Discussion of spatial and temporal relationships on Earth's surface is integral to any undergraduate geology course. The dry-erase surface of our Globes is unique, and naturally promotes the development of hands-on activities within the classroom.

Any exercise designed using this Globe should require critical thinking by challenging students to synthesize concepts and processes, e.g. plate motion, volcanic activity, distribution of igneous, sedimentary and metamorphic rocks at the planetary scale.

From Bamford (2013) it has been shown that visual learning improves understanding o f functionality, and by seeing the whole (the students) understand the parts. This research demonstrated the "students learning with 3D teaching aids weremore likely to use gestures o fbody language when describing concepts , had better ordering of concepts, and had enhanced skills indescribing their learning, including writing more, saying more, and being more likely to use models to demonstrate their own learning.

see Anne Bamford (2013) White Paper "The 3D in Education"

The 3D in Education White Paper Written by Professor Dr Anne Bamford, Director of the International Research Agency What is 3D in the classroom? Computer generated animation has been in development for some time with early work dating back to the 1960s. Not surprisingly, the first commercial use of three-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," 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-powered1 3D projectors use millions of microscopic, digital mirrors that reflect light to create a picture. DLP imaging technology is so fast, it can actually produce two images on the screen at the same time: One for the "left" eye and one for the "right" eye. Then 3D glasses combine the two images to create a 3D effect. The single-chip version of DLP is used in many projectors, with the technology being used in over 50% of the projectors currently sold. Children and 3D Children and young people own a lot of technological devices and use them regularly. As indicated by the recent pan European research2 , 90.1% of pupils had a computer, 85.3% had at least one mobile phone and 74.6% owned handheld games.3 It also found that pupils are 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 lives and in their learning. The teachers that were interviewed acknowledged the importance of good quality technology for the pupils of today as they are "digital native" learners, as the following comments from teachers exemplify: "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." -

Teacher comment “The pupils wanted, and expected, very high quality animations.” – Teacher comment Why is 3D important? Children find it hard to understand what is not visible. Visual learning improves the pupils’ understanding of functionality and by seeing the whole of something, children are able to 1 Digital Light Processing (DLP®) is a registered trademark of Texas Instruments. 2 Bamford, A 2011 Details provided at the end of the White Paper 3 Note: Many pupils had more than three different forms of technology. 2 | P a g e 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. “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.” – Pupil comment Complex concepts become more easily digested when reduced to imagery. 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 levels. This process of amplification and simplification seemed to be particularly effective as an aide to understanding. “The 3D comes in to the lesson… Makes an infinite difference and then goes back again. It really makes a phenomenal difference.” – Teacher comment “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.” – Teacher comment The 3D content in the classroom appears to ‘come out to’ the pupils. 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. The impact of 3D on academic results 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. Individuals improved test scores by an average of 17% in the 3D classes, compared to only an 8% improvement in the 2D classes between pre-test and post-test. 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 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 higher 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. 3 | P a g e “I think I will get better test results. It is easier for me to remember with 3D. Then I will do well.” – Pupil comment 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 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 “In this school we find that theoretical retention is a problem. As I see it, the 3D increases visual retention and this boosts learning.” – School principal The pupils in the 3D classes could remember more than the 2D classes after four weeks. Not only were there differences in the quantity of material recalled, but the pupils who studied with 3D remembered in a more connected ‘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.” “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.” – Pupil comment The impact of 3D on classroom interactions 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 3D technology led to a deepening of pupils’ understanding, increased attention spans, more motivation and higher engagement. “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.” – Teacher comment 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 when using the 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 five minute interval tests during the non-3D part of teaching the lesson, compared to 92% of pupils being attentive at five minute intervals during the 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. “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.” – Teacher comment “3D in the lesson makes them concentrate more. They have to focus and concentrate.” – Teacher comment 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. “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.” – Pupil comment “I can't describe it but in 3D lessons the teacher changes. She is better. Sort of happier… actually we all change.” – Pupil comment The teachers’ pedagogy often changed with 3D and 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. “As the teacher, I went to the back of the room. The pupils drive the computer and run the lesson.” – Teacher comment Strategies for implementing 3D in the classroom It is comparatively easy to implement 3D animations into the regular classroom environment. To begin teaching with 3D, a teacher would need access to: A DLP 3D-enabled projector: The majority of new projectors purchased for schools already• have this capability, and future purchases of DLP projectors are generally no more expensive than those that are not 3D-capable. 5 | P a g e A laptop or PC with good graphic capability: 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. 3D content: There are a number of 3D software content providers and currently more than• 3,000 pieces of free 3D content available online. 3D active glasses: There are a number of companies making ‘active’ glasses. They vary• considerably in quality and price. Ideally the pupils should have a pair of active glasses each so that the fit and comfort is suitable for the individual child. Class sets of glasses are also available. The 3D animations work best in a normal classroom with low level lighting. Special screens are not needed and the 3D can be projected onto almost any surface. It works effectively for schools to share portable equipment, though teachers preferred using fixed equipment in the classroom so that setup time was kept to a minimum. “We are sure that the system should be in every school and be available for every teacher.” – Principal comment The teachers were able to effectively use 3D in the classroom without any specific professional development. They found it easy to integrate 3D technology into their regular lessons with six out of the 15 schools also modifying their teaching and learning pedagogies in response to the introduction of 3D. The teachers and pupils also creatively proposed ways that 3D could be successfully integrated across the curriculum. The teachers felt that 3D animations allowed them to teach topics in more depth and use less time than conventional teaching methods. “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.” – Teacher comment There was an 8.8 out of 10 teacher satisfaction level for implementation of 3D in the classroom. Some fun activities to start using 3D Try some of the following ideas… Have pupils move their bodies to ‘feel’ the virtual 3D• Give pupils clay or dough to model as they watch the 3D animation• Re-use 3D animations; for example, use a science-based animation in the art class or use the• history animation in the language class Put the pupils in the 'driver's seat' and let them develop lessons around 3D content• Get a 3D camera and start creating your own 3D content – start with images in nature• Create your own 3D logo so that when the pupils see that on a worksheet, they know they• can also see things in 3D Encourage pupils to make their own 'commentary' to accompany 3D animations• Project the image on unusual surfaces – try your T-shirt or the surface of the desk• Study a 3D artist or learn about how our eyes see 3D• Compose music to accompany 3D animations• Use 3D animations without the sound or labels to revise for tests• Invent learning games to accompany the 3D animations• 6 | P a g e The pupils were asked to imagine how 3D animations might change their learning in the future. These are some of their ideas: "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." – Pupil comment "We will have screens built into the tables and then we can touch things and they will be 3D." – Pupil comment "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." – Pupil comment Background to the research 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, 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 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 countries4 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. 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. 4 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. 7 | P a g e LiFE 1 has provided a unique insight into the impact of an immersive and interactive classroom experience. Suggested further reading Annetta, Len, Klesath, Marta, Holmes, Shawn (2008) “V-Learning: How gaming and Avatars Are Engaging Online Students” Innovate: Journal of Online Education. Vol. 4, No 3, Feb-March Bamford, Anne (2011) “LiFE: Learning in Future Education. Evaluation of Innovations in Emerging Learning Technologies” in press Braintrack (2010) “VLearning: Is the Future Of Online Education A 3D Virtual Classroom?” http://www.braintrack.com/online-colleges/articles/vlearning-is-the-future-of-online-education-a- 3d-virtual-classroom Merchant, Guy (2010) “3D Worlds as Environments for Literacy Learning” in Educational Research Vol. 52, No 2, pp 135-150 Monahan, Jerome (2010) “Lessons in 3D Promise Students Entry into New Worlds” in Classroom Interactions http://www.guardian.co.uk/classroom-innovation/3d-lessons-in-schools Stroud, Sara (2010) “The Classroom in 3D” in THE (Transforming Education through Technology) Journal http://thejournal.com/articles/2010/02/01/the-classroom-in-3d.aspx Tay Lee Yong and Lim Cher Ping (2010) An Activity Theoretical Perspective towards the Design of an ICT-Enhanced After-School Programme for Academically At-Risk Students.” Educational Media International . Vol. 47, No 1, pp 19-37, March.