. I could see, for example, that you could use the senses in first or second class, but the teacher would then just give a simple description.

The majority of teachers felt that teaching with 3D saved class time as they were able to teach more and to more depth than without 3D.

I have found that the 3D saves time. Of course not in the beginning as you get to know how to use it. But it certainly saves time in the lessons. It is the only tool of its kind that exists. The pupils can learn all at the same time and they learn a lot at once and so I find I can actually cover more in the same time.

I was worried by how much time doing the 3D experiment would take, but actually we were able to cover more in less time so time was not a problem.

I would definitely say that it shortens the time to teach concepts. They can see everything and to a deeper level and they sort of get the concepts. We have tried it with the eye and the ear and they understand more in less time.

It certainly did not make teaching any longer. Actually I would say it was shorter... a little shorter and we covered more.

We find we can cover more material in a shorter amount of time. Also what the children are learning is more complicated and deep compared to what they would have learnt before. So in that way, it is excellent.

Even for a teacher who was not sure if the 3D saved time, she commented that the pupils learnt more in the lesson:

I really can’t say if I can teach faster or not with 3D. The 3D does not replace the role of the teacher. I still need to do the commentary. I would say it is complementary to teaching and so whether the pupils learn more I don’t know, but they learn deeply.

Teachers used 3D on average for between 8-15 minutes in the middle of the lesson.

We do 3D for between 5-15 minutes depending on the lesson. I think 30 minutes of 3D would be too long.

In almost all cases (except in three classes) the 3D became an added approach rather than changing pedagogical approaches. In other words, the teachers added the 3D into their usual way of working rather than changed their way of working around the introduction of the technology. For example, while a teacher may have previously taught ‘the body’ with a combination of explanation, text books, diagrams and activities, the teachers still used these same approaches but simply added the 3D.

I don’t think the technology has changed my pedagogy. It is a big support and a resource and that is important.

In the three exceptional cases, the introduction of 3D led also to changes in pedagogy. For example, in one school the teacher let the children ‘give the lesson’ and operate the 3D. The children enjoyed this very much and were able to effectively use the software and ‘teach’
the lesson, even using English instead of their mother tongue. In another example, the introduction of the 3D led to the teacher considering more varied assessment processes, and instead of pen and paper test, the teacher used model-making as a form of assessment.

*I was concerned that the class would be too passive. There are challenges in this class, so I decided that the children would teach the lesson and do it in English! As the teacher, I went to the back of the room. The pupils drive the computer and run the lesson.*

In reflection, many of the teachers felt that the 3D might - in the future - change their pedagogy, but only once there was more content and also when they felt more comfortable with the technology. The teachers said that 3D was much better than plastic models.

*I first I was a little nervous about using the 3D, especially when people were coming to watch, but now it is very good. No problem. We all had fun. I would like to keep using it, but not all the time. The 3D is more realistic. It is more interesting. It has been a real "wow" experience for these pupils.*

*It is not hard work at all to teach with 3D. It has made it easier in some ways as it really grabs the children's attention.*

Both pupils and teachers could see a wide range of ways the 3D technology could be applied to learning other subjects. The most commonly suggested subjects for particular application of 3D technology (in addition to science) were mathematics (78%), geography (46%) and

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20 Based on teacher interviews conducted at the end of the ‘live phase’ of the research.
Others also suggested art, music and language learning may also be possible with 3D technology. The pupils felt that they would not get bored if 3D was used in all different subjects.

[Teacher comment] It would be good for learning spelling and learning English. It could really be used in all subjects, but there should not be too much in one day so the teachers would have to talk to each other.

[Pupil comment] When you make things in art 3D would be good.

[Teacher comment] I can see it being used for a whole lot of lessons across lots of subjects, but we would have to be careful as I think it should never be more than for a third of all the day.

[Teacher comment] I think it could be used a lot more in maths to make it more interesting because maths is not interesting.

In summary (Figure 2.4.2), there was strong support for 3D in general (with an average score of 8.8 out of a possible score of 10) while the glasses and content were the least liked areas, with average scores of 6.1 and 6.4 respectively.

**Figure 2.4.2 Average teacher satisfaction scores**

![Average Score /10 Chart](image)

Note: Figures do not add to 100% as pupils and teachers could nominate more than one category, i.e. Respondents could say it was relevant to mathematics and geography. The percentages are obtained from adding and averaging both the pupil and teacher results.
At the level of the pupils, apart from some issues with health and safety (see section 2.5), the pupils adopted the technology very easily. In several examples, the pupils themselves began to use the technology and there were no issues at all with this. The pupils were independent and proactive in wanting to use the technology.

*It was very easy to use. No training was needed. We started with the skeleton and then the heart, the ear and the eye. We have also looked at some of the other content. The pupils like the supermarket.*

*The children are already very used to the 3D in lessons. If I say "Now we are doing 3D" the children get out the glasses and help set up the projector and it is really not a problem at all.*

The pupils interviewed in the research were split equally on whether it was better to have whole class teaching or small group teaching. Those preferring whole class said that they valued the input from the teacher and also that the teacher “added to” the learning possible with the image. The pupils who preferred the small group teaching commented that they wanted to be more “in control” of the technology and also that they could progress at their own rate and return to particular aspects for revision. One criticism made of the software was that it was not possible to return to particular parts of the image, and that if you needed to revise something you had to go through the whole section again. It was suggested that a ‘search’ capability would enhance usability (see section 2.2. on ‘Content’). Some pupils were concerned that group learning might lead to “chaos” or disruption in the school as “everyone did their own thing”.

### 2.6 Teacher professional development

- The teachers were able to effectively use 3D in the classroom without any specific professional development
- Teachers and pupils expressed a desire to share 3D content and lesson ideas with colleagues around the world

The teachers in the pilot study were a mix of highly experienced and lesser experienced teachers that could be said to be a representative sample of the spectrum of teachers generally encountered in schools. As can be seen in Figure 2.6.1, they had differing levels of teaching experience.
The teachers were able to implement the 3D pilot program without needing any particular teacher training or development, and within the first or second week of usage the teachers felt confident. The pilot teachers started to exhibit characteristics of leadership in the schools and to share the 3D with other subject areas.

I showed the 3D to my other colleagues in science. The other teachers want to try it. They can see the application to their teaching. The class that is only getting 2D is very jealous!

When will the other teachers get the 3D? They are all jealous of us! We invited the other teachers in to see the 3D. It was funny. They took the glasses and sat like the pupils. Some teachers came in and watched some 3D lessons. They said, "What is happening, the children want to listen so carefully!" Now they want to use it in other subjects.

In the school the 3D has led to a lot of discussions in the staff room. There have been six teachers that were really interested - three teachers from the English teaching area and three from the computer area.

The technology had been shown to other teachers from other discipline areas.

The attitudes to experimentation differed significantly between different schools. In some schools the teachers were very excited to trial the new technology and felt that being involved in the pilot was professionally rewarding, as this comment suggests, "It is part of a teacher’s role to learn new things. I am very supportive of this project.” Another school principal commented:

The system became fully activated on Friday. It is step by step but my aim is to get all pupils, parents and teachers to see this. I think the 3D has the potential to attract new students to this school. You have to do something different to attract pupils. But it is not just that, it will help pupils learn better and the retention rate is higher. Also pupils will need to be aware of new technology in their future career. Young teachers can easily adapt, but the older teachers have had no problems either.
Other teachers were less confident at the outset but soon managed to master the technology:

*I am not good with technology but this has been easy to use. The first time it was a little flat and the image takes a bit of tweaking to get is 3D.*

*In our school there is a big variety in terms of how comfortable teachers feel with technology but with 3D they have all found it very easy.*

*It was not easy from a technical point of view to begin with. It requires too many RAMs on the computer. We would fix it and get the 3D working and then the next day it would not work again. It was all new to us. We have to get to understand the 3D. One of the problems with 3D from a school point of view is that there are too many systems of 3D and you do not know which one is likely to ‘catch on’ and so you don’t want to invest but rather see what happens. It is hard to make a decision. It was hard to get the 3D image at the back of the board. We had to press the button to make it work. If a teacher is going to use this, we need to make it very easy to convince them that 3D is a good thing. Some of the teachers are not computer friendly! It depends on the teacher’s age.*

The technical requirements did not seem to be a prolonged issue in most of the pilot schools and did not require any additional professional development. However, schools should consider the provision of time for the teachers to plan and develop interesting learning projects to use the 3D content. Similarly, more focus should be given to the way 3D might enhance or innovate classroom teaching and learning pedagogy. The use of 3D seemed to stimulate changes in the flexibility of the learning environment (e.g. everyone as a potential peer, expert and novice). Some teachers were able to involve the pupils as learning leaders using the technology:

*The children set all the equipment up and run the lesson. Everything has worked. I think I will try this in other classes.*

*Pupils get to know new forms of technology that could in future support learning processes and promote innovative teaching concepts*

There was evidence that several of the teachers began to use the 3D in different ways at the start of the learning process, midway, at the end or after the end of the unit, as is suggested in this reflection from a teacher involved in the pilot:

*I build the lesson as I would normally build it. Does the new 3D technology fit into existing teaching and learning patterns or does it cause new patterns to emerge?*

In the pre-survey, 76% of teachers indicated they would like more professional development. All of the schools involved in the pilot project commented that the involvement in the research acted in a positive way like professional development, as these comments from teachers suggest:

*I am open to new technology and so I am very happy to be involved in this research project.*

*I am really thrilled by the project and a chance to have the project in our school.*
It was really not difficult to do this project. The pupils keep asking for more.

The 3D experiment has been a very good experience for the class and also for me as a teacher.

The whole experience of doing this experiment has been fantastic, really a pleasure. I want to meet with the other teachers too and keep trying things.
Chapter 3: Context
There is no doubt that technology has changed the way we learn and live. This chapter explores the experiences of the pupils and teachers with 3D and the attitudes towards technology that influenced the adoption and usage of 3D in the classroom.

3.1 Pupil’s experience of 3D

➢ The pupils are high-end users of technology and have considerable experience of 3D

The pupils owned a lot of technology devices and used them regularly, as is indicated in Figure 3.1.1. 90.1% of pupils had a computer, 85.3% had at least one mobile phone, and 74.6% had hand held games.22

Figure 3.1.1 Pupils’ use of technology

The first survey results indicated that over 91% of pupils use the internet for at least one hour per day.

Note: many pupils had more than three different forms of technology.

22
The pupils’ experience of 3D was high in all the seven countries where the pilot was undertaken. There was no discernible difference in experience of 3D despite the belief some teachers had that their pupils would not have access. For example, in one country the teacher asked, "Don’t you know this is not the right country to do this research? We don’t have this sort of technology at home." In actual fact, 100% of pupils in this class had seen a 3D movie with most seeing three or more movies. The first survey revealed that 90% of pupils had seen a 3D movie (see figure 3.3.2)

Figure 3.1.2 Have you ever seen a 3D movie?

The pupils were very knowledgeable about general innovations in 3D and quite informed consumers about the 3D products available.

[Teacher comment] Quite a few children in this class have the new Nintendo 3D and all of the children have been to 3D movies.

The pupils possessed very positive attitudes towards 3D and were keen to have more 3D in their life and in their learning. While some children had experienced some negative effect during a 3D movie, they were overall very positive (see Figure 3.3.3).

Figure 3.1.3 Reaction to viewing 3D movies

The pupils expressed a strong desire to own 3D objects such as 3D televisions or games consoles. Most pupils had attended three or more 3D movies. The following comments are a
small sample of the very positive comments towards 3D made by the majority of the pupil interviewed during the research:

[Pupil comment] I want 3D television [This was a very popular comment from the pupils].

100% of the class have seen a 3D movie

The pupils (especially boys) showed a particular preference for more gaming opportunities in 3D:

[Pupil comment] Computer games in 3D would be cool

[Pupil comment] 3D games would be really cool.

[Teacher comment] I have noticed the biggest difference with the boys. The boys really expressed their excitement. The boys play with computers more. They like this way of learning and are more focused.

It would be reasonable to conclude from the pupils’ responses that they are very sophisticated and high-end users and consumers of 3D. They were reflective about the quality of 3D and could make imaginative suggestions about how to improve the 3D experience in the classroom:

I would like the 3D to be able to stop and go as you want it, like you can with a YouTube video.

Shrek was a very popular movie. We thought 3D in the class would be like in the cinema. It is not as good as the cinema but it makes you understand more.

The teachers interviewed acknowledged the importance of good quality technology for the pupils of today as they are “digital native” learners:

The children know and like technology. We would usually use a plastic model. But it is small and hard to see. For children technology is the usual thing.

The kids are into technology. We need something different in the classroom. It is more philosophical than just putting computer in the classroom. Technology is not just about learning the content. Technology will change the view of life. Children must have different points of view on life. Their thoughts are important. It is a humanistic issue. Education needs to be about the board picture, including the children’s feelings and the spiritual world.

In one of the research schools, an interview was conducted with the school’s psychological councilor. She commented about the positive impact the 3D project had had on children with visual learning styles. She was also monitoring the impact of 3D on the children and felt that it was very exciting and positive experience.

I think it is definitely better for the children’s learning [psychological counselor]. It is especially good for the children who mainly use a visual learning style. As a school we have been doing a lot of thinking about different learning styles. In primary school, visualization is particularly important.
The children were happy about the project and were learning well. As one pupil succinctly described the days where he had a lesson in 3D:

*It is a bit different from other days.*

### 3.2 Teacher’s experience of 3D

- **The pupils were more experienced with 3D than their teachers**

In all but two of the classrooms, it would be reasonable to conclude that the pupils were more experienced with 3D than their teachers. The pupils were very supportive of their teachers but also were aware that their understanding of the technology was often better than that of their teachers, as the following comments from pupils show:

*The teacher is still getting used to 3D. She will stand in front of the image.*

*It is hard for her to point to things. She points to empty spaces.*

*The teacher did not say as much.*

*The teacher did not move the image around nor wear the glasses. The teacher was not aware of the image not being 3D. Teacher did not talk while the image was shown and used the English voice over.*

Despite these qualitative comments about teachers and technology, the survey results were very supportive of teachers with 94% of pupils either agreeing or strongly agreeing that their teacher(s) knows how to use technology.

In general, the parents felt that their children were happier and more positive when teaching with 3D.

*He explains more. He is taking the subjects to a higher level and we are doing more difficult work, but it is easier to understand and more fun.*

*In 3D she [the teacher] is better. She speaks less.*

*I think the teacher’s job gets easier with 3D. She sort of becomes happier. More visual. I can’t be specific but the teacher has improved since the whole 3D thing started.*

*The teacher is more fascinating.*

*She becomes funnier. More funny.*

*When there is 3D the teacher is sort of happier. I think because we like it, then he likes it. We understand things and there are better examples.*

*The teacher is better in the 3D lessons. The technology facilitates her explanations. She likes 3D and then she sort of passes this liking onto the class. She is showing us things in 3D and it is easier to learn.*
The teacher will get less tired as they don’t have to do as much. The pupils are more attentive and interested and everyone will learn better. The teacher had some work to do though as the 3D spoke in English.

I can’t describe it but in 3D lessons the teacher changes. She is better. Sort of happier... actually we all change.

We all change in the 3D lesson... even the teacher changes. We all change for the better.

The pupils comments about the teacher being “happier” in 3D lessons was also supported by the survey results with 68% of pupils feeling that their teacher was happier in 3D lessons (see Figure 3.2.1)

Figure 3.2.1 The teacher is happier in 3D lessons (pupils)

The teachers recognized the need to change their behavior in light of the new technology.

I try to point to things. It is very hard to point to things. I even tried using the laser pointer but it does not work.

It took a little while to get used to the 3D. Not the technology, that was easy, but how to change my behavior to work with 3D. For example, I am used to be able to point and that is not possible. Some glasses were not working and that was a nuisance, but apart from that I had no problems with the technology.

There was also explicit recognition on the part of the teachers that while things may improve during the pilot phase, that learning might return to normal patterns once the ‘novelty’ wore off. For example, a study conducted by MORI23 between 2000-2002 showed that after the early introduction of electronic white boards into the classroom, there was an initial positive impact on pedagogy but over time classroom pedagogy actually worsened. There was more copying and discussions, problems solving, talking with teachers and learning things about the real world actually went down (only 10% of learning was learning about the real world).

These results from earlier studies of the implementation of new technology were implicit in some of the comments from teachers:

When computers first came in, they were exclusive and then all children were excited and the same with the Smart board. Now these things are just part of learning. 3D is useful for learning so in no time it will become embedded and we won’t know how we taught before 3D!”

In the past I used a 3D plastic model. The 3D is better than the model. The 3D is very real. Of course the first time I gave the 3D lesson the children were very excited, but now they have had it many times and they are still excited about it but more because they are learning and understanding. Despite its success, I think around 15-20 minutes is enough time. I can easily see how we could also use it in history and geography.

While for many of the teachers it was their first experience with 3D (even as viewers of 3D) they seemed to adapt quickly and did not have any real problems. The teachers were keen to learn the technology and seemed to be genuinely impressed by its potential.

It is good. It was not hard at all. The children like it.

Wow, it’s so great. It’s not at all technical really. It’s so easy. It is very easy to use.

Wow, it’s great. There is so much enthusiasm from the children.

[Comment from school IT coordinator] The staff were absolutely excited.

The nature of the technology itself seemed to encourage more innovative attitudes from the teacher. For example, it is not possible to see the 3D nor operate effectively if you adopt the traditional ‘lecture’ position with the pupils and so the technology often ‘forced’ the teacher to teach from other parts of the room. The teachers adapted readily to this and were able to integrate the technology without any problems as either a new way to teach or as a way to introduce new technology into the design of their lessons. For example, during one classroom observation session, the teacher moved from behind the desk at the front of the room where she had been teaching all other parts of the lesson to a pupil’s desk at the back of the room for the 3D section of the lesson. She did this each time the 3D was shown (four times in total throughout the double lesson). In another example observed the teacher seamlessly moved between different types of teaching methods, including 3D. The lesson started with some oral revision, this was followed by explanation and a 3D (physical) model. During the lesson, 3D projections were used three times and for a total of 13 minutes (within an 80 minute teaching sequence). The teacher also used experiments, group discussion and worksheets in the lesson.

One aspect that was very apparent in the interviews with the pupils was that while they adopted an almost patronizing attitude to their teacher’s lack of technological understanding, they were totally committed to the value and importance of their teacher as a mediator of learning.

The teacher is the most factor. The teacher is much more important than the technology. The teacher is the most important thing in learning.
I don’t think that 3D will ever replace the teacher. The teacher knows the subject and they add detail. The teacher knows how to go at the right pace, but at the same time, teachers need to change to the innovations.

3.3 Visual and kinaesthetic learning styles

- The majority of children in a class are visual learners, whereas the majority of instruction is auditory
- The pupils said they learnt better when they could see the 3D image and see the functions of the body part through animation
- 3D tended to encourage visual and kinaesthetic leaning

Children find it hard to understand what is not visible. Visual learning improves understanding of functionality and by seeing the whole, children are able to understand the parts. The child is able to visually take the body organs apart and reassemble.

[Pupil comment] You can turn the things around. We can see the whole. It is more detailed and we can move the object.

The pre-survey indicates that the pupils had a strong preference for visual and kinaesthetic (85% preferring seeing and doing and only 15% preferring hearing) learning, as shown in the responses to the question, “How do you prefer to learn?”

Figure 3.3.2 Pupils’ preferred learning styles

Complex concepts become more easily digested when reduced to imagery. The 3D models were able to represent information in the most economical manner to facilitate learning and comprehension, thus simplifying complex, abstract and impossibly large amounts of information into a coherent form. By rendering the world visually the children were able to understand greater levels of complexity. Through being able to engage directly with the 3D, the pupils could define complex concepts visually and therefore understand these concepts more deeply and more profoundly, as these comments from pupils suggest:

I get that because it is there.

I understand things better. The images come with you.
It stimulates my brain to keep more. My brain captures more than when I just write something. I can see the content and the image. In 3D you see and you listen. The teacher is good at explaining things, but you see more with 3D. The image is important.

Teachers talk a lot and you just sort of tune out, but when you see things it is there and suddenly it all makes sense.

Before when we heard about the eye or the ear, we only had to imagine it, but now we can see it. It is much easier to get the message and really understand it.

I really want to see everything. 3D is cool. I learn more. Things come closer and I can see more detail. It is more vivid.

I see things better in 3D

It is very good to learn in 3D. You can improve through the images.

It is better in 3D because the images make you understand.

You can see the words and the pictures and it is clearer.

It is easier to learn in 3D. I feel, I can touch this. It is fun and more interesting. It is like real life. It's more real. I could actually see it and that makes it easier to understand.

You can almost touch it. You can see it better. The animations and close up... really the whole thing is great. You can see the actual point. It is much better than the plastic model as you can actually see how it works. You can see it in action and how everything goes together.

The teachers noted similar impression of the pupils' learning in 3D:

The children's reaction was "Wow!" They were moving their bodies and pointing and really into the 3D. Some felt a little uncomfortable the first time but then that seemed to pass quickly.

It gives the pupils a better chance to visualize various parts of the lesson. The children can easily imagine and it makes these imaginings visual.

There was only one child during the LIFE research project who preferred the plastic models to the virtual 3D, but in this case it was because the glasses hurt his eyes and did not fit his face.

The 3D plastic model is better than the 3D on the screen as you can touch it and you don't have to wear the glasses.

Understanding occurs through the process of restructuring and reconstructing. The child is able to see the physical association with learning. The child is able to physically and visually explore the available information and drill down visually where needed.
If the lesson is only text-based, if the children don’t see the visuals, it is hard for them to remember thing. If you use visuals, the children will learn more easily and they won’t forget. It is important to see something. With images, the children relate better to the content.

The 3D makes it easier to learn because it is color. You can see how the thing works.

The 3D in the classroom is quite graphic and it actually appears to come out to the pupils. This highly vivid experience made the learning very captivating to the senses. During class observations, 33% of the pupils reached out or used body mirroring with the 3D, particularly when objects appeared to come towards them and where there was heightened depth. A number of children are using their bodies during the 3D lessons and also used body language and gestures to explain their models or the workings of the body organs.

[Teacher comment] The children reached out to try to touch the 3D.

[Teacher comment] When I first showed the class it was the skeleton and some children even screamed. It was the biggest feeling for the children.

[Teacher comment] The pupils are very excited by the 3D images. Many reach out to touch the images, others squeal with excitement.

[Teacher comment] The children responding physically including hand gestures, reaching out and movements of the mouth.

The deepest 3D and the most animated content appeared to have the greatest effect on learning and retention. As stated previously, the pupils were highly experienced and critical consumers of 3D images and they wanted high quality images with effective levels of special effects.

Different piece of software seem to have different reactions from the pupils. Some are a bit ‘how hum’ but then others really have the wow factor. Of course all this is new and cool. Will the pupils just start getting used to it?

We need even more demanding teaching content from, say, geometry and physics, can be easily conveyed if presented in the right form and can increase the pupils’ and students’ comprehension and learning effectiveness.

The more interactive the image was the more the image appealed to the pupils as this quote succinctly outlines: “It [the image] comes out to us and goes back and front and we can turn it around.”

[Pupil comment] The eyes seemed real. It was like we could reach out and touch them. We were actually inside the eye.

[Pupil comment] The supermarket is the best because it is more like you are walking around there because it is like you move around it. More like a game. I feel different. It is better. I would like more. I could use it in maths. The shapes would be good in maths. I think it is easier to learn 3D.

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24 See Chapter 4 on impact.
Chapter 4: Impact

This chapter details the impact 3D had on the pupils. It looks at impact in terms of educational achievement, classroom behavior, motivation, classroom communication, and assessment practices. The chapter also reports on the response from pupils and parents to 3D in the classroom.

4.1 Pupil response to 3D

- The pupils are very excited by 3D in the classroom
- The pupils feel 3D improves their learning
- Learning in 3D is perceived to be more real

The overall view of the pupils towards learning in 3D was very positive, as can be seen from these comments:

I am very lucky to go to this school. The 3D is great fun!

It was nice... enlivening.

That was fun!

I think it is very fun. I can see things in different ways. I like the heart the best because you can see how it works.

3D is fun. Excellent!

The 3D is very fun. We see it three times a week. The heart is the best. I like the activities. The supermarket is far-out!!! It has been fun. My mother said it was good for some subjects.

This high level of pupil satisfaction with 3D learning was also evident in the survey results where only 3% of children felt that learning in 3D was ‘bad’ and an 83% approval rating (see Figure 4.1.1).

Figure 4.1.1 3D learning in my class is...

Apart from being fun, the pupils also felt that 3D improved their learning:
3D is better. You understand better.

I think I will get better test results. It is easier for me to remember with 3D. Then I will do well.

It enabled me to see parts I couldn’t see before. It is easier to learn that way.

It is faster to learn in 3D. I prefer it when I use it myself. I like a game best. There needs more activities and more fun. You could use it in maths, in symbols. It is fun. I am more interested so I will do better. 3D is less boring than the usual lessons. The pupils laugh more.

It is fun and good to learn. It is easier to learn. You see it in front of you. The heart is the best because I did not know anything about it before.

It will be easier to do a test because it feels better, because I understand and am more confident. The children are calmer. The teacher looks more interested in it. It is really good I want it to continue. I would like more games and activities.

It is more vivid

It is very nice. We learn more. I learn deeper. It is easier to understand. The children ask more questions because you get more engaged. It is different. It is a little more fun.

It was fun. Just to see it in 3D especially the heart. It is easier to learn but it is hard to understand the language but the teacher explains. The teacher sits with the pupils but I don’t know why. My parents were thinking it is exciting.

My learning is better with 3D. We can see all the detail.

The 3D is fun to watch and you learn more because you see it in a different way. You get more of the totality of things and more perspective. I had a little bit of a headache. You can see more what happens. I think I will be better at tests. Because I have understood more I will do better at the test. The parents think it is good we try new things. I would like more 3D. It could be used in cooking. I would like it to stay. Pictures make it easier to learn. Like more interactivity.

A theme that emerged during the lessons (see later sections on educational impact and attentiveness) was that the 3D was more “real” than the usual resources used in the classroom:

It is fun. It’s more real. You could see it from all sides. The other children [2D control group class] want to be in the project too.

We want to learn it real.

We see lots of movies with 3D. 3D is more real. This is the biggest thing about 3D. It’s not as boring as 2D. 3D is not boring at all. You are more excited so you pay more attention. I think it is still as exciting as the first time I saw it.
Several pupils commented that they felt they learnt more effectively because the 3D improved classroom behavior and the attentiveness of the pupils and was less boring:

_The children are not at all distracted. I would say the class is completely different. When we have to learn by reading the textbook, we are all bored and really we are all distracted, but with the 3D we pay attention. I think we will do better in the tests._

_This is good. It is a bit easier to learn. The heart is the best. It is best. The activities were only OK. The children are quieter and some concentrate more and are a bit more focused maybe because it is a novelty. It has to have a purpose to stay in the school._

The pupils felt that 3D could be applied to other areas of the curriculum and they were excited to suggest possibilities, but they also acknowledged that they would not want 3D to be used too much in any given school day.

_I can see 3D could be used for a lot of things, but it is good if you do a little of everything. You can't just do all 3D._

As mentioned in section 2.5 on Health and Safety, the only pupils who did not appear to like 3D were the very small number of children who continued to feel negative sensations that were prolonged beyond the first lesson.

_I did not like it [3D]. I had an eye ache and a head ache._

_I got a head ache from the glasses. After a while I got a headache._

Some pupils also found listening to the English to be difficult:

_It was fun to look at but the English was very difficult to understand. The teacher plays the film and the guy talks. It is easier to learn with the 3D but I would prefer it with the Swedish language. I learn better because I see it on the screen. The other kids want to do it. I think I could do it [3D] for one hour._

### 4.2 Parent response to 3D

- The parents were initially a little skeptical and concerned about the use of 3D in the classroom
- Once the parents saw 3D they were very impressed and considered it to be essential for learning in the future
- The parents expressed the view that 3D was likely to be a part of the future for their children
- The parents considered 3D to be a professional level learning aide

As part of the research process, parents were given an information sheet about the project and asked to sign a research permission form. This gave parents some brief insight into the project. During the course of the project parents were invited to come into the class and experience 3D themselves and also to watch their pupils engaging in 3D lessons. Small groups of parents were interviewed in focus groups and asked to comment on both their own experiences of 3D and the experiences reported by their children.

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25 Due to restrictions in place in some school districts the parent visits did not occur in Germany, Sweden or France.
In summary, the parents were initially concerned about the use of 3D in the classroom, especially the possible negative health effects, but after they and/or their children experienced 3D they tended to be highly positive towards 3D. If 3D were to be more widely implemented, it would be important that parents were also included in the induction process. It would appear to be important that the parents themselves get a chance to see the 3D learning in action. When a group of parents were shown the 3D as part of the research, they were very excited and asked a number of questions.

As the following comments show, parents tended to have initial concerns about health related issues but very quickly acknowledged the value of 3D to the child’s learning and were no longer concerned.

*I am worried about the health effects on my son. Is it some form of hypnosis? Maybe they remember more but what are the negative side effects? It is important that we know this.*

*Initially I was a little worried when I got the permission note. I thought, this is a very serious project and maybe it might damage my son’s eyes, but now I am not worried at all.*

*I don’t think 3D can ever be total education. It is only one way to learn, but images are powerful ways to learn.*

*I was a bit frightened at first when I heard. I was worried whether the glasses will harm the children, but it is fantastic really fantastic.*

*I want my child to have the glasses for herself. There could be hygiene issues of sharing the glasses. Individual is better. We have 3D at home and my children go to 3D cinema... but I only let them watch like 2 hours at one time.*

Some parents were not worried about 3D for the duration or scope of the research project, but were concerned if 3D were to become more ‘main stream’ in the school and be used for a greater proportion of the school day:

*The important thing is the time the children might spend on 3D in total. At the moment, they only have it in science and then only for 15 minutes, but if 3D started to be in lot of subjects and the teachers did not coordinate it then the children could have 3D for several hours. The time the children spend on 3D is important, especially if they were to have it in everything. I am not saying it is bad. I can see how 3D could be used in all subjects and be really good, I just wonder about what the effect could be.*

While there was genuine enthusiasm expressed by the parents for 3D to spread across subjects, this would need to be weighed against any concerns resulting from prolonged exposure to 3D.

*I feel positive about 3D as my child is very excited about it. I am not sure about the effects of 3D on the child’s health and learning. We need to leave it longer to see.*
I think it is great but it should not be used for everything. I don’t think it should be used for Italian [then another parent commented] “I don’t agree, even in Italian we could have an author talk about his story or saying a poem. Everything is possible. You imagine a lesson where Dante comes out!

The 3D is better. It will not replace reading. It is no the complete answer, but it does increase visual education. The image will remain in the children's mind for longer.

The parents could see the value of their child learning using “professional level” resources:

3D is being used in the medical community. Then our children are learning like the doctors are learning. This is fantastic. They are getting the very best material to learn from.

3D is used in medicine. European professors now use 3D.

3D is used in medicine and also I saw a show about 3D with this European professor. I think it is important that our children are using the professional level things. They use 3D in universities.

I am a Doctor and I really wish I had these lessons when I was learning.

For other parents the most important factor was that the 3D was really engaging their children and was fun:

Children like 3D. It is very nice to see the image moving. It is fun... not static. The children get a total physical response.

Children really like the 3D.

The parents felt that their pupils were more interested in learning and more likely to achieve better results when they were involved in the 3D lesson.

I have twins, and there is one in each class. The one that is not getting 3D is very jealous of the other one! I have noticed, the one getting 3D is more active and lively about the lessons.

I think it is good. If the children have 3D lessons they will get higher points in their tests.

3D in the lesson makes them concentrate more. They have to focus and concentrate.

3D is fantastic! The children won’t need the 2D anymore. I wished they had this when I was learning! I wish there were 3D tests.

I don’t know if it is the 3D, but my son’s favorite subject at school is science.

I think it is great. If you have 3D then you get higher points in the tests.

Of course it will help the children learn. It is more interesting for children.

What is really good is that they are learning about things from all different directions. That must be good.
When the pupils learn in 3D they learn better so even if they see it in 2D they will remember.

The majority of parents interviewed did not see any negatives with 3D learning and felt that if the technology was available it should be being used to help their children learn in the best possible way.

I really don’t see in any negatives.

It had the "Wow Effect". Now that they have seen 3D they are no longer satisfied with 2D.

It is more true... more realistic. It is good for children.

It is really fantastic. It looks real. I think things are more likely to stay in the children's brain for longer because it is eye catching.

My son was really excited about the 3D. He said it was like seeing the real scene. It was real. It hurt his eyes a bit the first time, but now he is fine.

My son was really excited at breakfast this morning because of the 3D.

My son was really highly motivated by the lesson and had no complaints. He had experienced 3D before and he is very excited and very happy with the program.

It is so beautiful! My child came home so excited. It is new and different. My daughter said 3D is good for us and she was very positive.

It's more real!

Learning like this the children will remember what they learn forever.

My child is telling me much more. Children need to talk when there is something new.

My daughter was actually sick on Friday but she wanted to come to the school because of the 3D.

My daughter was very excited about 3D.

If schools don't use 3D when the technology is out there, then they are crazy.

"It is amazing. I am hard of hearing and I never really understood why and now I can really see why I am deaf. Thank you really thank you."

It is amazing. It is like something from Star Wars, but it is real. 3D is better. Will we make 3D content in Turkish too? Are there companies in Turkey making 3D?"

It is very nice... It is alive and impressive. This has to be good for education!

It is like a video game for children. We have to be creative if we want children to learn.
There is no doubt that 3D will come into the school. In some ways it will replace traditional methods, but you can never replace the teacher. This will help my child do better in exams. I think it could be very useful for younger children too, even when they are learning to read.

When my son goes to secondary school, I want him to learn with 3D. Before he never said much about school, but with the 3D he came home very excited. He said, "Mum I want to be a science teacher". My son is usually quite an average pupil but with 3D he says he is able to learn more.

Several parents commented that they really did not understand 3D and that their children were more advanced with technology than they were. Similarly, many parents commented that they wished they had had access to 3D when they were learning.

How does this work? It is very exciting and important.

I am amazed by this system. I really wish they had it when I was young.

Some parents suggested that the whole process of both the implementation of the 3D and the research process (including the interviews and filming) had a ‘halo’ effect in making the children even more responsive, but that this was a positive thing. These respondents also felt that the 3D should continue beyond the duration of the research project.

My daughter is more enthusiastic. She is seeing this as a sort of exclusive project and I think that is part of her interest. We definitely should continue this in our school. It could be good in a whole lot of courses. This is something really good for the Turkish education system. We could be the leaders on this.

During the research interviews, the pupils said that their parents were overwhelmingly supportive of the research project and of learning in 3D, as is shown through these comments from pupils:

My family thinks I am very lucky. My brother and sister want this too. They want the same.

My parents think it is good and very relevant for the modern world, especially in maths. Very educational.

My parents think 3D is very good for me and very modern.

This is here now. If schools don’t use 3D they are crazy!

This is really super! I am very happy to see the 3D and for my children to have this to help them learn.

This is a fantastic chance for our children.

We are very, very happy about the project. My son never says much about school but on the days he has had 3D it is the most he has ever talked! He is really enthusiastic!

The pupils acknowledged that their parents did not really understand 3D.

My mum doesn’t understand it.
When I told my parent about the 3D they were jealous as they never had things like that when they were at school. They think it makes it fun to learn.

When I told my mum about the 3D project she said it made her feel really old because they did not have things like that when she was at school! This is very interesting.

Several of the teachers involved in LiFE 1 commented about enthusiasm from the parents:

[Teacher comment] The parents are really so excited about the 3D. This is a major thing for our school. I have put all about the experience on the class blog. The parents are telling me that their children love it. They tell me both ace-to-face and on the blog. The 3D really has so much potential. It makes things easier to learn. I think 3D is really learning for the future.

Some parents wanted home access to 3D learning material and technology used in the classroom so there is a strong potential for 3D to act as a conduit for home/school connections.

I would really like to have access to this at home.

4.3 Educational achievement

4.3.1 Teachers’ expectation

Teachers had not expected the large extent of positive educational impact that occurred from learning in 3D

Prior to the results of the testing, the teachers felt that there may be some changes — and certainly they had noted qualitative changes in the pupils, but were less sure that these would be reflected in the post-test results. Despite their indifference to what the results might show, the teachers were positive (and even surprised) by the impact they had observed amongst the pupils, as these responses from teachers indicate:

I really couldn’t say whether it has improved results for particular children. I would need to wait for the results.

I don’t know the impact yet. I am keen to see the test results. But if you want my opinion now, 3D has been a great thing. The technology is good and really useful in the classroom.

I find it hard to comment before the results. But I am happy to be a pioneer. In fact, I did not expect the sort of results I have seen already. The children’s interest – they are more imaginative and it has a good effect on their focus and concentration. When you concentrate more, you get more knowledge and when you get more knowledge you achieve and so you want to concentrate more. It is very positive for the pupils.

Several teachers noted that an improvement in attitude amongst the pupils was also likely to contribute to higher test scores.
I am not sure it has changed the pupil’s knowledge. I will wait to see the test results. But it has certainly changed their attitude. They are more imaginative. Learning is definitely easier for the lower level pupils. The visual information has a lot of impact.

A smaller number of teachers felt that the positive changes noted in the classroom would convert to improved results in the pre- and post-testing.

It is easier to learn.

The pupils understand things better in 3D. I can see that it could really be used in any subject area.

Some of the teachers felt (from their qualitative experiences) that pupils in the middle of the class would benefit the most from 3D.26

I really don’t know the impact yet and I will be very interested to see the results from the post test, but I think that maybe 3D works the best for the pupils in the middle. The ones who are clever, they can learn any way and the ones at the bottom of the class see 3D like a game and they enjoy it but I am not sure what they will remember, but the ones in the middle seem to get a much deeper understanding.

One of the pilot teachers theorized that 3D might not make a difference in test results, even though it had clearly improved learning and the teacher would certainly use it both to introduce new content and to reinforce learning of concepts. The explanation given by the teacher as to why 3D 'might not improve test scores' was that all the current tests were still in 2D so in that way, if traditional methods of testing were used, it would not show a difference. For example, if you learn the cell structure as a 3D, solid concept then you have a deeper understanding, but if the test is a 2D diagram, you will not be able to show this deeper understanding. Conversely, though, if the assessment task asked pupils to 'make a 3D model of the cell' then significant differences could be noted between the pupils who had experienced 2D and 3D. To analyze this further, this could mean that if 3D was widely adopted as a way of learning in the classroom, then assessment tasks would also have to be proportionately 3D to capture the greater depth of knowledge and skills pupils would possess.

4.3.2 Pre and post test scores

- 86% of pupils improved from the pre-test to the post-test in the 3D classes, compared to 52% who improved in the 2D classes
- Individuals improved test scores on average 17% in the 3D classes, compared to an 8% improvement in the 2D classes between pre-test and post-test
- 100% of teachers agreed or strongly agreed that 3D made the children understand things better
- 100% of teachers agreed or strongly agreed that the pupils discovered new things in 3D learning that they did not know before
- Pupils belief in their capacity to perform well in tests was higher in the 3D cohort

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26 In actual fact, statistically, the pupils who had achieved the lowest scores in the pre-test made the greatest percentage of gain, whereas the highest scoring pupils made the least gain. But it has to be noted, that this result is partly a statistical occurrence rather than a result as clearly the lowest scores have the most opportunity to improve.
3D led to a deepening of pupils’ understanding, increased attention spans, more motivation and engagement

The pupils in the 3D class were more likely to recall detail and sequence of processes in recall testing than the 2D group

While the most important aspect for the teachers was the happiness of the pupils, performing well in tests was seen as ‘very important’ by 92% of the teachers involved in the research. In each school, the 2D and 3D groups were pre-tested and post tested. Results were analyzed to determine the following:

1. Difference between overall results of the 2D and 3D pupils
2. Rate of improvement of 2D and 3D pupils
3. Quantitative differences in the answers of 2D and 3D pupils (e.g. amount of words, detail on diagrams)
4. Qualitative differences in answers of 2D and 3D pupils (e.g. elaboration, sequence, detail, visualization)

The results of the study showed consistent improved test scores for the 3D cohort. On average, 86% of pupils improved from the pre-test to the post-test in the 3D classes, compared to 52% who improved in the 2D classes. Individuals improved test scores on average 17% in the 3D classes, compared to an 8% improvement in the 2D classes between pre-test and post-test.

The post-survey responses from teachers indicated that 100% of teachers agreed or strongly agreed that 3D made the children understand things better. Similarly, 100% of teachers agreed or strongly agreed that the pupils discovered new things in 3D learning that they did not know before.

Figure 4.3.2.1 shows that the pupils felt strongly that 3D had improved their learning (based on their post 3D survey responses) with 84% of pupils saying ‘yes’.

Figure 4.3.2.1 3D improves my learning (pupils)

The teachers also felt that 3D improved learning outcomes (Figure 4.3.2.2)
The pupils in the 3D class were more likely to recall detail and sequence of processes in recall testing than the 2D group. The 3D pupils were also more likely to perform better in open-ended and modeling tasks. As the pupil data from the post-3D indicates, pupils felt they remembered considerably more when the learning was in 3D (see Figure 4.3.2.1).

There were also behavioral and communication changes and improved classroom interaction. For example 92% of students on average were attentive during the 3D part of the lesson while only 46% were actively paying attention during the non-3D part of the lessons. The rate of ‘on-task’ conversation and questions from pupils increased after the 3D part of the lesson. Pupils were highly motivated and keen to learn through a 3D approach. The teachers found that the use of the DLP 3D technology led to a deepening of pupils’ understanding, increased attention spans, more motivation and engagement.

These results were also supported by the case studies of performance as the following case studies show:

27 DLP 3D is a form of interactive 3D based on digital light projection. Unlike other forms of 3D it enables a ‘solid’ object to appear to be projected directly in front of the child.
**Case Study 1: France**

In a 5th form we had always worked with a plastic model of the heart or a diagram on the board. It was a flat image. When we introduced the 3D the effect was really noticeable. As one pupil’s commented, “I don’t get the diagram at all but I can really see the concept in the 3D projection.”

**Case Study 2: England**

In England, the case study involved two, Year Seven classes in a Girls Independent school. The pupils were aged between 11-13 years. Both classes completed a series of lessons on the structure of plant cells for biology (science) class. Both classes were mixed ability classes. Class A was taught using a mixed method with 3D included. Class B was taught exactly the same content using the same mixed method, but did not include 3D. For all the pupils, it was their first exposure to learning about plant cell structure. At the completion of the unit, both classes were asked to complete the same assessment task. In both classes, the instructions for the assessment task were identical and the material given to the pupils to choose from was the same. The task was to “Create a model of the plant cell structure including labeling all the parts.” The pupils in both classes were provided with the same range of materials to complete the assessment task, including play dough, colored paper, tissue, card, scissors, tape and glue. There were distinct differences in the responses from the two classes. The pupils in Class A all chose to complete the assessment task using 3D models. Their models were highly varied and contained considerably more details than the models presented by Class B. The models of Class A showed a clear understanding of the inside and outside structure of the cells and the structure had been interpreted (correctly) into a number of possible forms. The pupils also had more extensive and accurate vocabulary in terms of naming the parts. By contrast, the pupils in Class B all chose to use the material in 2D. There was less variation in the 2D depictions of the cell with most students replicated (with close resemblance) the 2D diagram shown to the class. There was less variation in depictions and the pupils had less recall of the names of the various cell structures. The test was completed at the conclusion of the unit of work. Children exposed to the 3D learning around the cell were more inclined to understand the enclosed nature of the cell and replicate the structure inside the cell. One problem was they did not ‘mirror’ the inside, but rather made it as a copy (as it was presented in the software). While this indicated that pupils were still gasping the complexity of the concept of cellular structure, that the imitation of the modeling presented in the 3D indicated that they had paid considerable attention to the detail within the 3D model. It also implies that the content needs to be both accurate and detailed as the pupils were discerning very specific elements within the 3D learning objects.

**Case Study 3: Sweden**

When we studied the eye the 2D group knew 5-6 things about the eye and 3-4 terminology related to the eye. In the post-test the 2D group knew 15-20 facts, but cannot describe the processes or sequence (from the eye to the brain). By comparison, the 3D group knew less than the 2D group at the pre-test knew (2-3 things) but at the post-test the 3D group knew 15-20 facts and many words related to the eye. The 3D group had acquired many new facts.
Case Study 4: Italy

The children got such a good concept. It is a big class with over 30 pupils and usually they are all trying to crowd around small model. Most of the class can’t even see it and they certainly can’t manipulate it. Using the 3D the whole class could see the large projected model very clearly. We could move it around, look inside, take it apart and put it back together... label it. Initially we just used it for revision, but now I think I will use it at the beginning too to introduce a concept. Revision tabs are good. No one has said they can’t see it (3D)

Case Study 5: Turkey

I use the 3D with the pupils to consolidate ideas. They can see the concepts more clearly. For example, with the eye they can see the path of light. The whole thing is much clearer and they understand. You can actually see it.

It would appear from the data that there were significantly higher level of improvement in terms of knowledge and conceptual understanding when the content was less familiar to the pupils. The difference in 2D and 3D test results was the greatest where the pupils had not previously been introduced to a topic. So for example, in Sweden, the greatest difference between test results occurred in the ‘eye’ and the ‘heart’ (which were new areas of learning for the pupils) whereas the lowest difference occurred in the ‘ear’ that had been learnt before. It appeared that if pupils had previously learnt something in 2D, they had to ‘unlearn’ it before re-learning it in 3D. While the results were still higher than the 2D group, the rate of difference was not as pronounced. Similarly, the results from the pre- to post-test were the highest in the 3D groups where the 3D content continued the most animations. Some teachers felt that the scores were the highest where the 3D was used as part of review process, but the actual test scores indicated that the highest difference (between the 2D and the 3D groups) could be achieved if the 3D animation was used in the first lesson to introduce the content (in other words, where the pupils learn the concept in 3D from the beginning of the learning process).

In another example from England, pupils had previously studied the eye structure, before being introduced to it in 3D. On the pre- and post-test on the eye, there was a difference with 3D but not as great as the difference that was noted in a similar project with the ear. The teacher contended that by introducing the ear in 3D form the outset (and it was a new concept) that the ear was automatically consolidated in the pupil’s mind’s eye and so as learning of the unit progressed, pupil could recall the vivid 3D image. These early results would suggest that 3D content might be particularly applicable as a way to introduce new learning to pupils. Concurrently, it was also noted that the 3D was very effective for pre-exam or assessment review. Teachers commented favorably about the use of 3D as a recall device and that it stimulates background or previous knowledge.

As can be seen in Figure 4.3.2.1a, 88% of pupils either strongly agreed, or agreed that they understood things better when using the 3D and 86% of pupils felt that they learnt new things in 3D (Figure 4.3.2.1b).
4.3.3 Functions and connections

- Pupils in the 3D group were more inclined to ask complex questions
- Pupils in the 3D group were more likely to recall processes and functions of the body parts

The teachers in the LiFE research commented that they felt that the pupils in the 3D class knew much more about how the body organs functioned than the 2D class and they were more able to explain processes and give more details. This meant that the pupils were able to cover the topic in far greater depth in the same amount of time.

[Teacher comment] Overall, the lesson is a much higher standard than I would normally deal with the subject.

The teachers also commented that the pupils were more inclined to ask complex questions. It was felt that this active engagement in 3D learning may have contributed to the higher test scores.
[Teacher comment] The children are answering more questions and giving new answers. They seem more active in the 3D lesson, in a good way. They remember things more exactly and give more detail about the subject.

[Teacher comment] During 3D sections within the lesson, pupils were much more inclined to comment and to link learning to their personal experiences.

[Teacher comment] It is fun interesting fun and the pupils want more. They are learning because they were getting more curious. They write down what they knew before and now they write on what they know on top of what they knew before and the comment was, “Do we need to write down everything?” Their eyes a little bit different. Those that have 3D have had more enthusiasm and I think they have learnt more. They are more inquisitive and they ask for more stuff. They became very curious and started doing things outside the school like looking-up illusions on the internet and connecting learning and relating to it.

Both the pupils and the teachers felt that 3D aided pupils’ focus and concentration and this also improved test results:

[Teacher comment] The children in this class are usually not very focused, especially in discussions, but with 3D they became more focused and were less likely to fiddle with things on the desk. They can easily make the link between the text book, the diagram on the board and the 3D. The pupils are more enthusiastic to answer questions.

[Teacher comment] The children concentrated more. It made learning fun. The children learnt more because they were having fun.

[Pupil comment] 3D helps me to learn hard things.

[Pupil comment] In the 3D lesson the pupils concentrate more.

[Pupil comment] It sort of draws in my attention.

[Pupil comment] In 3D lessons I concentrate more.

There was evidence that pupils linked the 3D more closely to other acquired knowledge or experiences. Teachers felt that because the pupils became really involved in the lesson, they understood much more.

I have noticed that the pupils have learnt much more about the topic. I would like to continue to use 3D. The pupils have a deeper understanding of the topic. They certainly understand more.

The pupils have been able to learn more. It has helped them to see everything. They think it is fun and they want more. Really the whole school is excited!

In one of the Swedish classrooms there was evidence that the introduction of 3D had led to different types of pedagogy. The teacher had continued the idea of 2D and 3D into the way the pupils reported their learning. Other 3D methods used in the classroom included dissections and model making. The 2D and 3D became part of the learning. Even in art
lessons, the pupils had explored 3D perspective and had completed perspective based drawings of the glasses to show them in '3D'.

In France though, the teacher felt that 3D also lent itself well to be used in more classical models of teaching: *in some way the 3D represents a return to more classical teaching. There is the object and the teacher it is more like a lecturer.*

4.3.4 Making it real

- The pupils felt the 3D was even more ‘real’ than actual specimens or models
Pupils were able to use the 3D technology to take the body organs apart and put them back together again as an aide to learning

A repeated comment made by both pupils and teachers was that 3D made learning more “real” and that these concrete, “real” examples aided understanding and improved results.

[Pupil comment] If it is in 3D, it is more real.

[Pupil comment] When the teacher speaks and shows the book it does not seem real. With 3D it is like real. Suddenly it is possible to have the real.

[Pupil comment] 3D is like real but 2D is a bit boring and not real.

[Pupil comment] I will remember things better because things are vivid. 3D is more fun and it is more realistic.

[Pupil comment] There is a big difference between 2D and 3D when you learn something. 2D is flat, but 3D has depth. It is real. We can see it and move it and then we understand it.

[Teacher comment] This topic is a hard topic but if pupils see it then it is more real... less abstract.

[Teacher comment] 100% of pupils think the 3D is better. They claim it is more real.

A major contributing factor to the perception that learning in 3D was more real was the quality of the animations. The better the animations were, the more the pupils could see the details and functions of the body organs. As one school principal noted:

*It is hard to know what gives the effect... is it wearing the glasses? Is it animation? Would it work as well in 2D animation? How does it change the way children think? I can see that they will think more holistically. Our teachers are quite comfortable with technology, but the children, they are the real experts. They will want high quality animations.*

This raises several key points. Firstly, the point (as previously mentioned) that the pupils wanted, and expected, very high quality animations. The second point inherent in the principal’s comment is whether a 2D animation of the same content would have also equally enhanced learning?

The animations allowed the pupils to see structures and to see how the body parts work. In particular, the 3D animations made it possible for pupils to move rapidly from the whole structure to various parts of the structure, including to the microscopic and cellular. This process of amplification and simplification seemed to be particularly effective as an aide to understanding - amplifying relevant details and simplifying their representation. This process combined with the capacity to move and interact with the images, appeared to enhance pupils’ understanding, as shown through these comments from pupils:

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28 At the time of conducting this study, it was not possible to get the same animations in both 2D and 3D to test this assumption, but subsequently ‘optional 3D’ software has been developed and it would be interesting to conduct another small research comparing directly the impact of the same animation software in 2D or 3D.
The technology makes it bigger and with more detail.

You can move it and see things inside.

You can see more.

You can turn the heart

It’s living... it’s life!

You see much more and it’s easy to see. You can see what is going on inside and outside.

3D is a much better way to learn. You can see how things work. It has got action. I want 3D to stay, but not for every lesson. We should not watch it for too long.

I never really understood about the eye and the ear. I now understand how the vibrations of sound travel in the ear. I could never have really understood this without 3D. It is easier to focus on the things we don't understand. It is not boring.

I never really understood the eye before, but after seeing it in 3D I understand the parts of the eye and what the eye can do.

I prefer 3D. You see things moving. It is natural for me to use technology

It is easier to see all the parts. The 3D is better because you can go in and out.

Learning is much better as you can see the inside structure.

4.4 Behavior and attentiveness

- 100% of teachers felt that the pupils paid more attention in 3D lessons than other lessons
- 70% of teachers noted that the pupils’ behavior had improved in 3D
- On average, 46% of pupils were attentive at 5 minute interval tests during the non-3D part of teaching the lesson compared to 92% of pupils being attentive at 5 minute intervals during 3D part of the lesson.
- 96% of pupils were attentive in the 5 minutes following the 3D. The 3D experience and resulting questions continued to promote attentiveness.

Prior to the 3D project beginning 38% of teachers said they were concerned or very concerned about pupil behavior impacting negatively on the 3D project. At the same time, 46% of the teachers (surveyed before using 3D) were concerned that pupils might be bored. In reality though, during the project, here was a strong link observed in the schools involved in the research between the increased attentiveness in 3D and improved classroom behavior. The post-survey of teachers revealed that 100% of teachers felt that the pupils paid more attention in 3D lessons than other lessons and 70% of teachers noted that the pupils’ behavior had improved in 3D. The main factor appeared to be that levels of attentiveness increased during and immediately after the 3D experience. As can be seen in
Figure 4.4.1, the pupils felt that they were considerably more attentive in 3D lessons than in regular lessons.

**Figure 4.4.1 I pay more attention in 3D lessons**

![Pie chart showing attentiveness in 3D and non-3D lessons]

On average, 46% of pupils were attentive at 5 minute interval tests during the non-3D part of teaching the lesson compared to 92% of pupils being attentive at 5 minute intervals during 3D part of the lesson. Interestingly, when the 3D part of the lesson was over, attentiveness continued to rise and would remain high for the rest of the lesson. For example, 96% of pupils were attentive in the 5 minutes following the 3D. It appears that the 3D experience and resulting questions continued to promote attentiveness.

Boys and pupils with attention disorders showed the most positive change in attention levels and communication (including asking questions) between 2D and 3D. There was some indication in the data to suggest that individual pupils with autism spectrum disorders showed some improvement in attentiveness, but there was only a small sample size and the results were inconsistent so it is not possible to conclude the impact on pupils with autism.

The teachers felt that the improved attentiveness contributed directly to the improvements in behavior that were noted, as these comments from teachers suggest:

*In class with 3D you have the "Wow" effect. This helps with behavior. The pupils are too interested to be disruptive. They get involved and forget to be naughty! I would like to keep using it and use it for different topics.*

*In ordinary classes, pupils can become bored easily. As teachers, we need to do a lot to keep them interested and focused. In that way 3D is fantastic.*

One school in the research study trialed 3D learning with a class that was considered to be the "worst class in the school". The teachers reported that the behavior improves markedly and in fact that the class behaved very well throughout the trial period.

*The children became less naughty. But I don't know if that effect is just because it is the first time. If we had 3D all the time would the children get used to it and be how
they always are? When the technology is older will they be naughty again, I don’t know? They certainly loved it and they were excited. They will tell you.

The strong improvement in difficult behavior was also noted in another ‘challenging’ class that participated in the study:

The class certainly pays more attention in 3D. They are more focused. That is important in this class - 8 out of the 26 pupils in this class have attention problems, so I am thrilled with the impact of 3D. They sit up and are really alert.

The pupils also commented that their behavior improved, as these comments from children show:

I have to say, I usually spend most lessons looking out the window, but in this lesson I really watched. The ball was amazing and I wanted to reach out and grab it. It is better than 3D in the movies because the things come out more.

It is amazing! Fantastic! It is a different experience and really exciting and interesting.

These qualitative comments were also supported by the results in the survey where pupils felt that the children were better behaved in 3D lessons (68% Agreed or strongly agreed).

Figure 4.4.2 The pupils behaved better in 3D lessons

In all the classes observed, the pupils became more settled and focused on the learning while wearing the 3D glasses. While this would be pleasing news to most teachers, there is a danger that the effect of greatly enhanced concentration and the ‘quieter’ classroom, could be ‘abused’ by a poor teacher as a way of maintaining discipline not as a way of enhancing learning. There is a danger that pupils could then be left for longer and longer periods with the glasses on and quite passive ‘playing’ of the 3D by the teacher. But, this was not observed in the pilot classes, and the teachers were very active in the learning process and actually the teachers, if anything, adopted more innovative and active pedagogies.

In the 3D lessons the pupils are very focused and quiet, but actually different children are asking questions and when they talk it is more focused, more about what they are meant to be learning. So I would not say it has stopped communication. I would say communication has changed and become more focused. The visual make the
content more understandable so I don’t have to ask so many questions and the pupils can ask more questions. Their observations are stronger. Their observation is stronger. Then the pupils want to know more so they ask better questions. It is a good thing.

The pupils are not distracted. I was concerned that the children would be quite passive, but now there is more interaction. It has changed the classroom dynamics too. I find I am teaching more in a circle and we all share the moment together. That is very nice.

The pupils were very curious with the 3D and ask more questions.

Some teacher thought that the increased focus may be due to the “blinkering” effect of the glasses or the darkened room, or just the fact that 3D is ‘new technology.’

Pupils are concentrating on the subject very well. The class is a little darker than normal and this seems to also help focus the pupil’s attention. The darkness and the glasses help to filter meaningful knowledge from the ‘noise’ of the classroom. The children are definitely more attentive. Concentration can enhance the brain response to sound stimuli. The children’s attention span lasted longer when viewing 3D images.

The children are used to technology. The children pay more attention and listen more carefully. Their learning is enhanced by the technology.

The following case study based on a class observation shows the way the 3D served to enhance concentration and reduce ‘off task” behavior.

The teacher began the lesson with a 3D plastic model of the eye. The pupils tried to gather around the small model. 50% of the class became distracted and were not paying attention to the model or the teacher’s explanation. The demonstration with the model lasted three minutes. By contrast, when the 3D began, the initial “ooohs” and “aahs” subsided and all pupils were quiet and attentive. The sound played on the animation, but the teacher paused at the end of each section to provide additional explanations. The 3D demonstration lasted for nine minutes and all pupils remained quiet and attentive. At the end, the teacher and pupils were keen to see the 3D again and still 100% of pupils remained on task and attentive. Two pupils became distracted for about two minutes but then paid attention again. One boy continued to be distracted, but was unable to distract other pupils, despite attempts to do so.

Some teachers had feared that the pupils might get too ‘excited’ and that this would lead to disruptive behavior, but this did not occur.

I was unsure at the beginning. The students were very excited.

3D is a maybe a little bit too exciting, but then it is new for the pupils

The pupils are a bit excited, but in a good way.

4.5 Motivation

- 100% of teachers agreed or strongly agreed that pupils had fun learning in 3D
- 87% of pupils found learning in 3D more interesting
Teachers’ pedagogy often changed with 3D and this helped to maintain pupils’ motivation

There was strong evidence of the pupils being highly motivated to do 3D. The post survey results showed that 100% of teachers agreed or strongly agreed that the pupils had more fun learning in 3D. As one teacher described it, “The children’s reaction was like WOW!”

[Pupil comment] I really like to come to school. I can’t wait to go to school when the 3D is there.

[Teacher comment] 3D is very motivating. I can use 3D as bait. I can say, “If you are not quiet, you won’t get to see the 3D” Theory can be boring, but when it is in 3D then suddenly the children are interested!

The survey results suggest that the majority of pupils felt that learning was more interesting in 3D (Figure 4.5.1) with 87% of pupils either agreeing or strongly agreeing. Concurrently, 71% of pupils felt that learning was “less boring” and 79% of pupils found learning to be “more fun” when 3D was used.

Figure 4.5.1 Learning is more interesting in 3D

The motivation of the pupils was very obvious in the classroom visits. For example, there was a murmur of excitement when the teacher said they would be studying in 3D in biology today. The excitement was obvious despite this being the pupils’ third experience. Some teachers felt that the motivational effect of 3D might ‘wear off’ over time, but during the eight week pilot this did not appear to be the case.

At the moment they are really into it but I am not sure if the effect will wear off.

Of course it is more exciting, but then again, is this just a novelty that would wear off?

The pupils remained motivated as the teacher’s pedagogy often changed to become more engaging and interesting. For example, a sequence from the 3D senses unit is shown to a class of 24, 12 year olds. The teacher feels that the 3D at the beginning inspires the pupils and makes them excited to learn the topic. The pupils could propose many exciting
possibilities for the potential future use of 3D technology in their learning, as these comments from pupils show.

*Maybe in a school we could have 2-3, 3D equipped rooms in the school.*

*All thinking and learning will be different in the future. We will always have 3D in the classroom and we will use it when we want. There will be books with 3D inside them. You hit on the image and then it becomes 3D. It will sort of come up from the page. I want this.*

*We will have screens built into the tables and then we can touch things and they will be 3D.*

*The classroom should be more like a planetarium. We would all sit in a circle and then the image would be all around us. Let us call it a 3Dtorium! We would not have chairs. We would sit on bean bags. We would not need to wear glasses and it would be interactive, like Kinect. Maybe we could program our own 3D and make PowerPoint presentation in 3D. Maybe there will even be 4D and we would have sensory experiences... jets of air, smell, great sound. There would be simulators and we would follow the flow of the blood. We could have electronic text books on a kindle or iPad. Technology makes learning more interesting. Technology will never stand still. It will always be advancing and that is exciting. We will need to know technology for our future jobs.*

The pupils were very enthusiastic to share their experiences in 3D with other pupils form around the world:

*[Pupil comment] We would really like to share with the kids in the other countries. We could Skype to Twitter or Facebook. It would be good because we are all doing 3D and we could practice our English. Maybe we could even Skype in 3D. Would that work?*

The teachers felt that technology was an important part of teaching and learning in the future and that the pupils needed to be exposed to the ‘latest’ technology as part of their learning experiences:

*As a teacher you need to make use of all the different methods that are out there. Technology will be more important in the future, but not to replace the teacher but as another tool teachers can use.*

*It is important that children are familiar with the types of technology they will face in the future. I have to say, I was not really interested in 3D but now I have seen it in education I have changed my mind. It will certainly help with learning. Things are more realistic. It raises the pupils’ 3D awareness. Of course they have seen it in the cinema, but now they see it applied to learning.*

*The pupils are very, very lucky. In this project we are seeing the latest in technology. Usually schools are at least 10 years behind. I the old times, the lesson was very teacher-centered. But now it is more student-centered.*
The IT coordinators in the schools saw the possibilities of taking the technology further through greater interactivity and user generated content.

In the future I can imagine multimedia walls with interactive multi touch. Maybe PICO (micro, individual projection) for individual pupils? Perhaps 3D will be integrated into mobile devices and internet-based. There could be distant or remote learning links with family/parents or the community. There is likely to be more user-generated content. We could make better use of informal learning. Gaming could be a learning driver.

Interactivity and user-generated content [will happen in the future]. Perhaps over time from this 3D illustrated landscape aggregated content will emerge that creates new meanings, new knowledge and new understanding. In a way becoming a form of ‘spatial montage’ from schools around the world.

The teachers felt that the improved motivation of the pupils increased their test results and understanding, as these comments from teachers indicate:

100% of the pupils wanted more 3D

The biggest difference I have seen is in terms of motivation and atmosphere. The children are more focused and can concentrate longer. I can’t really substantiate this, but that is my feeling. They [the pupils] are interested so they are learning.

The class is filled with ‘OOOHS’ and ‘aaaahs’ the moment the glasses are put on.

The motivation has been very positive.

The pupils the children can really say a big difference. They are so excited. The whole project they have been really interested. We are now using the software for revision. The children are working in groups and they have to choose one of the body organs and then cover the content with the rest of the class. The children get their own glasses, set up the equipment and adjust the lighting in the classroom.

There were lots of 'ooohs and aaahs' for the film of the blood.

The pupils also commented that learning was more fun and they were more focused:

I really want to say thank you for the LiFE 1 project. Sometimes we are bored, but 3D really is not boring. I love 3D and I love to do this project.

It’s more fun

The balls [in the 3D] are our friends. They come out and show us what to learn.

3D is very nice. I have discovered a lot of new things about bodies.

3D lessons are much more interesting, but now we know it, we won’t want to go back to 2D lessons. The other class don’t know 3D so they don’t know what they are missing!
3D should definitely stay. It is fun and because it is fun you learn more. It is much better than learning from a book.

I think it is a fun way to learn.

The 3D is fantastic, very good. It is interesting and interactive. It is certainly much better than traditional lessons. You can observe better the process and you see more details.

3D is very interesting. It isn't boring. It is cool. 2D lessons can sometimes be boring, but with 3D you can see the detail. You can turn it and see things. I can see the detail even if I sit at the back of the room.

4.6 Communication

- “On task” conversations and questions increased after 3D was seen in a lesson
- Natural communication continued when the pupils were wearing the glasses
- Teachers were more likely to adopt different teaching pedagogy in 3D lessons that encouraged more conversation and collaboration with pupils

There was some concern expressed that wearing the glasses in a darkened room during 3D teaching might result in the pupils being too passive and not communicating. While many teachers dream of a quiet classroom, conversations and communications are a vital part of the learning process. The following comments from teachers show that while the pupils were initially more settled and focused in the 3D lessons, that, in the longer term the pupils became more attentive and also more communicative:

- I was worried that the children are too passive. At first I think they were more passive in 3D lessons than in 2D lessons. But their level of observation is deeper in the 3D lessons. They really like the activities.

- I was worried that the pupils would put on the glasses and be in a world of their own. They cannot connect to each other. At first I had the classroom too dark for good interaction. But then I realized I did not need things so dark.

- The children get quieter when the 3D is on, but then actually ask more questions after it and they are better questions. I would say that they are more on task.

- We have to turn the lights off and the pupils have the glasses on and that sort of cuts the pupils off from the teacher. There is no eye contact. Maybe they become "too focused". I know that is a funny thing to say, but it is like TV. You can sit a child in front of the TV and they are quiet.

In reality, the interval tracking showed that the children were quiet during the 3D episode, but immediately following the 3D animation, the levels of ‘on-task’ discussion and questioning actually increased. Several teachers noted this pattern and also commented that pupils who were not generally inclined to ask questions were often stimulated to ask questions related to the 3D animation.

- I notice that the pupils are very quiet during the 3D but then are livelier and ask more questions at the end of the 3D.
I was worried about communication as you can’t look the children in the eye and I thought it would be hard to promote discussions under those conditions, but the children actually talked more with the glasses on. But it was a different talk - more focused on the content, asking better questions. No one was talking to their friends or distracted.

The children get quieter when the 3D is on, but then actually ask more questions after it and they are better questions. I would say that they are more on task.

Before the teachers began teaching in 3D there was some thought that perhaps 3D learning would have the best impacts on male pupils. While the evidence would suggest that boys enjoyed the 3D learning, the system appeared to be equally popular with girls. In each of the measures, there were very only a few areas where there was a statistical difference between boys and girls.\(^{29}\)

I thought the boys in the class might like it better than the girls, but actually there was no difference. Everyone worked together and everyone was looking. The whole group was sharing the moment, even me as the teacher. I really like the "whole".

The pupils and teacher tended to leave the glasses on even though they were no longer looking at the content. This appeared to be very natural and did not seem to in anyway impede normal classroom interactions. Pupil volunteered some information and to answer questions and more children responded to questions than before the 3D episode. A pupil volunteered some answers. The teacher commented that that particular pupil had never answered before. In general\(^{30}\) just 40% of pupils attempted to answer a question (raised their hands) however during 3D, with teacher questions, 68% were actively trying to answer questions.

It would appear from the data that images can be a catalyst for conversation. It is something that naturally leads to spontaneous sharing. Pupils discussed concepts around the image – and the image became a point of basic of commonality. Therefore, making 3D a very participatory media. There appeared to be no negative impacts on communication with only positive outcomes reported.

**4.7 Assessment**

- The pupils moved easily between the 3D content of the lesson and 2D assessment tasks
- 3D was useful to introduce a topic and as a form of revision exercise
- Pupils in the 3D cohort were more likely to represent their knowledge in open-ended tasks in 3D
- Pupils in the 3D cohort showed the greatest difference compared to the 2D cohort in open-ended assessment tasks.

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\(^{29}\) Boys’ pre- and post-test scores increased more than girls and boys’ level of communication (questions asked) increased more than girls.

\(^{30}\) Based on the 5-minute interval tracking in any given lesson for the ‘general’ Lesson time before the 3D episode began.
It was a very straightforward process for teachers to link the 3D with their current curriculum and assessment practices. The pupils moved easily between the 3D content of the lesson, a class experiment and the completion of worksheets. The pupils seemed to have no trouble at all in linking 3D content to 2D diagrams.

It was felt that 3D was especially effective as a way to introduce a topic and also as a powerful tool from revision. In the post-survey for teachers, 70% of teachers felt that the pupils remembered more when they had learnt in 3D. Some of the sample content software had “revision” tabs enabling pupils to practice vocabulary, review structures and sequences and apply their learning through a range of activities.

[Teacher comment to pupils] Just to remind you, you have had this in 3D. You can use the revision tabs.

[Teacher comment] The children get such a good concept. It is a very big class and usually they have to crowd around a small plastic model. It is great to be able to manipulate the image and move it around. I have mainly been using it for revision. The revision tabs are good.

The pupils felt that the 3D was an effective revision tool that would help them achieve better test scores, as the following quotes show:

I think I will do better in my tests. Because you like something more you remember things better.

My tests will be better because we saw the insides and we saw everything working. 3D is sort of like a movie and you can see better and my learning is much better. It makes sense.

I think I will do much better in the tests as I can visualize things better. It is 100% better!

You can sort of relate to what you see. You can see the cross section. It is not flat. You can see all sides.

Once I have learnt it in 3D I don’t feel that I have to see it in 3D to get it right in the test. It is sort of in my head and I will understand it no matter how the test draws the heart. I know it now and that is the difference.

As the teachers and pupils became more familiar with 3D there was also the acknowledgement that wider use of 3D in the classroom may lead to reforms of assessment procedures with 3D itself likely to become more “3D”, as these comments from teachers’ propose:

I could see that 3D could be really helpful for children revising for exams. We try to not put pressure on about exams, but of course the children still worry about it. The center of the lesson must be the pupils not the teacher. We use assessment for learning and in this way I think 3D is good. Maybe the tests should be in 3D too, but we will see when we get the post test results from the children.
We must change the way we assess. Maybe if learning goes 3D then assessment will also need to be 3D. We usually use words and write questions but maybe we can do this in different ways in the future.

I think it will not be long before there could be 3D assessment. I could see it working especially for assessing pupils’ understanding of the systems of the body, such as the circulatory system.

Will assessment need to also change? It is often said that assessment drives learning; could 3D learning drive innovations in assessment?

It is important to adopt the experimental approach, not just give the pupils the answer. I think it will not be long before there could be 3D assessment. I could see it working especially for assessing pupils’ understanding of the systems of the body, such as the circulatory system.

The research results tended to support the notion that 3D learning could lead to reform in assessment processes. Assessment needs to shift its global and national focus on standardizing the child to more accurately mapping the child’s qualities, actions and behaviors that indicate enhanced understanding and the active making of meaning. Conventional learning and its associated assessment patterns are simply not compatible with innovation and future learning practices.

During the research study, several tests were undertaken to test for regression. Teachers were asked to note the pupils’ retention after one month, both in terms of qualitative and quantitative differences between the retention in the 3D based learning and the non-3D based cohorts. Open ended tasks were given to determine the impact both on retention and on recall. The teachers noted changes in the manner in which the 3D and 2D pupils recalled the learning. For example, the 3D pupils were more likely to use gestures or body language when describing concepts; the 3D learners had better ordering (sequence) of concepts; the knowledge of concepts was greater (especially when a new concept had been introduced through 3D) and the 3D cohort had enhanced skills in describing their learning including writing more, saying more and being more likely to use models to show learning.

The pupils in the 3D classes could remember more about the functions of the body than the 2D classes after 4 weeks. Not only were there differences in the quantity of material recalled, but it was also remembered in a more connected a ‘systems’ manner. Pupils in the 3D class gave more elaborate answers to open-ended tasks and were more likely to ‘think’ in 3D. In one example, when asked to make a “model of a plant cell” all the pupils in the 2D control group made 2D models that were almost identical to the teacher’s example. Whereas pupils in the 3D class all made 3D models that were very different (not copies of the teacher’s model) but showed a more complex understanding of the cell structure. Similarly, in another example, a class experience of 3D led to a pupil creating a 3D lung from a plastic bottle and balloons. Many pupils when answering test questions used hand gestures and ‘mime’ to recreate the 3D experience and to enable them to successfully answer the test questions. To quote one teacher, he commented: “The children said "I won’t forget it." It was more in their faces.”
The following case study comes from a school in Sweden and shows the way 3D led to deeper understanding amongst pupils:

In this project I have felt an enormous engagement from the whole class, not just the 3D group. My enthusiasm I believe has contributed to this. I have seen that the group that has looked at the body in 3D has a greater understanding for how it works. They have a greater understanding of the sequence of events. They can also describe things in more details. The greatest difference was when I asked them to describe the function of the heart. When we moved on with the eye and the ear then you saw that the 2D group made an effort to learn as much as the 3D group. I have experienced that the 3D has helped to get a deeper learning and better and more engaged (“levande”) learning. I also think that an engaged and interested teacher contributed to the pupils’ internalization of learning, but I however think that 3D is a good complement. The pupils who have watched 3D used more models to represent their learning. Many in the 3D group chose to show things with the use of clay. When the pupils in the 2D group saw what the 3D pupils had done (in terms of the model making) they also wanted to work in that way.

4.8 Pupils with special educational needs

- Pupils with special education needs were fully integrated into the classes involved in the research
- There was some early indication that 3D might be helpful for children with autism or attention or behavior disorders

All the European countries involved in LiFE 1 have classes where it is policy and practice for pupils with special educational needs to be integrated into the regular classes.

As is evident in Figure 4.8.1, while the majority of pupils involved in the project were considered to be ‘average’ in terms of their achievement levels, the full spectrum of learners was represented in the sample classes in LiFE 1.
In some countries it is not possible to know the numbers of pupils with special educational needs as parents and pupils have the right to confidentiality. Yet it was an integral part of LiFE 1 that children with special needs were included in the 3D classes. As the numbers of pupils with any particular educational need were quite small it is not possible to conclusively prove the impact on pupils with different needs, but there was a general view amongst teachers that 3D learning had a positive effect on some of the more challenging groups of learners, as these comments from teachers suggest:

*It is hard to say the impact on the special needs pupils. It worked very well with the Roma pupils. We have one child with autism and another with Attention Deficit Disorder. The 3D held their attention and they were interested and responding and reaching out to touch the objects, but really it was more entertainment. I am not sure about their learning. You really would need to use the technology on a one to one basis to see the impact.*

The majority of teachers who participated in LiFE 1 felt that the duration of the study was too short to make any conclusions, but that there was some indication of a positive impact on pupil with special needs:

*It is a little early to tell the impact here [in 3D lessons]. What I can say is that the special needs pupils in the class were paying more attention and apprehending more.*

*The girl with autism was interested at first. She had a good reaction at the start but now I don’t think it is any different, but she does like to watch it.*

Other teachers felt that the initial impact of 3D had been very positive as an extra ‘tool’ to help captivate and educate more challenging pupils:

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Note: In all the schools there were children from immigrant backgrounds but these did not form the majority of the class or it was not allowed for these pupils to be identified.

31 The Roma are a widely dispersed Indo-Aryan ethnic group numbering about 15 million worldwide. Historically they have suffered discrimination and they tend to have had low educational attainment.
When I heard about the 3D, we had a very difficult class in the school. Four of the children have serious behavior disorders. It is a difficult class. They had particular problems with concentration. We try to use movies, pictures anything.

The 3D has been really good for this group. It is a bit of a problem class and 3D really works with them.

The children are really enthusiastic about 3D. You can see that it has a particular effect, especially with the children with learning disabilities. Children use multiple intelligences to learn and 3D really accentuates this. They are concentrating more. In this class there are 6 pupils with some form of learning disability and the 3D has been excellent.

There is one boy. He is slower than the other pupils. He tries to learn but it is not always easy for him. He thinks 3D is a game. He is excited about it. When he is watching the 3D he is using his body. He tries to grab the things he sees.

One pupil with special learning needs indicated that the 3D enhanced his learning:
I have dyslexia it is easier for me to learn. I would like more. I would like more 3D in other subjects... A lot more in lots of subjects. It is difficult in English. The teacher says things after. Today I got a sore eye. It was worse when the image was going in.
Chapter 5: Conclusions, recommendations and future directions

5.1 Conclusions

This research would not have been possible without the 15 incredible schools who agreed to take part in the study. These schools cannot be named because of the confidentiality surrounding research involving children, but none the less they are true champions of advancement, demonstrating openness to technological input and change.

The teachers involved have used 3D in an innovative manner that has resulted in the optimization of 3D teaching materials and methods. They all possessed enthusiasm and a disposition that was open to possibilities. In all the classes involved in the research the focus was on learning and the pupils - not on technology. The teachers felt that 3D was very easy to implement in the classroom and that 3D actually saved time as the teachers could cover more material in less time.

*I like it very much and the pupils were very impressed. This must now be used in the educational field. I have really found that there are no problems with it at all. It takes less time for pupils to learn more. They understand the subject faster.*

In the classroom, 3D images focused the pupils’ attention and in so doing, sharpened their understanding and retention. The 3D animations supported learning and allowed more material to be covered in less time. The 3D images promoted greater pupil engagement and communication. These images provided photo-realistic visualization and animated sequences that explained processes and this combination of image and movement aided retention of subject matter and led to better test results and deeper learning. The difference between 2D and 3D learning was particularly apparent in open-ended tasks and tasks requiring more abstract understanding. There was evidence to suggest that 3D assisted the pupils to move from concrete to abstract concepts and enhanced the visualization of concepts. The pupils exposed to 3D commented that learning was more “real” and that learning “comes alive”. The pupils in the 3D classes were able to effectively communicate ideas and demonstrate more accurate conceptual understanding. The post-test results indicate a positive impact of 3D on both comprehension and retention of concepts.

While 3D led to enhanced learning outcomes, there was equal evidence that 3D might be a powerful tool for motivation and learning for less-engaged pupils. The teachers commented that 3D was ‘Attention grabbing’ and an ‘Immersive’ learning environment. It appeared to be particularly effective at engaging visual learners and kinaesthetic learners (rather than more traditional teaching and learning methods that tend to favor auditory learners). The 3D images appeared to be widely accessible to different types of learners, including learners with special educational needs. While the numbers of pupils with special educational needs were too limited to make reliable conclusions about the impact of 3D, the results indicate a positive trend for the use of 3D with pupils experiencing behavioral or learning disabilities.

The 3D technology appeared to keep the pupils active and collaborative. They were focused and quickly took an active role in using the 3D including even teaching the lessons in some cases. In this way, the 3D proved to be an ‘Open tool’ that was readily used by both teachers and pupils.
Despite the undoubted success of this trial of the LiFE 1 research project and the demonstrable positive impacts of 3D on learning processes and outcomes, some reflections have been made in terms of recommendations to improve the technology and its implementation in the future. These recommendations are listed in section 5.2, following.

5.2 Recommendations

.1 LiFE 1 has shown very significant positive educational results for 3D but these findings need to be substantiated through further studies, particularly with different aged pupils

.2 Further research should be conducted into the health and safety of 3D for children

.3 Further research should be conducted on the impact of 3D on the enhanced learning of pupils with special education needs

.4 Continuation of the implementation strategy via a LiFE 2 process has the potential to enhance take-up of 3D and develop further models of innovative practice, especially with different aged pupils

.5 More content is needed to be developed, especially content in different languages, content for other subjects and content related to the curriculum

.6 The design of the 3D glasses needs to be significantly modified to be suitable for children

5.3 Future Directions

At the outset of the LiFE 1 project, it was envisaged that a “LiFE 2” project would follow to consolidate the findings of LiFE 2. It is proposed that LiFE 2 focuses on the broader implementation of 3D into classrooms through greater “buy-in” from educational authorities and the development of a “critical mass” of early adopting schools, teachers and systems.

In LiFE 1, eight\(^{32}\) countries were involved with two or three schools in each country. The content and resources\(^{33}\) were provided for free and the research was centralized\(^ {34}\). In LiFE 2 the proposal is to expand the project to 10-12 European countries, including Austria, Norway, Spain and Hungary and to expand the number of participating schools in both the existing LiFE 1 countries and the new LiFE 2 countries so that each country has between 5-10 schools involved. It would be the expectation of LiFE 2 that schools and/or systems buy-in to the project and pay\(^ {35}\) for the equipment and content. To effectively manage the on-going research and the formation of the networks and learning communities, partnerships will be formed with universities and teacher education providers in each of the LiFE 2 countries. This will increase the impact of the expanded project and provide a wealth of evidence and research-informed case studies to be gathered.

Availability of suitable content will be a crucial factor as to whether 3D learning will be able to be enacted in the classroom. One teacher commented: “The potential is infinite from primary through to university level… we just need the software [suitable content].” As described in section 2.2, the future implementation of 3D will rely on the development of internet-based content for 3D technology. The most effective software seemed to be the

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\(^{32}\) Including Finland
\(^{33}\) Computer, projector and class set of glasses
\(^{34}\) Although local researchers were involved, for consistency, the one method and the one analysis and report was undertaken.
\(^{35}\) Though a reduced price and partnership arrangements will be offered to incentivize participation
content developed specifically for education. It was important that 3D images were rich and realistic. It was not so essential that they contained either written or spoken language as teachers tended to want to discuss the images with their pupils and could then adapt more generic learning resources to a range of ages and curricula.

It is important to the pupils that the 3D images are ‘real’ . Software developers in 3D should avoid any temptation to ‘dumb down’ or simplify images for children. Stylized, simplified or cartooned images should also be discouraged as pupils showed a strong preference for complex, detailed and realistic images. Discussions are underway with text book publishers on the possibility of including generic 3D software as part of the text book package. Teachers should be encouraged to work closely with 3D software developers to create relevant and meaningful software.

It may be possible in the future for a Cloud-based ‘software as a service’ subscriber model for the delivery of 3D content into schools. This would work well and there are a number of exciting opportunities that could exist in this field.

It was suggested that teachers and pupils may in the future create their own content. There is great potential for teachers and pupils to develop their own 3D content. Currently, 3D cameras provide the easiest way to achieve this. In the future, software may be developed that enables pupils and teachers to readily develop 3D content, but at the moment, the making of high quality 3D content is both labor and time consuming and so user generated content is unlikely to be a widespread possibility in current classrooms.

Other possible future directions might include the embedding of 3D technology in assessment or as pupils suggested, 3D social networking. The pupils were also very keen to explore the potential of immersive learning environments. The pupils were keen to share their 3D learning with pupils in the other countries with 68% of pupils indicating in the
survey that they would like to exchange ideas with other pupils from around the world learning in 3D. As a number of pupils had experienced immersive 3D ‘gaming environments’ they were keen to see the possibility that this technology could be incorporated into classroom learning. The teachers were also interested in sharing learning with other teachers around the world with 89% of teachers saying they would like the opportunity to exchange experiences.

There was the overwhelming view form the pupils surveyed that 3D would be part of learning in the future (see Figure 5.3.1).

*Figure 5.3.1a Will 3D be part of learning in the future (pupils’ response)*

The teachers (Figure 5.3.1b) were also very happy to be involved in another 3D project, though slightly less than the pupils, but 100% of teachers wanted to continue with 3D when the research project ended.

*Figure 5.3.1b Will 3D be part of learning in the future? (Teachers’ response)*

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36 This finding was also consistent with what the teachers said, with 79% of teachers saying that they would like the pupils to be able to exchange ideas with other pupils working with 3D.
For effective adoption of 3D, schools would need to see the value of 3D within the whole school ICT strategic framework. This research provides an evidence-base for ICT planning that includes a commitment to a provision of advanced 3D resources for the classroom both in terms physical and technical (hardware, software and knowledge) components and the promotion of ‘enabling technology’ in terms of technology that is easy and empowering for both pupils and teachers to use. School principals were positively inclined towards the economic, knowledge and skill sustainability of DLP in the classroom and felt that the integration of 3D into the school was generally achievable within current resource constraints.

To conclude, LiFE 1 has provided a unique insight into the impact of an immersive and interactive classroom experience. It is hoped that LiFE 2 will allow more projects involving 3D in learning to be rolled out around the world. LiFE 1 has shown that 3D can create an immersive learning environment that is a different way to learn that made school subjects come alive and drew students into another world that they described as being “real.” The results indicate that 3D provided a different and highly effective way to learn.