Space Mission: Ice Moon

A Futurelab prototype context paper

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INTRODUCTION

This context paper provides an overview of the research literature in:

- the changing science curriculum, ie 21st Century Science
- the multimodal and multisemiotic nature of the science classroom
- the provision of science education in out-of-school contexts, such as science museums and galleries
- the use of videoconferencing and other web technology in science education
- the role of computer games to support science learning, and the inculcation of players' identities as 'scientists' through motivated game-play.

It also then identifies a number of recommendations and considerations for research that should be addressed during the research and development phase of the project.

THE CHANGING SCIENCE CURRICULUM

The science curriculum is currently in transition, as it responds to widespread warnings that young people perceive it as 'difficult', the exclusive domain of the 'intelligent', and that it leaves pupils uninterested and disaffected (Warwick and Stephenson 2002). According to some commentators, the attitudes of many school leavers after 12 years of compulsory science are at best ambivalent, and at worst entirely negative (Newton and Newton 1992; Jarvis and Rennie 1998), with many of them lacking familiarity with the core scientific ideas that they will meet outside of school (Millar and Osborne 1998). The debate around the purpose and function of science education increasingly leads many to conclude that educating young people to see science as consensually-agreed 'rational truth' erects barriers to their understanding, and that a successful program of science education, rather, should seek to teach its processes, modes of scientific thinking, and the nature of uncertainty in science (Warwick and Stephenson 2002; Osborne and Hennessy 2003); it should address the human activity of practised science, which is full of biases and accidents, agendas, competitive struggles, and egos (Lemke 2000). These approaches, it is argued, will make science more meaningful to students.

At least since science became compulsory under the National Curriculum in 1988, science has been taught as a program suitable only for the small minority of students who are likely to go on to study it at A-level or degree level, or who might pursue it in employment (Osborne and Hennessy 2003). This course tends to privilege learning decontextualised knowledge, assessment through fact recall, and is content-heavy, rather than promoting the acquisition of skills that are transferable from science to everyday life (Chell et al 2004). Furthermore, science educators are restricted in the quality of the science education they can offer by an emphasis on teaching for what can be easily assessed, and thus on a system of measurement oriented towards representing the quality of service that schools offer (Black 1998). Such high stakes assessment, a corollary of the emphasis on league tables as an indicator of good provision (William 1999), minimises teachers' opportunities to go beyond pure content (Osborne and Hennessy 2003).

The new 21st Century Science curriculum, due for deployment in September 2006, on the other hand, seeks to develop all students' broad understanding of the main scientific explanations that can act as a framework for making sense of the world around us. Divided into three distinct GCSE awards (core science for all, applied science for those with a further interest, and general additional science for those intending to pursue science post-16), it provides both science for citizens and science for scientists (Nuffield 2004). The 21st Century Science project also rests on the understanding that the relationship between science and society is changing. A litany of technological and ecological disasters over the last two decades - including Chernobyl, Bhopal, global warming, ozone depletion and BSE - has changed the public perception of science from one of awe and wonder to one that seems more threatening and dangerous (Osborne and Hennessy 2003). The *Beyond 2000* report (Millar and Osborne 1998), upon which the 21st Century Science program is based, therefore claims that science needs to address how people, as citizens, can become informed users and consumers of scientific knowledge.

In turn, the new curriculum addresses two distinct things. The first is 'ideas about science', namely, what practices have produced it, how scientific arguments are developed, and what issues arise when scientific knowledge is put to use. The second dimension is 'science explanations', or the major scientific explanations which have something important to tell us about ourselves, our environment, and our place in the universe. In the core science and applied science provision, modules are set in a context in which scientists' procedures and scientific understanding are both involved, and likely to be encountered by students in their personal and/or working lives; it enables them to appreciate the significance of major theories of science in society (Nuffield 2004). For some commentators, the fact that young people have immediate access to large bodies of information from ICT-based resources also means that the decontextualised acquisition of knowledge, and assessment based on fact recall, is increasingly irrelevant and non-indicative of the processes that even professional scientists follow (Chell et al 2004). More broadly, it has been argued that science "cannot be equated with its products":

> "What science says about the world is not science itself. Science itself is the human activity that produces these statements and theories, and to learn science is not to learn what the last generation of scientists thought the world was like: it is to learn how each new generation of scientists re-makes our view of the world. Ultimately, it is to learn how to have some degree of participation in this process of invention and discovery."
> (Lemke 2000)

The curricular emphases in science, then, are transforming from content-heavy knowledge acquisition and fact recall to process-based inquiry; from an emphasis on 'rational truth' to an emphasis on making meaning; and from decontextualised specific understandings to broad understandings of the contextual relationship between science, society and citizens. In short, 21st Century Science seeks to promote a 'scientific literacy' that will prepare young people for life in a modern democracy; it is an end in itself, not just preparation for the minority who wish to pursue science for further study. This is 'science for all', not 'one science for all'.

MULTIMODAL AND MULTISEMIOTIC SCIENCE

'Scientific literacy' is a term intended to catalogue the competencies and content knowledge that young people need to become active and critical consumers, rather than simply passive and unquestioning recipients, of science. It should allow young people to be able to question and make personal and informed decisions about science issues, such as cloning, GM foods, animal testing, and so on. Particularly, being literate in this sense means being knowledgeable and familiar with the discourses of the discipline, that is, the words, actions, values and beliefs of scientists (Gee 1996); even more particularly, it means being critically reflective about the practices of scientists, about the major scientific explanations, the beliefs which underpin them, and the ways in which science is used and abused (Osborne and Hennessy 2003). If the emerging emphasis in science education is on how young people make meaning, then scientific literacy is the framework of content understandings and process competencies that will allow them to accomplish this.

There is another dimension to the term 'literacy' which should not be ignored. This concerns the panoply of practices, discourses, and modes of representation which underpin being literate in the broadest sense. The New London Group (2000) introduced the term 'multiliteracies' to refer to the multiple competencies required in a fast-changing world of linguistic heterogeneity and hybridity, communication and information technologies, new visual modes of representation, the new forms of order and control that are manifested in such an age, and the meanings that can, therefore, be created within it. Scientific literacy means being familiar with the language and actions and practices of scientists, and it also means being able to interpret scientific language, 'reading' scientific evidence, understanding why science is represented in multiple modes such as pictures, diagrams and tables, or in statistics and equations and verbal text, and how and why it is communicated in the media. Furthermore, it means being able to critique these processes and practices.

Science is a particularly 'multimodal' discipline, meaning that its data and its arguments appear in forms as diverse as written text, photo and video evidence, statistics, diagrams, tables, and graphs (Kress et al 2001; Jewitt et al 2001). Each of these modes communicates meaning in distinct ways. According to Lemke (1998, 2000), science education also makes "multimedia literacy demands" across multiple media, modalities, semiotic systems and hybrid genres of communication and representation, and he concludes that "not only must students master each separate disciplinary and literacy demand at a high level, but they must also learn to co-ordinate and articulate multiple literacies simultaneously" (Lemke 1998, p247). Being scientifically literate, accordingly, means being able to juggle the multimodal aspects of any single scientific concept, and being able to translate amongst them. Scientific literacy implies the ability to decode meanings from multiple symbol systems, each of which are interdependent. It is in the inter-relations of these modes mobilised in particular situated contexts that meaning resides, not abstractly in each mode taken individually. Further, according to socio-cultural theory, meaning resides in how these particular situated contexts are themselves situated in larger social structures, such as the institutional structures of the school, the family, local community, peer group, gender, race, class, age, cultural heritage, and the roles which one takes in each of these (Lemke 2000).

For Kress et al (2001), the regular use of action and image in the science classroom foregrounds the contributions of the multimodal "material 'stuff'" (p11) that teachers orchestrate in their teaching, and the social conditions in which they become relevant. Learning science, in this account, is a process of transforming signs in specific contexts. It sees semiotic systems as unstable - far from the Platonic Ideal of rational truth - and "undergoing constant transformation through the interests of social actors engaged in interaction with others" (p19). This is not a radical re-imagining of the classroom, but a call to attention to the multimodality of science education in particular, and education in other subjects more generally. All teaching is multimodal, and all learning a process of transforming signs and symbols, whether these are represented in verbal text, numbers and equations, images, gestures and actions, sounds, or spoken language. Making science meaningful is bound up in the transformation of these signs in social contexts. In this view, what is useful to learning and doing science is primarily the socially learned discourses and practices that young people know how to use themselves. Being able to orchestrate multiple meaning-making modes of communication is an essential part of this educational mechanic.

Science education is, then, multimodal and multisemiotic. Different modes, as semiotic resources, communicate different parts of different meanings, and only when viewed as partial representations in a whole multisemiotic system do they fully begin to communicate particular meanings. When taken alone, textbook descriptions of phenomena, charts and graphs, photographs and illustrations, and teachers' spoken explanations, offer only narrow entranceways to the business and practices of science.

SCIENCE IN INFORMAL CONTEXTS

Science museums and centres have long been the favoured location for the school day trip. These offer some interesting and exciting diversions from learning about or learning how to practice science in the classroom. However, as Hawkey (2004) acknowledges, little is known about learning in such settings. Many museums and galleries celebrate different forms of learning, by offering formal lectures and practical workshops alongside the free-choice interactions that visitors enjoy by exploring at their own will. Many museums, as Hawkey points out, are now also able to support the learning that goes on during a visit after visitors have left through well-maintained websites.

For the purposes of this review, it is important to recognise that the dominant view of learning in these contexts is one in which the learner is viewed as actively constructing knowledge, and that therefore the social, personal and cultural context of learning is increasingly significant. The extent to which museums and science centres actually promote such learning-by-construction is, however, contestable: in most cases. According to Falk and Dierking (2002), it is a model to which they should subscribe actively, as well as rhetorically; museums, galleries and science centres need to motivate free-choice learning experiences, should be stimulating and enjoyable, interdisciplinary so that multiple pathways into materials are possible, and progression between exhibits is necessary so that intellectual development is possible.

A number of recent initiatives in the use of mobile technologies to support learning through museums and galleries have indicated the value of providing visitors with access to context- and location-sensitive information as and when it is appropriate, for example the Hypertag initiative (www.hypertag.com/Visitor/Home.jsp). A prototype development at Futurelab has indicated how it might be possible to create evolving museum and science centre tours, during which visitors create records of their visits in photos, illustrations, sound files, and written text, by recording on a PDA, for others to access on subsequent visits (Sutch and Sprake 2005). Similar web-based activities are also available through the Science Museum's In Touch site, and At-Bristol's Get Connected exhibition. Some critics, however, suggest that placing interactive screen-based technologies in museums demotes the interactions that visitors may experience with the artefacts and objects on display (Boon 2000). According to Hawkey (2004), such simplistic claims against 'interactive' technologies in museums ignores those interactive exhibits which encourage individuals or groups to work together to understand real objects or phenomena through physical exploration which involves choice and initiative. He also points to research indicating that it is visitors who are interactive rather than exhibits: they rarely behave in ways which exhibition designers intended. The growing popularity of live webcasts from museums to online visitors, too, points towards a change in emphasis where talks and lectures are replaced by online exchanges.

Clearly, then, an important emerging aspect of learning through museums and galleries that are augmented with interactive technologies is the two-way communications these allow. The expertise and enthusiasm of visitors, as well as curators, contributes to the work of the museum. As these technologies develop, these centres will increasingly allow visitors to access and interrogate databases, to experience direct communication with expert staff and peer-to-peer communication with other visitors, and will also offer greater location- and context-sensitivity. They are already moving beyond the template of the digital brochure into online representations of the physical museum.

ICT IN SCIENCE EDUCATION

Given the shifting emphases in the science curriculum to account more for the processes of scientific investigation, alongside the recognition that science is a multimodal and multisemiotic domain, and the increasing use of ICT to augment the experiences of museum and gallery spaces, it is unsurprising that ICT is seen to have real potential in science education. However, it is not straightforward, and there exists little consensus over its use. As McFarlane and Sakellariou (2002) have identified, it is difficult to make progress in understanding the most powerful ways of embedding ICT in science education when the design of the science curriculum is still undefined. With the 21st Century Science curriculum approaching, the way in which the very curriculum itself is navigated is likely to be questioned. However, a number of researchers (McFarlane 2000; Ball 2003) have identified a number of congruencies between the types of science processes that children should learn to work with in school and how new technology can be used. Murphy (2003), furthermore, has catalogued the use of new technology in science as: using tools (spreadsheets, databases, dataloggers); using reference sources (CD-Roms, the internet); as a means of communication (e-mail, online discussion, PowerPoint, digital cameras); and for exploration (control technology, simulators, and virtual reality applications). The latter are, as yet, the most under-used of these categories. For McFarlane (2003), though, simulations offer opportunities for children to interact with complex systems:

> "The value of dynamic representation is likely to reside in the rendering of the abstract as concrete. For example, it is possible to see, and interact with, a representation of the molecules in a gas […]. By experimenting with the behaviour of these virtual systems it is possible to infer, and understand, the principles often underlying often complex and otherwise abstract systems." (p223)

Such simulations, of course, must be built on adequate models or algorithms of the reality being simulated, which is not always the case; some oversimplify or even misrepresent the phenomena under simulation. Similarly, caution should be taken with computer simulations since they represent 'cleaned-up' versions of the complex and messy real world (Osborne and Hennessy 2003). Similarly, simulations do need to present viable and convincing alternatives to children's existing, everyday beliefs if their thinking is to develop; otherwise those existing frameworks of comprehension and the meanings that children associate with them are likely to remain uncontested (Hennessy et al 1995).

However, the value of interactive computer models such as simulations is not just in representing scientific ideas or phenomena, according to Osborne and Hennessy (2003); they can also encourage pupils to pose exploratory "what if…?" questions, to try out and observe what happens when variables are manipulated, and to revise both their hypotheses and their investigative practices if they have made mistakes. The capacity to be iterative in this fashion, and to receive immediate feedback, supports the development of young people's repertoire of scientific methods.

As McFarlane and Sakellariou (2002) point out, however, it is not possible to provide templates for every scientific method; there is no algorithm for scientific investigation. Thus, according to these authors, the necessary skills for young people to learn in science are reasoning skills. Even though they may be non-expert in particular domains, and have only an understanding based on media accounts of scientific explanations, scientifically literate people should be able to ask, "How do they know that?" In an age of information bombardment, having the ability to make informed judgments about the likely validity of a scientific claim and the credibility of its sources is essential in order to avoid intellectual paralysis. The internet is therefore an important resource for developing these skills, where it is necessary to be able to identify and interpret relevant resources; without scientific reasoning abilities it is impossible for a learner to make a judgment about the likely validity of any scientific claim.

These arguments, however, take little account of the potential for two-way communications that web technologies offer. Osborne and Hennessy (2003) suggest that "peer collaboration between students working together on tasks, sharing their knowledge and expertise, and producing joint outcomes is becoming the prevalent model for the use of educational technology" (pp26-27). Such activities may be self-regulated, they argue, but teachers remain instrumental in supporting and sensitively managing pupil collaboration. The same technologies can also, as in museum environments, be used to facilitate discussions between learners and expert scientists. The potential role of video-conferencing facilities to support science education in the classroom has been under exploration for the last 15 years. Pea et al (1995) see science education as a key driver of 'cyberspace technology' development, and their CoVis (Collaborative Visualisation) project integrated desktop video-conferencing with a suite of other collaborative tools such as screen-sharing, a Collaboratory Notebook, alongside e-mail, and Usenet news services. Aimed at supporting systematic science inquiry, CoVis allowed students and teachers to conduct cross-school collaboration, to go on virtual field trips to museums too far away for them to visit in person, and to attend virtual 'briefings' with science experts, during which they could ask questions about the data presented to them, and seek explanations for anomalous information. However, the project identified a number of key issues, notably, that while teachers found it useful to collaborate with other staff via video-conference, they did not perceive such cross-school activities to have much curricular benefit; it also identified the need for technologies that have emerged in the business realm to be radically redesigned for use by schools. Other similar projects (Klease et al 1996; Ray et al 2002) have also identified the potential effectiveness of linking students with experts, but as yet provide little solid evidence to support this hypothesis.

A number of more recent initiatives, however, are in progress at a range of UK schools and museums (Monahan 2005). Global Leap, part-funded by Becta, is brokering up to 50 video-conferences a month between schools and other institutions, even by loaning out the kit where appropriate; the Motivate Maths project run from Cambridge University regularly links students with professional mathematicians; at a consortium of Bristol schools students are in contact with law tutors; and in the US, two organisations, Chat the Planet and Global Nomads, have linked US teenagers with others in Baghdad. A DfES report on video-conferencing was published September 2004.

COMPUTER GAMES AND LEARNER IDENTITIES

Increasingly, videogames are being viewed as media which promote informal and motivated learning. The argument goes that playing games is fun since they are challenging - in Papert's (1980) term, "hard fun" - and that they are specifically designed 'to be learned'; in Gee's (2003) view, they are "little learning engines" that players must learn through the activities of game-play. However, the debate has gone beyond this view more recently. Others have identified how knowledge about games, and the material artefacts related to games (ie magazines, demo discs) can lead to the creation of informal exchange 'communities' of games players that might meet physically or even on the web (Suss et al 2001), in which some members take on roles as expert tutors and others novice apprentices (Williamson and Facer 2004). According to Gee (2003), video games offer players opportunities to get 'networked' with others in ways which promote distributed smartness, going on to argue that knowledge exists not in 'nodes' but in the interconnections in the network of affiliates as a whole. Steinkuehler (2004) suggests that such 'affinity groups' create informal learning spaces where they participate in "apprenticeship into doing [and] being", in other words, engaging and participating in the practices of 'doing' in the game or 'being' through certain behaviours in it.

Extending outwards from this model, Gee also discusses the kinds of identity work that go into the process of playing video games, suggesting that players develop 'projective identities' in which their player identity and virtual character identity are merged to allow players to perform actions in a role, within a context of games play with and between other participants. In effect, players learn to 'own' the character identities they create and may take on projective identities as, for instance, scientists, both working within that role and having a critical overview of the role from outside of it.

IMPLICATIONS

A number of recommendations for the development of the Space Mission project arise from these readings:

- Through the experience children should see themselves as participants and inventors in the creation of meanings in science.
- Children need to be engaged as producers of science and as critical consumers of science, not just passive unquestioning consumers of it.

- Students should have to deal with uncertainty in their data, and will need to use scientific reasoning, science process skills, and scientific thinking to resolve it.
- Children should be prompted with data and tasks that encourage them to ask, "how do they know that?", and to ask exploratory "what if…?" questions.
- There need to be multiple pathways in to problems, presented in multiple media formats, to allow children to begin to identify with the multimodality of the science discipline.
- There need to be opportunities for children to translate their discoveries into other, appropriate, media formats that allow them to make meaningful sense of the data.
- Children need to be able to see themselves 'as scientists' using the instruments, practices, and discourses of the professional domain; they also need to be able to know what to do when they are stuck, and to ask, "What might scientists do in this situation, where might they look for information, how would they find out what to do next?"
- Children should be encouraged by the experience to understand that science is part of science and of citizenship, and that scientific decisions have implications outside of the science domain itself.
- The simulation needs to be 'real', that is, deal with problems that might be relevant in their personal lives, even though the scenario is fantastical (eg planetary science such as radiation and gravity, health monitoring, energy and power).
- Children need to be able to interact with artefacts to support their investigations, even if these are presented to them virtually; they should also be able to create and upload artefacts and content that they have produced.
- It is likely to be beneficial if sufficient resources are available both before and after the experience for children to be able to prepare and follow-up on the science investigations that form the basis of the mission.

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