Digital Literacies and 3D in Education

Anne Bamford
International Research Agency
England
eenc@interarts.net1 Einleitung

1 Introduction

A hand reaches out for the hammer. It's right there, next to the anvil and the stirrup. But that small hand passes straight through, because this particular model of a human ear is a 3D projection.

Primary school pupils at Munich's "Grundschule an der Simmernstraße" are experiencing new ways of learning. Innovative technology is helping them better understand what they are learning. While 3D movies and television are seen as being perhaps as a gimmick or an 'added' extra enhancing the movie narrative, the value of 3D as an aid to learning has largely been overlooked.

Educational systems around the world are struggling to find cost effective ways to enhance learning – some system that will capture the interest of children largely bored by the regular menu in schools. They seek something which will bridge the gap between high achievers and the children left far behind and something that will build the quality of teaching to ensure every child is capable of achieving at his or her potential.

Clearly, no piece of technology alone will answer every educational challenge, but education has been comparatively slow in looking to the potential of resources and 'aides' to forge the monumental leaps many learners, teachers, schools and educational systems need to make.
Let us look perhaps at medicine as an analogy. We know that in the last century, death rates in the developed world have dropped markedly. Diseases that were life threatening are now a mere inconvenience. What has made all the difference? Arguably, the Doctor's surgery itself is relatively unchanged. Similarly, while the doctor's training has improved a bit and patient's knowledge of how to keep healthy has slightly improved, these factors have not led to the massive step-change we have seen in health care and survival rates. So what has made the difference? The key factors have been improved diagnostic technology and better medicines and devices for treating patients. In other words, it has been the resources available to patients and doctors that have really driven the rapid improvement in outcomes.

If we turn our minds back to education, there has been a relentless focus on the 'doctor's surgery' (billions spent on new school buildings), the 'doctor's training' (teacher education been extended by several years) and the 'patient' ("Children these days do not know how to read and write"). While most education systems around the world are spending double the amounts (in real terms) on education than they spent thirty years ago, the results have remained largely unchanged. More young people than ever are graduating from the education system with little or no chance of being employed. One could say that the patient is very sick! The increasingly bulimic approach to education is failing. Force feeding learning down the collective throats of children and getting them to regurgitate that in standardized tests is not producing a healthy education system.

So let us return to the medical analogy, it is time that the focus turns to the diagnostic tools and medicines needed to fix the educational system. Perhaps by providing teachers and children with better resources, that are more targeted to the way they learn and natural systems of making meaning, we can increase the life expectancy of the 21st century classroom. It is from that view that I want to focus on the impact of visual tools, in particular 3D animations as a way to both diagnose and remediate learning in the classroom. Furthermore, I would like to suggest that the use of enticing educational resources acts as a conduit for promoting more favourable learning behaviours – in other words a healthy approach to education.

2 Redefining literacy

In a general sense, literacy as a term is largely synonymous with reading and writing. Certain literacies are more or less powerful within education. Arguably, traditional reading and writing are the dominant literacies in the school classroom, whereas multi-modal literacies (‘reading’ images, sounds, movement, and emotions and so on) are the dominant forms of literacy used in daily life and certainly evident within the way young people communicate in the virtual world.

This hierarchy of literacies within schools is different from the hierarchy of literacies outside of school. This hierarchy has led to the emergence of the term *discourses* to imply the power assigned to different literacies. To accommodate the importance of these discourses, the idea developed of “many literacies” of different types. These were described as *multimodal literacies* or the shorter *multi-literacies.* In recent years the available modes of learning continue to expand and rather than making a decision between modes, individuals are likely to operate their communication through many modes. The term ‘literacy’ can also denote proficiency, such as in ‘computer literacy’ and ‘media literacy’. Under the notion of proficiency, literacy is viewed as a process of making meaning both as a producer and a receiver.

Visual images are becoming the predominant form of communication of learning and teaching resources, delivered across a range of media and formats. The proliferation of images means that visual literacy is now crucial for obtaining information, constructing knowledge and building successful education outcomes.

Henderson’s 1999 definition of visual culture “what it is to see and what there is to see” in its simplicity probably most accurately captures the complexity of perceiving and reflecting on the visual. The term “Visual literacy” was first coined by John Debes (1968) to describe the process of sending and receiving message using images. It involves more than just looking, but rather emphasises the importance of active reading of visual information.

To build a meaningful understanding of structure, function, and process, it is essential that students become visually literate by mastering key cognitive skills that are essential for interpreting and visualizing ERs. Ben Shneiderman once said (Card, Mackinlay and Shneiderman: 1999) “A Picture is worth a thousand words. An interface is worth a thousand pictures.” The ability to successfully decode and interpret visual images is a key skill in today’s world. A visually literate person is able to “discriminate and make sense of visual objects and images; create visuals; comprehend and appreciate the visuals created by others; and visualise objects in their mind’s eye.” (Bamford[85] 2004 p 1). External representations such as diagrams, animations, and dynamic models are vital tools for communicating and constructing knowledge.

[85] http://wwwimages.adobe.com/www.adobe.com/content/dam/Adobe/en/education/pdfs/visual-literacy-wp.pdf

3 The role of technology

Children and young people own a lot of technological devices and use them regularly. As indicated the recent pan European research[86], 90.1% of pupils had a computer, 85.3% had at least one mobile phone and 74.6% owned hand held games.[87] The pupils were frequent users of online technology with over 91% of pupils using the internet for at least one hour per day. In terms of their experience of 3D, 90% of pupils had seen a 3D movie, with most pupils having seen three or more 3D movies. The pupils were very knowledgeable about general innovations in 3D and were highly informed consumers of the 3D products currently available. The pupils possessed very positive attitudes towards 3D and were keen to have more 3D in their life and in their learning.

Yet in the classroom electronic white boards may exist and computers are generally available, but the full potential of the medium remains relatively untapped. The development of new modes of delivery of education, especially the profound impact of e-learning, have generally had resulted in only limited changes in teaching and learning practices.

Yet, technology in the classroom offers a wealth of promising opportunities, not least because recent years have seen various technological innovations emerge that are particularly suited to use in schools. For example, the development of multimedia resources and simultaneous teaching could be used to provide high quality instruction in areas of teacher shortage or where facilities or expertise are scarce. The focus though of this paper is the way in which technology impacts on pupil learning. In particular, the ways in which 3D images enhance learning for children and young people.

It is often extremely difficult to impart an understanding of complex three-dimensional (3D) relationships when using two-dimensional diagrams. Animated 3D graphical representations make a simple, economical, and effective addition to visual resources available classroom. Computer generated animation has been in development for some time with early work dating back to the 1960s. The first commercial use of 3 dimensional (3D) animations was a representation of a human, known as the "Boeing Man". It was not until the 1990s that 3D within the general entertainment industry became more widespread. The release of "Avatar"[88] the movie broke all box office records and established a new level of sophistication in 3D imaging.

The use of 3D in the classroom has emerged in the past 12 months and offers enormous potential as a tool in teaching and learning. DLP[89] 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 many modern colour digital projectors, with the technology being used in over 95% of the projectors currently sold so teachers do not need additional equipment or modifications, to implement 3D in education.

[86] Bamford, A 2011 http://www.gaia3d.co.uk/wp-content/uploads/2012/11/Evaluation-of-Innovation-in-Learning-using-emerging-technologies-by-Prof-Anne-Bamford-2011.pdf
[87] Note: Many pupils had more than three different forms of technology.
[88] http://www.avatarmovie.com/
[89] Digital Light Processing (DLP) is a trademark owned by Texas Instruments.

The LiFE 1 project[90] provides insight into the impact of an immersive and interactive 3D classroom experience. Known as the “Learning in Future Education” or “LiFE” project, a team of researchers undertook a detailed research investigation of the impact of 3D technologies on pupils’ learning. 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 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[91] 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 in France, Germany, Italy, Netherlands, Turkey, United Kingdom and Sweden. 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. 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 results of the research showed that visual learning improves the pupils’ understanding of functionality and by seeing the whole, children are able to understand the parts. The research results indicated that the pupils had a strong preference for visual and kinesthetic learning, with 85% of the pupils preferring seeing and doing while only 15% of pupils preferred hearing.

The research results suggested that the 3D animated 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, as the animations allowed the pupils to see structures and to see how things worked. 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.

The deepest 3D and the most animated content appeared to have the greatest effect on learning and retention. These highly vivid experiences make 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. This embodiment by the pupils indicated that the 3D environment is immersive. This depth of immersion appeared to help the pupils to filter meaningful knowledge

[90] Bamford, A 2011 http://www.gaia3d.co.uk/wp-content/uploads/2012/11/Evaluation-of-Innovation-in-Learning-using-emerging-technologies-by-Prof-Anne-Bamford-2011.pdf

[91] 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.

from the 'noise' of the classroom[92]. This was evidenced in the measurement of logged gaze behavior of the pupils that showed very high levels of attention during the 3D sections of the lesson.

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. 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 five 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.

It would appear that complex concepts become more easily digested when reduced to imagery. An earlier study of the application of 3D technology in Greek classrooms found that 3D illustrations, 3D animations, and interactive 3D animations combined with narration and text, contributed to the learning process of 13- and 14- years-old students in science courses.[93] This exploratory study conducted with 212 8th grade students in Greece utilized three different versions of interactive multimedia applications. The results indicated that multimedia applications with interactive 3D animations as well as with 3D animations increased the interest of students and made the material more appealing to them.

In the LiFE 1 research, the 3D animations were also a catalyst for learning conversations in the classroom. The use of 3D in the classroom led to positive changes in pupils' behavior and communication patterns and improved classroom interaction. The "on task" conversations and questions in the classroom increased after 3D was seen in a lesson. The pupils in the 3D group were more inclined to ask complex questions. The 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 readily discussed concepts around the image – as the image was a basis of commonality. Therefore, making 3D a very participatory media. The 3D images become 'social objects' to be linked, connected, commented upon, in other words learning was also accelerated by utilizing the "Wisdom of the crowd". The results of the research indicate a marked positive effect of the use of 3D animations on learning, recall and performance in tests. Under experimental conditions, 86% of pupils improved from the pre-test to the post-test in the 3D classes, compared to only 52% who improved in the 2D classes. Within the individuals who improved, the rate of improvement was also much greater in the classes with the 3D. Individ-

[92] Similar findings were noted in the study of the use of 3D on biological learning reported in Yuri Chugui, Yongsheng Gao, Kuang-Chao Fan, Roald Taymanov and Ksenia Sapozhnikova (2010) "3D Visualisation" *Measurement Technology and Intelligent* Instruments Volume IXpp 555-559

[93] G. Korakakisa, E.A. Pavlatoua, J.A. Palyvosa and N. Spyrellis (2008) *3D visualization types in multimedia applications for science learning: A case study for 8th grade students in Greece* Laboratory of General Chemistry, School of Chemical Engineering, National Technical University of Athens, 9, Heroon Polytechniou Street, Zografos Campus, Athens GR-15780, Greece

uals improved test scores on average 17% in the 3D classes, compared to only an 8% improvement in the 2D classes between pre-test and post-test.

Bill Indge[94], author and examiner, suggests that learning in 3D may improve test scores because it makes pupils more able to answer the often diagrammatic questions in exam papers. Pupils may be 'thrown' in answering a question when the 2D diagram is presented differently from how it was learned in class. By contrast, a pupil who has learned in 3D is able to understand a diagram no matter what 'angle' the diagram may be presented. Indge argues that diagrams in tests may cause poor scores because the candidates have difficulty in:

- Linking 2D diagrams with 3D reality
- Realising that diagrams are only a model, and do not represent reality
- Relating diagrams in exam papers to what is shown in their textbooks
- Understanding scale and magnification.

Indge's observations may give a clue to why 3D appears to greatly improve learning outcomes. While further research would be needed to understand fully the elements of 3D that have the greatest impact on children's learning, the following elements appear to be significant:

- Scale – Being able to see an image in both macro and micro (even cellular) scale
- Dimension – See an image from all angles in in 3 dimensions
- Motion – Being able to travel through, around, over an image
- Framing – The ability to zoom in and freeze frame to focus on particular aspects or to proceed at a pace appropriate to the learner
- Colour – For example, being able to show the colour of oxygenated and deoxygenated blood moving through the heart
- Flow of movement – To see sound waves in action, blood flowing, body parts moving and so on
- Perspective – To not have to imagine what a 3D object may look like from a 2D diagram but rather to be able to see it as a solid, realistic interaction
- Relative size – To be able to see in large size detail not normally visible to the naked eye
- Labelling – The ability to label and name parts of the whole within the animation
- Simplification – the 3D animation, although realistic is easier to see the component parts that the real thing
- Layering – The capacity of 3D animations to layer information, compressing space and time
- Vicarious experience of things that are not possible to show in the classroom – For example to be able to split atoms, dissect the human ear, go back to a Roman battle field, watch a dinosaur egg hatch and so on that could never occur in a classroom
- Increasing exposing pupils to vicarious, first-hand experiences - Promoting insights by offering a 'real' experience

The marked improvement in test scores was also supported by qualitative data that showed that 100% of teachers agreed or strongly agreed that 3D animations in the classroom made the children understand things better and 100% of teachers agreed or strongly agreed that the

[94] Salters-Nuffield Advanced Biology, seminar at the Nuffield Foundation in June 2001. http://www.advancedbiology.org

pupils discovered new things in 3D learning that they did not know before. The teachers commented that the pupils in the 3D groups had deeper understanding, increased attention span, more motivation and engagement.

The findings from the teachers was also evident in the findings from the pupils with a higher level of reported self-efficacy in the pupils within the 3D cohort compared to the 2D control groups. The pupils felt strongly (84% agreed or strongly agreed) that 3D had improved their learning. High levels of pupil satisfaction with 3D learning were also evident with an 83% approval rating.

The pupils in the 3D class were more likely to recall detail and sequence of processes in recall testing than the 2D group. Both pupils and teachers stated that 3D made learning more "real" and that these concrete, "real" examples aided understanding and improved results. The 3D pupils were also more likely to perform better in open-ended and modeling tasks.

During the LiFE 1 research study, several tests were undertaken to test for regression. Teachers were asked to note the pupils' retention (memory) 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 in the 3D cohorts (especially when a new concept had been introduced through 3D)
- 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 than the 2D classes after 4 weeks. Not only were there differences in the quantity of material recalled, but the pupils who studied with 3D 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. 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, "The children said "I won't forget it." It was more in their faces."

The teachers were more likely to adopt different teaching pedagogy in 3D lessons as compared to 2D lessons. The teachers encouraged more conversation and collaboration with pupils during the 3D lessons and the pupils felt that their teachers were better and "nicer" when they taught with 3D. This helped to maintain pupils' motivation - 100% of teachers agreed or strongly agreed that pupils had fun learning in 3D and 87% of pupils found learning in 3D more interesting.

4 Brain research

According to Sue Barry[95] (a neuroscientist at Mount Holyoke College) seeing in 3D provides a fundamentally different way of seeing and interpreting the world because animations can be used to show how representations of structure from macro to micro relate to each other.

Scientists at UCL (University College London) and Birkbeck, University of London have found that children younger than 12 do not combine different sensory information to make sense of the world as adults do. This does not only apply to combining different senses, such as vision and sound, but also to the different information the brain receives when looking at a scene with one eye compared to both eyes. The brain is only interested in obtaining knowledge about those permanent, essential or characteristic properties of objects and surfaces that allows it to categorise them, but the information reaching the brain from these surfaces and objects is in continual flux (Zeki, 2007 p2). In other words, as children learn, they need to be guided to see the connection between 2D, 3D and narrative.

For example, UCL researchers[96] used special 3D discs in which perspective and binocular information sometimes disagreed. Because adults tended to take an average of the perspective and the binocular information, they were poor at determining whether the slant of some discs was the same or different as a comparison disc. By contrast, 6-year-olds had no trouble in spotting differences between discs of this kind. This shows that 6-year-olds can “see” separate kinds of visual information that adults cannot.

This neurological research suggests that providing children with 3D (actual and possibly virtual) may be particularly relevant to their development and learning.

5 Conclusion

Teachers can use 3D visualisation as a strategic teaching and learning tool in almost any curriculum area. Visual technology enables teachers and pupils to explore how combining traditional learning methods with multimedia 3D projections can help children to learn and to retain what they have learned. Technology, such as 3D animations provide a tool for combining both visual literacy and multimodal literacies. Complex concepts become more easily digested when reduced to imagery. 3D visuals increase students’ engagement and knowledge retention. They provide the opportunity to learn by interacting and doing rather than passively receiving information. Visual literacy skills are increasingly in demand and need to be developed alongside traditional forms of literacy. 3D visuals allow for experimentation, exploration, collaboration and can bring real-world vocational applications into the classroom. Below are some ways 3D can enhance education for both students and teachers.

The potential exists for 3D assets to be created by students as part of assessment and learning. Current assessment models based around conventional learning are simply not compatible with innovation and future learning practices

Technology is not a panacea for education. Used incorrectly, it could even detract from the true objectives of modern-day teaching. More research is needed about nature of benefits of

[95] https://www.mtholyoke.edu/acad/facultyprofiles/susan_barry

[96] Note specifically the work of Professor Denis Mareschal http://www.bbk.ac.uk/psychology/our-staff/academic/denis-mareschal

using 3D to enhance pupil learning. Similarly, there is an urgent need for improved teacher education in the area of technology, neuroscience and understanding how children perceive and learn.

Despite these caveats, we conclude that technology should be more at the centre of active learning and critical curriculum and that visual literacy is fundamental to the development of sound conceptual understanding and meaningful learning outcomes in all curricula.

Biology teacher Ros Johnson in the UK[97] says 3D projections of body organs have given lessons a new direction at the Abbey School in Reading. "So cool", "It's huge", "I thought the diaphragm was a flat muscle," "I didn't realise it wasn't under the ribs" were just a few of the comments made when the girls put on their glasses to examine the model of the thorax in more detail. "It is an amazing experience, so good for learning," said one pupil. "Much more interesting than looking at a flat text book," added another pupil.

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[97] City Am 10/1/11