Space Mission: Ice Moon

Research report

by Lyndsay Grant

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EXECUTIVE SUMMARY

Space Mission: Ice Moon is a real-time simulation of a space disaster in which students find themselves in the roles of scientific experts in an Emergency Response Team. Up to 30 students work in teams to rescue four astronauts lost in the ice tunnels of Jupiter's moon, Europa. Using video-conferencing facilities, they communicate with the only astronaut left in the space station, and work with real-time data feeds to devise and implement a rescue plan in a constantly changing situation.

This executive summary provides an overview of the conclusions drawn from the development and trials of this project; broader implications for the role of technology in the design of learning environments; and areas for future research and development work. A full description of the prototype created, development process, research methodology, findings, analysis and conclusions can be found in the body of the report.

Key findings

Space Mission: Ice Moon

Space Mission: Ice Moon was clearly an engaging and enjoyable experience for the students who took part in the simulation.

The strong narrative, problem-focused approach and the impact of video-conferencing and video-streaming technology supported students in imaginatively entering into their roles as scientific experts with responsibility for rescuing the stranded astronauts. Students responded positively to this responsibility, with almost all remaining focused and on task for the entire mission. Acting in role, students began to try to think and act like scientists, understanding science as a process of interpreting evidence to make explanations, solving problems and working together.

The video-conferencing technology made a significant contribution to the experience. Because students could see and interact with the Mission Commander remaining on the space station, and see video clips of the trapped astronauts as if in real-time, the experience seemed authentic and supported the students in imaginatively entering into role. The two-way dynamic communication between the Mission Commander and the students also allowed variation of the level of challenge, as the Mission Commander was able to support struggling students with prompts and hints, and provide extra challenges when students were working comfortably.

Students analysed and interpreted raw data to create explanations, and some began to understand how valid interpretation must be based on firm evidence. Students worked closely together, cooperating within and between their teams to complete tasks and build an overall understanding of the situation.

Space Mission: Ice Moon would benefit from further work to complete the prototype to a point at which it could be distributed more widely to schools, science centres and other institutions. Development of additional resources to support students' and teachers' preparation prior to, and reflection on learning after the mission would enable students to get the most from this experience. Consideration should also be given to developing a greater number of variable narratives and outcomes to the scenario.

Implications for learning beyond Space Mission: Ice Moon

The immediacy of communication via video-conference was a powerful factor in the students' experience, contributing to the authenticity of the learning environment and enabling students to suspend their disbelief for the period of the simulation. More generally, video-conferencing can allow expertise from other areas to be brought into the classroom. This connection to real experts, and engaging with real problems, provides an authentic context in which learning is meaningful and engaging for students. Experts in this sense may be scientists working at the forefront of their fields, but could equally be individuals with particular expertise from the students' own communities, or students' peers in other locations.

Students became immersed and emotionally engaged with the powerful narrative, and their activities were seen as relevant within a coherent context. Dramatic and narrative approaches are often not considered in subjects such as science, which is often considered abstract, but appeared to support students' engagement and understanding.

Layout of the room played a part in facilitating students' communication, cooperation and collaboration. Communication was more effective within and between teams when teams had a defined 'base' such as a desk around which they could all gather and speak to each other, and where others knew to find them. The presence of a PC in a team also needs to be managed carefully. PCs, initially designed for individual office use, lend themselves to use by single operators. In groups, the PC operator can often take control through control of the PC. When using PCs with groups, all members of the group should have access to screens on which shared information is represented to enable full participation. It may be that different display and input devices, such as tablet PCs, could further facilitate group communication and collaboration if they allowed the information on screen to be shared more easily.

Future development and research opportunities

As the Space Mission: Ice Moon prototype is completed to make it more widely available to schools, there are several elements for immediate consideration. These are noted in detail at the end of this report. Longer term development and research opportunities, both specific to Space Mission: Ice Moon and wider themes arising from this study are summarised here.

The current model of dissemination relies on the National Space Centre hosting the mission on its computer servers and providing a Mission Commander to guide students through the mission. If large-scale dissemination of Space Mission is to be achieved, then responsibility for taking the role of the Mission Commander, and for hosting the mission, could be distributed to other participating institutions. An open source model in which participating institutions contribute to the running and development of the mission may achieve greater dissemination of the mission as well as benefiting from the contributions of a community of users.

As well as practitioners contributing to the development of the mission, participation of students should also be considered. In thinking about how to develop the simulation for peers, students would be both contributing to the future development of the mission and articulating their knowledge and understandings of what they have learnt through their experience of the mission.

Further development may allow students in multiple locations, for example in different schools and science centres, to participate together in a mission. The role of teamwork, sharing information, and negotiating decisions would need further investigation and support in this scenario, but it may also open up further opportunities allowing students to share knowledge and understanding across geographical boundaries.

Further research should look at whether and how students' learning experiences during Space Mission: Ice Mission transfer, or fail to transfer, into learning activities in other contexts such as science lessons and more generally in problem-solving and inquiry-based learning. How can schools and science centres support students who have participated in Space Mission to build on this experience in their later learning?

Further research and development could also look at simulations similar to Space Mission in the wider context of learning with computer games and in simulations where learners are able to manipulate variables to achieve different outcomes. If the mission supported a greater number of variable routes and outcomes dependent on students' actions, then students would have the possibility of trying out different tactics and manipulating different variables to understand their effect on the mission. Research would be needed into the different types of engagement that this approach would support and particularly whether this diluted the powerful effects of immersion in the narrative and engagement in role.

As this study showed, the roles that students adopted during Space Mission were highly significant, allowing them to think and act like scientists. Further research into how students' roles affect their learning would be very useful. For example, if learners take on the expert roles in other, non-fictitious situations, can they think and act like experts in these other domains (and where do they get their ideas of expertise from)? What other imagined roles might open up different avenues for learners to act and think in different ways? Perhaps most importantly, how do learners' identities as learners affect their approach to learning, and can they reflect on, control and adapt their own identities for different situations?

CONCEPT AND AIMS

Space Mission: Ice Moon was developed in partnership by the National Space Centre and Futurelab. The project was accepted by Futurelab through its Call For Ideas programme, which invites ideas for projects to be taken through a research and development process to prototype stage. The prototype was developed to a sufficient state that it could be trialled with users. The findings from the research, development and trials are intended to provide information for further development and completion of the project, to identify areas for future research and to draw out implications relevant to other learning environments.

The Space Mission: Ice Moon prototype developed a multimedia website with video-conferencing, pre-recorded video streaming, streaming data, a (currently paper-based) 'research' library, and other resources to support a role-playing activity for Key Stage 3 science students. The role-play involves students acting as an Emergency Response Team on Earth, managing and overseeing the rescue of four astronauts who have become lost in ice tunnels on Jupiter's moon Europa. A facilitator at the National Space Centre plays the role of the Mission Commander who has been left safe on the space station on Europa, and runs the video-conference, plays video and other media clips and guides the students' activities.

The prototype is designed for Year 8 and 9 science students. It will be available for use in science classrooms where facilities exist, city learning centres, and science centres. It is intended to demonstrate the potential for learning facilitated by a broadband-enabled learning environment.

The overarching aim of the project is to enable students to 'work as scientists', engaging with ideas about science that will enable them to be scientifically literate and well-informed consumers of science, supporting the vision and goals of the 21st Century Science curriculum.

RESEARCH CONTEXT

The changing science curriculum: 21st Century Science

Space Mission: Ice Moon is designed for use in science classrooms and science centres, and so addressing the aims and content of the science curriculum is important. The science curriculum is currently in transition, as it responds to widespread warnings that young people perceive it as 'difficult', and that it leaves many pupils uninterested and disaffected (Warwick and Stephenson 2002). 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). These approaches, it is argued, will make science more meaningful to students.

The 21st Century Science curriculum addresses these issues through the curriculum in its 'ideas about science' strand, namely, what practices have produced it, how scientific arguments are developed, and what issues arise when scientific knowledge is put to use. 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. Space Mission: Ice Moon, then, is about putting the power of creating meaning from evidence, and experiencing the process of creating science, in the hands of students.

Scientific literacy and multimodal science

'Scientific literacy' is a term intended to catalogue the competencies and content knowledge that young people need to become active and critical consumers of science. It should allow young people to be able to question and make informed decisions about science issues, such as GM foods, animal testing, and so on. 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). 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. 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, and the meanings that can, therefore, be created within it. Scientific literacy therefore 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, 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. Being scientifically literate, accordingly, means being able to juggle the multimodal aspects of any single scientific concept, and being able to translate amongst them. It is in the inter-relations of these modes in particular situated contexts that meaning resides, not abstractly in each mode taken individually. Being able to orchestrate multiple modes of communication in order to make meanings is an essential part of learning 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.

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. (Hawkey 2005).

Important emerging aspects of learning through museums and galleries that are augmented with interactive technologies are 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.

ICT in science education

There is little consensus over how, when and where to make best use of ICT in science education. Murphy (2003) 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), simulations offer opportunities for children to interact with complex systems that would be impossible without technology. Such simulations, of course, must be built of accurate models of reality rather than oversimplifying or misrepresenting the situation. However, interactive computer models such as simulations 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 (Osborne and Hennessy 2003).

According to McFarlane and Sakellariou (2002), the necessary skills for young people to learn in science are reasoning skills. Scientifically literate people should be able to ask, "How do they know that?", even if they have limited knowledge in the domain. 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.

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" (26-27). 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's (1995) CoVis (Collaborative Visualisation) project integrated desktop video-conferencing with a suite of other collaborative tools to allow 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. A number of more recent initiatives, however, are in progress at a range of UK schools and museums, linking students with experts and peers (Monahan 2005). In 2004, Becta published a report on the use of video-conferencing in the classroom (Becta 2004).

Implications for development

The following implications for development of Space Mission: Ice Moon were drawn from the context of relevant projects and research and theoretical literature, and used to inform decisions throughout the project. As decisions were made, not all of these implications could be followed through, for various practical reasons. However, they stand as a useful guide for developers and educators seeking to create similar learning resources.

- 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 and 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 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.

Learning intentions and research questions

From the background and context of this project, the following key learning intentions and related research questions were developed:

Learning intentions	**Research questions**
1. To engage in scientific problem-solving, understanding science as a process of inquiry	To what extent do students display understanding of the problem-solving aspects of the mission through their dialogue and actions during the mission and during reflection after the mission?
2. To evaluate, interpret and analyse evidence and understand its limitations	To what extent are students able to create coherent explanations of events from available evidence, modify these explanations in the light of new evidence, and show awareness of what the evidence does not tell them?
3. To work collaboratively both within small groups and between different groups to achieve larger aims, developing an understanding of science as a collaborative activity	During the mission, are all children observed completing tasks or are some children uninvolved in the activities? Does the mission promote team working, and what sort of group dynamics (or individual behaviours) can be observed during it? Who is doing each part of the task? Do students report an understanding of the overall mission, or only their individual role within it?
4. To develop skills of scientific literacy, negotiating multiple modes to read and communicate scientific concepts and explanations	To what extent are students able to combine raw data, graphs, and other modes of scientific communication to make meaning?

Additional supplementary learning intentions and research questions were also identified:

5. To develop positive attitudes towards science as an area of work, life and study	Are students' attitudes towards science altered after completion of the mission in comparison to reports prior to the mission? Are students engaged in and motivated by participation in the mission?
6. To demonstrate the potential of a broadband-enabled	What are teachers' and pupils' perceptions of the role of video-conferencing and broadband technology in the

classroom	simulations?

Additional research questions evaluating the mission	Is the mission at an appropriate level of educational challenge and stimulation? Do students require significant support to complete tasks, or complete tasks very quickly?
	How does the teacher's personal attitude towards science impact on the students' experience of the mission? How does the teacher's role before, during and after the mission, and the usual science schooling context impact on the students' experience of the mission?
	How do the actions of the Mission Commander, such as his adjustments to the mission and responses to the students, impact on the students' experience of the mission?

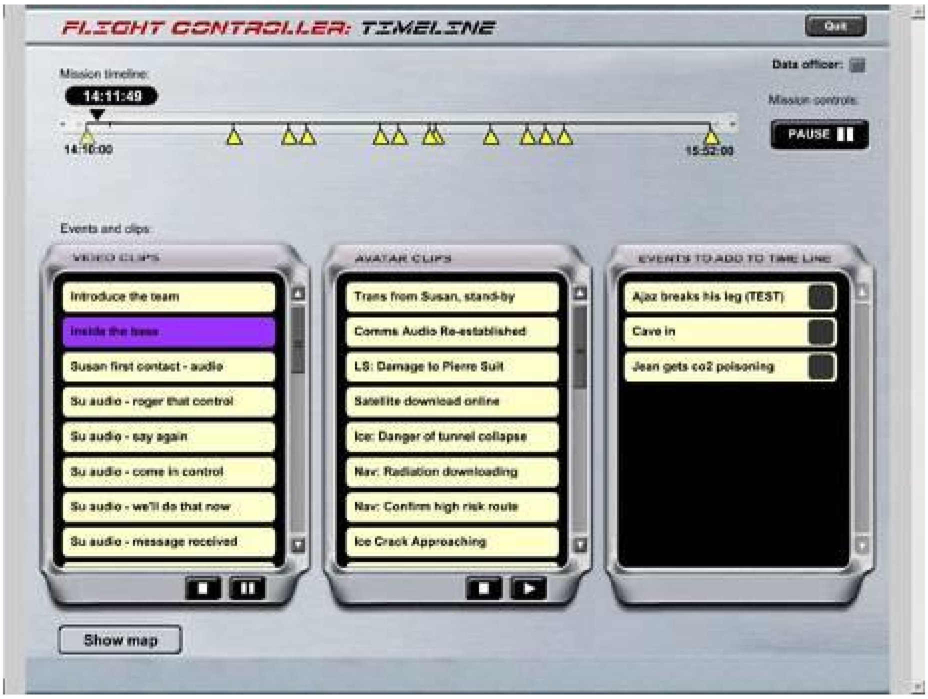
THE LEARNING ENVIRONMENT CREATED

Software prototype for the mission

The software prototype developed for the trials of Space Mission: Ice Moon included most of the functionality necessary for a final product. In the simulation a group of students take on the roles of an Emergency Response Team on Earth, connected to a space station on Jupiter's ice moon Europa by video-conference. At the start of the mission they discover that all the astronauts living on the space station, except the Mission Commander, have been lost on a routine exploration of the ice tunnels beneath the surface of the planet.

The simulation is remotely controlled by a facilitator from a video-conferencing booth at the National Space Centre in Leicester, who plays the role of the Mission Commander, the only astronaut remaining on Europa's space station. Students are divided into six teams, with an option for a seventh: Medical, Life Support Suit, Ice, Navigation, Satellite, Communication and optional Data Officer. Each team has a specific responsibility and requires a different number of students to complete the task.

Each team has a PC, and as the mission progresses, students must process, analyse and interpret data received through their unique interface via broadband internet connection. The Mission Commander can see each team's inputs and so monitor how quickly and accurately they are completing their tasks. The data streams constantly and dynamically adapts to reflect the astronauts' changing situation and location, for example as they get injured, run low on oxygen and move through the ice tunnels. The Mission Commander can also dynamically move events on the timeline or introduce further events, for example an astronaut may have a problem with his oxygen valve or break her leg, which would then be reflected in the data received by the students. The Mission Commander also has at his disposal a video library of clips of the astronauts in a range of different possible scenarios that he can show at any time. There is also a set of statements and responses from an 'avatar', a computer-generated character who takes the role of the space station's computer and occasionally answers students' questions or provides information from the space station's computer.



Mission Commander’s control panel showing dynamic timeline

Teams do not receive their data feeds automatically; they must request them from the satellite team. In the scenario, data is transmitted from Europa to Earth via a satellite that orbits Europa every three minutes. Teams can thus receive a new set of data with each orbit of the satellite. In order to make students think about the value of different data, it was decided that they would not be allowed to download all available data every orbit. It is explained to the students that the satellite only has a limited bandwidth of 20 KB, and every piece of available data takes up some of that bandwidth. Therefore students must negotiate within and between their teams to prioritise the most important data at that moment. The Satellite team are responsible for taking each team’s request for data and downloading it every three minutes.

The Medical team and Life Support Suit team monitor each astronaut, keeping track of several variables. Each variable is plotted on a graph to show change over time, and is divided into white, yellow and red zones, indicating level of danger. To calculate the overall Medical or Life Support Suit status of each astronaut across all variables, students complete a table. Starting with 100%, they subtract 10% for every variable in the yellow zone and 20% for every variable in the red.

The Ice team receive data about tremors in the surface ice, which could indicate a likelihood of cave-ins in the tunnels in which the astronauts are travelling. Sensors placed on the ice give the time and direction in which a tremor was sensed. From this information they plot bearings on a paper map and triangulate the position of the tremors. They then input the coordinates of identified tremors to their computer, which then appear on a digital map of the area.

The Navigation team are responsible for planning the astronauts' route back to base and calculating how long it will take. They are told the coordinates of the astronauts' current position by the Mission Commander, and given a set of coordinates to which they must plan a route. They have an interactive map in which they can see the main tunnels that the astronauts can travel through, and click to select sections of tunnels to indicate their chosen route. When a route is selected, the map shows the duration of each straight section of tunnel, based on the input walking speed of the astronauts. To calculate the duration of the total route, they must add up each individual section. The Navigation team also download data to show radiation levels across their map. The radiation data is given a very high data size, which is designed to force discussions about prioritisation of data downloads with other teams.

The Communications team are responsible for ensuring communication between the Mission Commander and each individual team, and between teams. The Data Officer is responsible for ensuring each team submits their processed data when requested.

Training

Prior to the mission commencing, the students need to undergo a period of training to introduce them to the scenario, to their roles, and to give them some practice in the tasks they will be required to complete. The training takes around two to three hours. For the purposes of these trials, a lesson plan was created by a curriculum coordinator at Frankley CLC, which comprised the following main elements:

1. Research on Europa: students were given worksheets with a number of questions about Europa, which they were asked to research using the internet. Students produced presentations in Publisher or PowerPoint.

2. Context of scenario: teacher-led session explaining the overall role of the Emergency Response Team, the role of each team, and further information about life in space.

3. Practice: students were divided into their teams and given a more detailed explanation of their role and a chance to practice analysing the kind of data their team will receive. The Life Support Suit and Medical teams worked together for this part of the training as they deal with similar types of data. They were given copies of the graphs and summary tables that they would use in the real mission, and, via a timed PowerPoint presentation, data for two astronauts was steadily streamed to them. The Ice team also received data by a timed PowerPoint presentation, plotting and triangulating bearings. The Navigation team were given a paper map, and asked to measure the distance and calculate the time taken on two alternative routes and recommend the best route. The Communications and Satellite teams did not have specific task training, but visited each group to understand their roles. Each group also discussed their role with an adult facilitator, making this session quite intensive in terms of staff resources, with a minimum of three staff required.

The training session took place in the mornings before the mission, making the whole trial a full day. The full training session lesson plan and examples of graphs and status tables can be found in the appendices.

Role of researcher and teacher in trials

Present at the trials were: a City Learning Centre (CLC) curriculum coordinator, an advanced skills science teacher, three researchers, and in three out of four trials, the participants' teachers remained in the classroom during the training and mission.

The lead researcher took an active role in supporting aspects of the delivery of the mission, including liaising with schools, coordinating and planning resources, and supporting students in the training session. The additional two researchers remained as observers and were largely disregarded by the students.

The CLC curriculum coordinator delivered the training session in the morning, worked with students during their team-specific training and introduced the mission.

Once the mission had started, the management of the mission was left entirely to the Mission Commander. While students occasionally asked for assistance with some more technical aspects of completing their tasks, most of their actions were autonomous or directed by the Mission Commander during the mission.

RESEARCH PROCESS AND METHOD

Sample

The sample of four schools was drawn from those who had worked previously with either the National Space Centre or Frankley CLC and who responded to an invitation to take part in these trials. Schools were asked to select a minimum of 24 Year 8 or 9 students to participate in the trials, and used their own methods for selecting students.

- School 1 was a mixed secondary community school (ages 11-16) in Birmingham, recently awarded specialist science status, and described by a science teacher as "in challenging circumstances". Students were drawn from the Year 8 high ability science sets.
- School 2 was a mixed secondary community school (ages 11-16) in Birmingham with specialist sports and technology status. Students were drawn from Year 8 high ability science sets.

- School 3 was a mixed secondary foundation school (ages 11-16) in Birmingham with specialist sports and technology status. Students were drawn from across Year 8 as rewards for effort or achievement.
- School 4 was a mixed secondary and sixth form community school (ages 11-18) in Leicester with specialist technology status. Students were drawn from one Year 9 science class.

Four trials allowed comparison across different contexts with different participants and also allowed each of the main teams to be observed in detail (see appendices for observation schedule).

The first and fourth trials were carried out in the participants' schools with their own hardware. The second and third trials took place at Frankley City Learning Centre in Birmingham.

Data collection, analysis, and purposes of final trials

The purposes of the final trial were to investigate the research questions and overall learning intentions (see above) in a similar situation to the prototype's intended use in schools and science learning centres.

Observational data

The core data collected was observational. Three researcher-observers in each trial session each completed observation schedules (an example of this is shown in the appendix). The researchers were asked to look particularly for evidence of the four key learning intentions, but were also asked to record notes on any other behaviour or dialogue of significance. One researcher focused on the navigation team in every trial, while a second focused on a different team each trial, in order to establish both continuity and comparison across trials. The third researcher-observer moved around the room, paying particular attention to the Mission Commander's role, the role of any staff in the room, and responding to any critical incidents outside the remit of the other two researchers. A case study student was chosen from each group and observers were asked to focus their attention on this one student to provide some continuity of notes, and to follow this student if the group dispersed about the room. They were asked to also include all the activity going on around the case study student. This approach was taken in order to build up a rich picture of the whole mission, including the insular detail within teams, but also the larger patterns of interactions between teams and between students and the Mission Commander.

The two teams that were being observed were also videoed, to pick up behaviour and language that may have been missed or unclear during the note-taking, and to provide a point of triangulation with the notes taken from the observers' point of view.

The observation notes were analysed using an emergent themes analysis (Sapsford and Jupp 1996). The notes from all sessions were read together in detail, looking for common themes, with particular reference to the research questions. Many themes emerged in the initial analysis. The video tapes were analysed (see table in appendix) in relation to this initially identified set of themes, while also allowing for new themes to emerge. When a large list of themes had been identified, these were collated into a set of broader categories, which were described and analysed in relation to the overall learning intentions and research questions (see findings below).

Interview and questionnaire data

To supplement the core observational data, interview and questionnaire data were also collected.

Immediately following the mission, a focus group interview of students was conducted. One student from each team was selected to ensure that there was a representative from each type of task. The focus group was designed to discover what students thought they had learned, what challenges they had faced, what their general impression of the experience had been and how the media and technology aspects had affected their experience. The focus group interviews were videoed and summarised and selectively transcribed according to the research questions and categories identified through observational evidence.

Teachers were interviewed using a semi-structured approach prior to the mission to gain a picture of science education in that school, the students' previous experience of media and technology in science education, and teachers' perceptions about the value of media and technology in science education. Teachers were also interviewed following the mission to gather opinions on the strengths and weaknesses of the mission, what they felt the students gained from it (if anything) and what they felt were the critical factors in the achievement or otherwise of the mission's aims. In two out of four trials, post-trial teacher interviews were not captured, in one trial because teachers did not attend the mission and so could not comment on it, and in a second because the teacher interviewed prior to the mission was not available afterwards. Interviews were recorded and summarised in relation to the research questions and themes emerging from the analysis of observational data.

Teachers also administered a questionnaire to participating students prior to the mission, which was designed to elicit attitudes towards science in school and society. This questionnaire was also administered following the mission to gather whether attitudes had changed. Additional questions relating to experience of the mission were also asked. Questionnaires were summarised (see appendix).

Summary of final trial procedure

Pre-mission student questionnaire 20 mins	Administered by teachers before mission, as a class exercise. Completed and handed in before mission begins.
Teacher interview 15 mins	Conducted by researcher over phone or face-to-face before mission. Audio recorded.
Pre-mission preparation activities 3 hours	Researcher or CLC teacher introduced session and led pre-mission training session. See lesson plan in Appendix. Two researchers took observation notes.
Space Mission: Ice Moon 90 minutes	Space Mission: Ice Moon ran under direction of Mission Commander from National Space Centre. Teachers and CLC staff present minimally participated. Three researchers took observation notes, one always focused on Navigation team, one focused on a different team each trial, one looking at overall and between-team interaction.
Post mission student small focus group interview 30 mins	One student from each team, immediately following mission, interviewed by researcher and recorded on video.

Review 30 mins	Three researchers compared observations immediately after trial as a check on validity, preliminary analysis, comparison across cases and identification of emerging themes to focus on in subsequent cases.
Post-mission student questionnaire 20 mins	Administered by teacher in the weeks following the mission, as a class exercise.
Post-mission teacher interview 20 mins	Conducted by researcher over phone and audio recorded.

FINDINGS

Findings are discussed in relation to the learning goals and research questions detailed above.

To work collaboratively both within small groups and between different groups to achieve larger aims, developing an understanding of science as a collaborative activity

- ***During the mission, are all children observed completing tasks or are some children uninvolved in the activities?***
- ***Does the mission promote team working, and what sort of group dynamics (or individual behaviours) can be observed during it? Who is doing each part of the task?***
- ***Do students report an understanding of the overall mission, or only their individual role within it?***

In order to complete the data handling and interpretation tasks, fully understand the changing situation and make appropriate decisions in order to rescue the astronauts, students must cooperate with one another within their teams and as a whole class. In the training sessions, students chose leaders for each team, and to varying extents discussed the role and responsibility of each member of the team. As the mission began, leaders were often seen reminding team members of their roles:

> *[Ice team leader]: You work out the time on Europa, the first sensor… the second sensor.*

Leaders delegated roles and responsibility to other team members as the mission progressed. In many groups, roles had been clearly defined prior to the start of the mission, and students quickly settled into a routine, working on information then passing it on to the next team member. In most cases, students fulfilled their roles conscientiously, perhaps aware that their team were relying on them. However, in the few cases where members of a team did not pull their weight, other members found it difficult to compensate. In groups where roles were less clearly defined, cooperation and completion of tasks occasionally broke down and information was lost when students did not know who to pass it on to.

However, sometimes clearly defined responsibilities made cooperation and understanding the wider picture more difficult, when students were inflexible about their roles, or focused very narrowly on their individual role. In one case, roles were assigned to the ice team by a teacher in the training session, with one student tasked with spotting patterns in the ice tremors and calculating speed of approaching ice cracks. As this only forms a very small part of the overall task she was unengaged and appeared bored for much of the task. Why she did not change role to share out the tasks more evenly is unclear, but perhaps they were inflexible because these roles had been determined by a teacher, rather than by themselves. While students need support in defining roles prior to the mission, the roles need to remain flexible so that they can adapt to suit changing circumstances during the mission. In another case, a student complained that he didn't feel "part of it" because he was focusing on his immediate task, filling in graphs, and didn't really understand how what he was doing related to the bigger picture. This could indicate that defining roles too narrowly and breaking the task down into too small constituent parts can lead to a feeling of disengagement with the overall purpose of the mission.

To communicate effectively with other teams and build up a bigger picture of the astronauts' situation, it was important that teams understood each others' roles and how they related to each other. In one trial the Ice Team were very aware of how their work directly related to the Navigation Team. As a result, these two teams worked very closely together, with relevant information continuously moving back and forth to plot a safe route for the astronauts' escape.

Layout of the mission room also affected the flow of communication within and between teams. This is discussed in more detail in the Space and Layout section below.

The way that the work in Space Mission was divided amongst small teams with specific areas of responsibility, and within those teams into individual roles, meant that to succeed in the mission, students had to cooperate and communicate within and between teams to complete tasks and to understand the overall situation. As the situation was constantly changing, this understanding had to be continually negotiated between students and teams as information changed. In order to work in this structure, students had to organise and define roles carefully, understanding their own contribution to the wider shared aim, but not becoming too narrowly focused or inflexible.

Students understood that they were relying on each other and had to work together to complete their tasks and rescue the astronauts:

> *I think we all had to rely on each other because without one bit of information we couldn't get another. So I think we all rely on each other to get them [the astronauts] back.*

Role play and authenticity

While not a stated research question, the themes of role play and authenticity emerged as important during the mission. An authentic scenario provides a relevant context for the tasks in which the students are engaged. The perceived authenticity of the mission allowed the students to suspend their disbelief in order to engage with the story and their own roles in acting and thinking as scientists.

In interviews following the mission, students were keen to discuss how Space Mission had seemed like an authentic simulation, eg:

> *It did feel real while we were doing it.*

> *What it's like in real life.*

The use of video-conferencing and broadband technology appears to have been a significant factor in allowing the students to engage in the role play as scientists and feel part of an authentic experience.

> *You know when we first walked in the room and there was that big screen and you could see the men on the screen [image of a real mission control] I felt like we were scientists looking at that big screen.*

> *Researcher: Would it have been different if Tim [the Mission Commander] was sitting here in the room?*
> *Student: Yeah, because you wouldn't have thought like this was actually being beamed from a satellite from space.*

Some students very explicitly took on the role of scientists during the mission. In one trial, a boy used a scientific calculator as a 'prop' to support his role as a scientist, carrying it around through most of the mission, even though he did not need to use it very often. He explained to a team-mate: "It's a scientific one".

Their knowledge of what a real-life Mission Control or space rescue might be like was partly derived from films and NASA was mentioned by more than one group.

> *You see people working for NASA in films and it was just like that.*

Many statements showed how students imagined that they were indeed responsible for saving the lives of four astronauts:

> *Researcher: How do you feel?*
> *Student: We didn't kill anyone, so not guilty.*

> *Student 1: I don't think we're going to make it.*
> *Student 2: We're cutting it so fine it's unbelievable!*

Some students felt pressured during the mission and 81% of post-mission questionnaire respondents ticked either 'strongly agree' or 'agree a little' to the statement 'Getting the work done in Space Mission was stressful'. In some cases this was related to students' emotional involvement in the scenario and perhaps feelings of responsibility towards the astronauts. This student is commenting on the fact that although she knows the astronauts are not actually on Europa at this moment, she is so involved in the simulation that she is behaving as if it were real:

> *It's not even real and I'm getting stressed out.*

However, some students also recognised that a certain amount of pressure was necessary for the overall experience:

> *It's a lot of pressure, but you know if you succeed at the end then it's quite rewarding.*

Girls tended to make more comments about stress and pressure experienced during the missions, perhaps indicating that they coped less well with these aspects, although it is also possible that the boys expressed their ability to cope more than their feelings of being unable to cope with the stress and the pressure. Further work may be needed on adjusting the pace and demands of the mission so that all students feel engaged with the urgency of the narrative but not overly pressurised.

In some cases, students seemed to become very personally engaged with the characters of the astronauts. In one case, the Communications Officer referred as if with personal familiarity to the astronaut Ajaz as "AJ", and another student commented:

But we were worried about Jean because she had a very big heart rate, and we were all worried about her but we found out that when she got back to base, well we were all relieved.

In the third trial this identification with astronauts may have been heightened by a change in procedure. Instead of plotting graphs for one variable across all four astronauts, Life Support Suit and Medical team members worked in pairs to plot all variables for one astronaut, as it was felt that students may be more engaged focusing on a character rather than a variable. Some students did seem to identify with 'their' astronaut (eg "I was Susan"). However, in this instance, the student also felt he had a 'boring' astronaut because not much happened to any of Susan's variables and so he did not have much to do. Personal involvement and identification with the characters in the scenario was a factor in fostering students' engagement, but close identification with a character perceived to be unsatisfactory had a negative impact on engagement with the work of the mission.

In one trial, a member of the Ice team referred to the Navigation team as "Navvies". This informal naming suggests an easy familiarity with his own and others' roles. The reference to another team by function suggests responding to others first and foremost by role rather than as individuals. The elements of imaginative role play in this way appear to be closely related to students' ability to work in task-defined roles, as discussed above in the section on working collaboratively.

In all trials we observed excited discussion about whether the scenario was really happening. While students eventually concluded that it was unlikely they would be left in charge of rescuing astronauts and that therefore it was probably only a simulation, there were moments where at least some were genuinely unsure. A gasp of "It's real" was heard in one trial when the first video of the astronauts was shown. In another trial, after surprise at the fact that the Mission Commander was responding to them 'live', a student tried waving and speaking at a pre-recorded video clip of the astronauts. The immediate and dynamic two-way communication that the students were able to have with the Mission Commander, and the dynamic use of media clips added to the sense of an authentic, real-time experience.

Discussions about the reality of the scenario often led on to discussions about the extent to which students were able to influence the development and outcome of the scenario. In all trials there was discussion about whether it would be possible to kill the astronauts or whether the outcome was "fixed". In one trial, a small group of students were not imaginatively involved in the scenario, but instead were more interested in trying to work out whether they could kill the astronauts. Their focus was on the structure of the simulation, which they found wanting when they realised they could not affect the outcome, and, unengaged with the narrative, they stopped contributing to their team's work. This was only seen with a minority of students in one trial, but the question of how far the students should be able to affect the outcome was also raised by several teachers. One teacher suggested that varying the outcome depending on the students' actions would provide an opportunity for discussing what could have been done differently, allowing students to reflect on their learning by considering the consequences of their actions. However, there is a possibility that this might undermine the students' imaginative involvement in the narrative. Breaking up friendship groups, and situating the team with most work to do furthest from the screen so they are drawn in from the back of the room, and teams with less to do are under the eye of the Mission Commander, has been seen in other e-missions to help keep a majority of students engaged.

These unengaged students laughed at the video of a cave-in in the ice tunnels, whereas in other trials students responded with shock. They did not fulfil their roles in completing team tasks and when challenged by a team-mate one student responded:

It doesn't matter, it's not real.

This lower imaginative engagement was associated with lower commitment to completing tasks and cooperating with other students. Some of the factors that may have contributed to this lower engagement include the layout of the room, which made it difficult for groups to communicate effectively; the distance and small size of the video screen which may have restricted access to the video-conferencing aspects of the mission; and limited individual team training due to under-staffing in this mission. Further discussion of the importance of space and layout of the mission room can be found in a separate section below.

For the majority of students, taking part in Space Mission was an authentic experience. This authentic nature allowed students to become imaginatively and emotionally involved in the story, providing them with the motivation to care about the astronauts and to commit to the demands of their tasks in order to save them. Imaginatively engaging with this scenario provided a context in which students could take on the mantle of experts, acting and thinking as scientists.

To develop skills of scientific literacy, negotiating multiple modes to read and communicate scientific concepts and explanations.

To what extent are students able to combine raw data, graphs, and other modes of scientific communication to make meaning?

Science uses a range of modes to communicate its processes and explanations. Data, tables, photographs and graphs combine with text and verbal communications to build up the complete picture. As such, to be scientifically literate, students need to be able to work within and between a range of modes, translating from one mode to another, choosing the most appropriate for their purposes.

Students in the Life Support and Medical teams plotted raw numerical data onto a graph for each variable (heart rate, battery power, etc), and then used the graphs to complete a table giving the overall health status of each astronaut. Students had some difficulties with the status tables (discussed in more detail in the following section) and focused instead on the graphs of individual variables. The graphs were printed with white, yellow and red zones, indicating the danger level of the variable. In this way, they supported a visual analysis of the data, with students able to quickly 'read' the colours to tell the status of variables.

> *Student 1: Pierre's in the red. Jean's in the red.*
> *[…]*
> *Student 2: Is anyone else in the red apart from [unrecorded]*
> *Student 3: Jean's battery!*

Rather than referring to raw data or extrapolating to describe what was happening to the astronaut, students' analysis focused on colour. Colour was easily understood as a shorthand for danger, and was used as a shared common reference point, supporting communication and interpretation.

The Ice and Navigation teams also communicated using a shorthand developed from visual representations of the surface of Europa provided on their screen and paper maps. When the two teams realised they shared these reference points, much of their communication was through reference to the lettered grid square of the map, or by physically pointing to the grid square on each others' maps.

> *[Member of Ice team, speaking to Navigation team]: It's confirmed – must avoid that square.*

In communicating findings between teams, students chose the modes in which to best convey their information. This was often verbal, but students also made great use of writing short notes on post-its, often referring to the commonly understood shorthands discussed above. In situations that were particularly urgent or that students found difficult to communicate verbally or through short notes, they would physically take their maps or graphs to show to other teams, or bring others over to look at their screen. These artefacts seemed to have both greater authority and were better at conveying complicated information than notes or verbal messages.

Occasionally students were observed using what could be described as 'scientific' language. For example:

> *It's so erratic.*
>
> *That could be anomalous.*

The words 'erratic' and 'anomalous' are particularly scientific-sounding language used to describe patterns in scientific data. It seems that students chose to use language such as this in a similar way to the student who used a scientific calculator as a 'science prop' (discussed above in 'Role play and authenticity' section), to reinforce their role as scientists. Using such vocabulary is dependent on having this language at their disposal prior to the mission, and so on the few occasions when it was used may have been among those students already particularly interested in science. Despite these few examples, students more frequently used more 'natural' descriptive language for communicating findings and observations.

To evaluate, analyse and interpret evidence and understand its limitations

> ***To what extent are students able to create coherent explanations of events from available evidence, modify these explanations in the light of new evidence, and show awareness of what the evidence does not tell them?***

In Space Mission: Ice Moon students must work with a constant feed of changing data and other sources of evidence including information from the Mission Commander and video clips of the astronauts. In this way, they build up explanations of what is happening to the astronauts from the evidence available. They must engage with competing explanations and understand how a valid explanation is based on a solid interpretation of evidence. Discussion of the findings for this question is split into three sections. *Science and maths data handling skills* looks at the skills students were able to use to work with the raw numerical data. *Processing and analysing data* looks at how students organised themselves to complete their data analysis tasks. *Interpreting data* looks at how students built explanations from the data and evidence available.

Science and maths data handling skills

The Life Support Suit and Medical teams received data for a range of variables (heart rate, battery power remaining, etc) for each astronaut. Each graph is printed with red, yellow and white zones that show whether that variable is at a dangerous level. The graphs are also intended to allow students to see patterns and trends forming in the progress of a variable over time. Most students were familiar with plotting graphs and plotted data at the correct value point on the y axis. The x axis showed time points for every three minutes to show every possible new data download (see example graph in appendices). However, because data is not necessarily downloaded every cycle for every astronaut, students often moved onto the next point on the graph rather than locating the correct time point, which would have meant missing points out when no data had been downloaded for that cycle. This may have hindered attempts to spot and interpret patterns and trends; there was little discussion of this kind observed and focus was generally on the latest information rather than taking an overview.

To gain an overview of each astronaut's Life Support Suit or Medical status, teams were required to record the effect of each variable in a summary table (see example in appendix). Every three minutes, each astronaut starts with an overall status of 100%. If any of their measured variables are in the yellow or red zones of the graph, 10% or 20% is deducted respectively for each variable. The resulting percentage is the astronaut's overall status and is input into the computer. For example, an astronaut with oxygen levels in the yellow zone and battery levels in the red zone would have 30% deducted and an overall status of 70%.

Students were invariably confused by this activity and entered the value of each variable (eg recording heart rate beats per minute) rather than subtracting 10% or 20% as appropriate. Recording numerical values seemed to the students a more intuitive use of this table, and despite training, in all trials they had to be corrected during the mission and computer records show that overall status was often not input at all, or input incorrectly, particularly near the beginning of the mission. Most instances of discussing overall status were prompted by the Mission Commander, in contrast to a high volume of discussion about individual variables between students. For the students it is clear that the individual variable measurement was far more meaningful than the overall status, which was a later add-on that was frequently ignored:

> *Student 1: We need to top [tot?] up those green sheets, they still think Ajaz is 100%.*
> *Student 2: It's too stressful man!*

It may be that students did not find the overall status meaningful because there was no obvious effect when they input this into their computers and because it did not match their understandings of the risks to an astronaut's health. When students input the astronaut's status into their computers there was no immediate feedback from the computer or Mission Commander and it did not affect the astronauts' behaviour, and so the purpose of this calculation may have been unclear to the students. It may also be that focusing on overall status overlooks high risks in an astronaut's variables from the students' perspective. For example, if an astronaut's oxygen was about to run out but all their other variables were OK, this would result in an overall status of 80%; however, students would be very worried that this astronaut was about to die despite their apparently high overall status. However, the data in the system was designed to avoid such situations; if an important variable such as oxygen was in the red, then many other variables would also be in the danger zones.

The Ice team's main task was to locate ice tremors by triangulating the distance and direction of movements in the ice from different ice sensors. Most students were unfamiliar with the mathematical skills involved in triangulating bearings in this way. Teachers were asked to choose students with good maths skills for this group, and, given training, were generally able to handle this data well as the mission got under way. More challenging for these teams was calculating the speed of approach and time of impact of a moving ice crack. While most groups had encountered the 'time = distance/speed' equation needed to complete this task before, they needed prompting to apply it in this context. In all cases, students asked for additional adult support, and in some cases relied more on guesswork than calculations to calculate time of impact. This process also had not been covered in the training session. Further, students did not know how to measure the distance between tremors, since the tremors were shown on their computer screen which is difficult to measure with a ruler and uses a different scale, so instead they had to estimate the distance between tremors using their coordinates. This challenging task would benefit from some further training and tools, and possibly should be reserved for groups who require a further challenge during the mission.

Processing data

Students placed a high value on new data arriving, and developed strategies for processing it quickly. This may indicate that the new data was highly valued and that students saw the speed of processing data as particularly important.

> *Student 1: Only 18 seconds until new update, hurry up! 'Ere we go!*
> *Student 2: 'Ere we go!*
> *Student 3: Coming in a minute – when it gets to – watch – here.*

It is possible that the emphasis on speed indicated that students were aware of the need to work with current data to keep abreast of the rapidly changing situation:

> *[…] The medical team took a bit longer to log on because when I got reports of like, somebody's heart rate I got like at 3 o'clock time and it's like 2:49 when they got the information. It's 11 minutes ago.*

However, students were often reluctant to download further data if they had not completed processing data from the previous download. This was a frequent observation, particularly in the Ice team, perhaps indicating that their task was more time-consuming. In the third trial one student was responsible for plotting bearings and triangulation. She made several requests that no new data was sent through until she'd dealt with the current set:

> *Student 1: 15 seconds 'til next data upload.*
> *Student 2: I can't do it I'm still doing this one. It's going too quick I haven't done that one or that one.*
> *[…]*
> *Student 3: Don't send for any data until we've got this all plotted.*

This suggests that students emphasised speed because of their perceived need to complete the task in the three-minute cycle rather than because the data they are working with is out of date and therefore not valid evidence of the current situation. Usual school practice emphasises the importance of completing work on time and students are usually required to finish one task before moving on to the next; so in this simulation students may have perceived moving on to new data before finishing the previous set as a sign of failure. It may be possible to partially address this by reducing the volume of data delivered to each team or allowing more time for data processing. However, this would not address the issue of supporting students to make decisions based on relative validity of more current data rather than whether processing tasks have been completed. The computer interface does display a 'data obsolete' warning after three minutes; this perhaps needs to be more prominent and its importance emphasised in training. The optional 'data officer' role, which was not employed in these trials, may also provide further encouragement for teams to discard older data in favour of more valid, current data.

Interpreting data

There were many instances where students' explanations of what was happening to the astronauts and their recommendations for action were clearly based on interpretations of the data and other evidence they were receiving. They were also seen questioning interpretations and explanations, showing they understood that explanations must be based on valid interpretations of the evidence, and that the data was reflecting what was happening to the astronauts.

> *Student 1: Ajaz is slowing down, there's something wrong with Ajaz*
> *[…]*
> *Student 2: It's Ajaz for O2. 43 minutes left.*
> *Student 3: How do you know?*
> *Student 1: Ajaz has got a broken leg and is now in the red.*
> *Student 2: Why is Jean in the red?*

In the following example, the team leader questions her team mate about the sudden change in the estimated time the astronauts have left, in effect questioning the validity of her team mate's interpretation:

> *38 minutes? A minute ago it was 1 minute!*

Students were also occasionally able to interpret data to predict future behaviour, using information from the graphs to help. (See above for discussion of why the graphs were perhaps not as useful as they could have been.)

> *Student 1: Pierre's radiation is rising.*
> *Student 2: Ajaz is going to go into yellow*
>
> *There's no way they can get back to base now.*

Students were also observed to change their explanations and their course of action as the evidence changed:

> *So now we need to go this way.*

Evidence was also interpreted to assess the risk of various courses of action:

> *Navvies, I've told you about these tremors but they're only moving at [inaudible] so they might be able to make it.*
>
> *Student 1: We can't go a quicker way unless we send them through a tremor.*
> *Student 2: But we need the minutes.*

Students built explanations by interpreting the data at their disposal. Occasionally students went beyond simple interpretation to speculations that were not based firmly on evidence, for instance one student speculating that rising temperatures may be caused by radiation coming through the ice or that the astronauts will make it safely back to base, despite having no evidence to suggest this. These speculative interpretations were perhaps an indication of students beginning to work towards dealing with alternative interpretations, and trying to draw on limited knowledge. Speculating about possible interpretations can be the first stage in making decisions about the most valid interpretation. On both these occasions, with some prompting from the Mission Commander, more evidence was brought to the speculation and a more solid interpretation proposed. Reminded of information discussed in the training session, the students interpreted rising temperatures as possible evidence of an ice volcano rather than of radiation, which does not raise temperature. In the completed version of the software, a research database will be included that will allow students to explore their speculations, bringing further evidence to bear on their interpretation of the available data.

Students were also aware that their interpretations of data in their teams were only a limited part of the bigger picture, and that they had to rely on information from other teams and from the Mission Commander to fully understand what was happening. In focus group discussions, students were aware that the data they were interpreting had helped them work out what was happening and what they should do next:

> *Researcher: How did the data you were receiving help you?*
> *Student 1: It helped us to see how long they had left and how much oxygen they had. […]*
> *Student 2: I could see where the tremors were so I could help navigation plot a route.*

When students realised they had discovered something through their interpretation of data, they were very keen to communicate this quickly, and a pattern of interpretation followed by dissemination was often observed. They often told the Mission Commander of their findings, and quickly learnt to tell other teams too. They realised they were part of a larger enterprise and that other teams needed to know what they had discovered and vice versa.

However, students felt that their most trusted and authoritative source of information about the astronauts was information received from the Mission Commander and the video clips of the astronauts. In one discussion there was an indication that students felt they should be equipped with all relevant information prior to the mission. A member of the Life Support Suit team had complained that she had not been told prior to the mission about the equipment in an astronaut's pack and what it was for. However, she had been given a diagram of this and successfully used it to solve a problem. She did not value her own initiative in this instance, saying that she had "guessed" the answer and that she should have been given the information, when she had actually shown that she was very competent at working out the answer for herself using the materials at her disposal.

Where students had difficulties interpreting the data, for instance arriving at unfeasible results for the time the astronauts have left to get back to base at the end of the mission, this may have been partly due to inadequate training as these difficulties were mostly observed in the first session where there were fewer adults giving the training. In these situations the Mission Commander's role was very important in prompting the students to analyse their data. He was also able to manage the role play aspects of the mission, so that students were gaining some experience of the imaginative aspects of working as scientists, even when they had missed some of the skills that would have enabled them to interpret and analyse the data to form their own interpretations, explanations and recommendations.

To engage in scientific problem-solving, understanding science as a process of inquiry

> ***To what extent do students display understanding of the problem-solving aspects of the mission through their dialogue and actions during the mission and during reflection after the mission?***

Problem-solving skills are essential to engaging with the processes of science. Creating new scientific knowledge begins with identifying problems and questions, or a gap in knowledge, and setting out to find the solutions or answers. Space Mission is focused around the problem of a group of astronauts stranded on Europa. In order to address this problem, the mission is broken down into separate problems and questions specific to each team. The Mission Commander can also pose further additional problems and questions during the course of the mission, such as an astronaut breaking a leg or a failure in the oxygen supply.

Students engaged in problem-solving should be seen identifying problems and questions, planning strategies to address the problem, hypothesising and reasoning about potential outcomes and solutions to the problem, evaluating proposed solutions and identifying further questions. Beginning with a problem to be solved is intended to allow students to see science as a process of investigating answers to problems rather than simply learning accepted facts and solutions to problems already solved.

Questioning and framing problems can be seen as the beginning of the problem-solving process. There were many instances where students were seen asking questions and stating goals, identifying the task to be solved or gaps in knowledge to be addressed:

> *Student 1: We've gotta go around the edge here.*
> *Student 2: There's a tremor so they're gonna have to go here.*
> *[Student in Ice team]: We need to know where the tremors are.*
> *Student 1: Need very quick route. Need a fast route.*

Solving one problem often leads to the identification of subsequent problems. For example in one case, as the Ice team became competent at identifying the location of tremors, they began to ask questions about patterns in the tremors, and began to analyse patterns by calculating the time difference between tremors. In another case a pattern emerged in the Navigation team where students began by asking a scientific question or posing a scientific statement, followed by a discussion of evidence, and deciding on a solution to the question.

For the most part students did not explicitly plan strategies to address the problems, probably as their team tasks were already structured to enable them to do this. Each team's task contributed to the solution of the overall problem of rescuing the astronauts, so organising the work of the task and the roles of the team was a key strategy in solving this problem.

> *Student 1: Come on, get started, if you don't do that we can't do this [pointing to her Medical Status table], just do what you did last time.*
> *[…]*
> *Student 2: Has everyone done it?*
>
> *Student 1: Walking speed… […] We need to add all this up.*
> *Student 2: 43 + 20 + 41 + 24 + 21 + 8 + 27 + 18 [one student reciting numbers while team mate writes down on paper as preparation for calculating total].*

Teams established strategies for requesting information from the Satellite team, for example choosing information on alternative pairs of astronauts or the astronauts most in danger each round. However, as discussed above, some teams prioritised completing the task over downloading more recent information, suggesting that they more narrowly focused on the task at hand rather than the overall problem to be solved.

Students identified relevant resources to solve problems, drawing on their own interpretations of data, information from other teams and the Mission Commander, information remembered from the training session and from a 'research library'. Students more readily turned to each other and the Mission Commander for information than to the paper resources of the research library, which they only accessed when prompted. Identifying and using relevant resources is part of a strategic approach to problem-solving, and the students' preference for consulting people rather than paper is relevant in this respect. The research library in this prototype is simply a set of paper diagrams and information, but will be developed into a searchable database in the final version. Careful thought will need to be given to make it searchable in such a way to allow students to identify the relevant information to their problem and appreciate its importance.

In the following sequence, students have been asked to suggest solutions to the problem of an astronaut's leaking oxygen tank, using a diagram from the research library. The problem is identified in the first line and they start to make suggestions and identify two potential solutions. This sequence shows how problem-solving was often a collaborative activity, however deciding on one solution to propose was difficult to achieve in a group, and they deferred this responsibility to the Mission Commander.

> *Student 1: [pointing to sheet] That's been malfunctioning.*
> *Student 2: Need to open that*
> *Student 1: [pointing] Open this [point] here and [point] it goes in here.*
> *Student 3: Open here?*
> *Student 1: So the air can't get through?*
> *Student 3: All you need to do is get a spare connection.*
> *Student 1: Who votes right?*
> *Student 2: But if valve 1 is broken…*
> *Student 3: What's the point of…?*
> *Student 4: Oh my god, just choose one.*
> *Student 2: No – tell him [ie Mission Commander] both ideas and he'll tell you which one.*
> *Student 1: That [pointing] needs to be open – 'cos that's already open and malfunctioning.*
> *Student 2: That valve is broken.*

Collaborative problem-solving was also seen with members of different groups bringing their different experience and knowledge to bear on a problem. In this exchange, the

Communications Officer identifies the problem to be solved, and together with the Navigation team begins to make and evaluate suggestions.

> *Communication Officer: We have to find a route. We've got to find a route that's shorter than 41 minutes.*
> *[Communication Officer and Navigation team all pointing to screen, making suggestions]*
> *Navigation team member: The radiation's lower here.*

A similar episode was seen in another case, when a student from the Medical team suggested an alternative, shorter route to a member of the Navigation team, but which involved passing through an area of dangerous high radiation. They then continued to discuss the pros and cons of the alternatives before settling on a solution that involved taking as short a route as possible through the radiation zone.

Hypothesising and predicting are important parts of problem-solving, as students make suggestions and decisions based on how they predict events will unfold and the likely outcome of their decisions. Students did not often make explicit hypotheses but their recommendations for action can reveal the underlying hypotheses and assumptions with which they are working. For example, a student attempting to reduce the time for the astronauts to get to base, made the following suggestion, revealing his understanding that it was the limited oxygen that meant the route needed to be shorter:

> *Tell them to hold their breath as long as they can.*

Students enjoyed successfully solving problems. In discussion following the mission, students from one group related a particular instance with relish, when they had finally found a way for the astronauts to move quickly despite one of the astronauts' broken leg. The positive feedback they had from the Mission Commander, the video clips and the successful end to mission contributed to their enjoyable feeling of success.

Two teachers also specifically commented on the problem-solving and reasoning aspects of the mission. One teacher felt that the main strength of Space Mission was the opportunity for students to perform problem-solving, reasoning and communication skills, and that this would greatly benefit the students when back at school.

Space and layout

The layout of the room in which Space Mission took place appeared to affect the kind of communication that was possible within and between teams, and with the Mission Commander, and therefore the students' ability to effectively work at their tasks and enter into their roles as scientists.

The trials were held in three different locations: a school library, a dedicated video-conferencing suite at a City Learning Centre, and a school IT classroom. The space available for the students and technical equipment influenced how the students were able to work. Unsurprisingly, clear sight of the main video-conferencing screen was important, especially given that interaction with the video-conferencing screen was significant in supporting the role play elements (see above). Where students' team bases and computer screens were not within sight of the video-conferencing screen, they missed video transmissions and communications from the Mission Commander, and were less imaginatively involved with and committed to the scenario.

A shared 'base' for each team helped students work cohesively as a team. One trial, held in the school library, used computers along the side of the room, separate from the teams' bases. There was not enough space for teams to congregate around the computers and many students were seen wandering about the room without a clear purpose. Communication within teams suffered as one member of each team sat at the computer with their back to the room, and the rest were scattered about the room. Communication between teams also suffered as it was difficult to identify members of a specific team when they were not grouped together at a specific place. Within the shared space for each team, proximity to the computer screen influenced how involved students were in their team's activities. In two trials, students in two large teams were spread out along long tables, with the computer at one end. Students furthest from the computer were less active, less involved and asked for help from staff more often than those near or operating the computers.

The teacher in one trial at the City Learning Centre felt that visiting another site was important. He felt that leaving the normal school context helped students imagine they were in a 'Mission Control' situation. In the two cases where trials were held in students' own schools there was less imaginative engagement with the scenario, although this may have been due to a number of other factors, as well as location.

More significantly, the use of video-conferencing to create a simulation such as this can be seen to dramatically change the space of a school classroom. Metaphorically, the classroom became 'Mission Control' for 90 minutes. The video-conference screen acted as a window to the imagined space of a space station on Europa, which in turn transformed the classroom into 'Mission Control'. In other contexts, the video-conference screen could act as a window to other worlds, both real and imagined, where learners can communicate with peers and experts, extending the boundaries of the normal school classroom and transforming that space by linking it to other places.

To develop positive attitudes towards science as an area of work, life and study

Are students' attitudes towards science altered after completion of the mission in comparison to reports prior to the mission? Are students engaged in and motivated by participation in the mission?

Students in focus groups unilaterally reported that they enjoyed the mission, even those who found it stressful. One student went so far as to ask to record on camera during the focus group his thanks for being invited to take part, "it's been a privilege", and in questionnaires, 86% of students reported that they would like to do it again. This feeling of enjoyment was perhaps largely to do with feelings of success at a challenging and occasionally stressful task ("it was harder but funner" than normal science lessons), as well as the emotional relief from rescuing the astronauts when they had been so involved in their plight. The feeling of working as a team also seemed enjoyable:

> *Researcher: How did you feel when the astronauts got back to base?*
> *Student: I was happy because we'd worked as a team to get them back.*

In focus group interviews, students discussed their experience of the mission as compared to school science very positively. Students reported that Space Mission was more like they imagined 'real' science to be, with 88% of students agreeing to the statement, 'Space Mission gave us experience of how scientists work'. In focus groups, many students agreed that they would like to be scientists "if it was like this" and some reconsidered science as a career:

> *If you were actually doing this job you'd get a lot out of it because you'd have got them back safely. But it would be nervewracking.*

However, in questionnaires, while 66% of students reported that doing Space Mission had made them more interested in science, there was only a very small increase in positive responses to questions about attitudes to science and wanting to be a scientist as a career.

As well as being more enjoyable than science lessons in school, students also talked about how they felt they had learnt more, often referring to the fact that although the Mission was more difficult than science lessons in school, they were active and involved, rather than science lessons which many characterised as boring:

> *Student 1: I think more people would want to come to school if it were like this, because it's fun and you learn a lot more.*
> *Student 2: And you remember it during tests because you can think back to it.*
>
> *I found I understood more, even though it was harder, I found my job was capable [ie could cope with it], but in my science lessons we have to copy things from books… but because we're just writing things down we're not actually doing anything to make us understand it and then at the end he asks us questions and I'm like I didn't read it 'cos I'm just writing it down.*

However, some students were aware of the requirements to learn detailed facts in order to pass tests, and felt that detailed lessons focused on learning content would still be necessary.

In discussions about what they had learnt from Space Mission, students identified team-working and communication skills, but they did not see these as especially scientific skills. This may be because their understanding of science is focused on content knowledge and practical skills instead of these more abstract skills.

Other skills that students practised and developed during the mission included problem-solving, interpreting and analysing data, and skills of scientific literacy (see relevant sections above). It may be that students did not recognise that this is what they were doing, or be familiar with thinking explicitly about these skills.

In questionnaires, students were asked to agree or disagree with three statements about what they learnt in Space Mission: 'experience of how scientists work' (88% agreed), 'learnt about the moon Europa' (95% agreed), and 'learnt about how to rescue astronauts in a space disaster' (85% agreed).

While the simulation itself can give students engaging and enjoyable experiences and allow them to practice and develop important skills, it is likely that it is during debriefs following the mission that students will be able to identify and reflect on what they've learnt. A report from the Mission Commander could provide a basis for this reflection and allow students to identify the skills and understandings they have gained, making it more likely that they would be able to build on these in other learning contexts such as school science lessons. For this reason, it would also be important for students' teachers to understand and attend the mission, so that they are able to support the students to reflect on their experiences afterwards.

To demonstrate the potential of a broadband-enabled classroom

What are teachers' and pupils' perceptions of the role of video-conferencing and broadband technology in the simulations?

As far as teachers and students were concerned, the key contribution of the video-conferencing technology was to support the immediacy of communication with a live 'expert', the Mission Commander, which made the whole experience seem authentic. They all agreed that seeing the Mission Commander and video clips of the astronauts on the large video-conferencing screen was important in sustaining the idea that they were actually communicating with Europa. The importance of role play and authenticity is discussed more fully above.

The instant feedback that the video-conferencing communication affords was also important to tailoring the mission to the students' needs on a continual basis. Because the Mission Commander could see and hear the students, he was able to offer supporting prompts and extra challenges when appropriate. The students were also motivated by the instant feedback provided by the Mission Commander or the video clips of the astronauts, and by seeing their proposals immediately put into action. The large screen seemed to foster a sense of immediacy with regard to the simulated scenario that allowed students to engage with the narrative. More broadly, communicating with a range of experts via video-conferencing can offer more personalised approaches for learners, as learners can ask questions of experts relevant to their current field of work.

Students and teachers were explicit about the benefits of connecting to the Mission Commander and the astronauts via video-conferencing, feeling strongly that it would have been a poorer experience without these elements. However, they were less clear about the purpose of the avatar, AMIE. In focus group sessions, some students expressed that they did not know why AMIE gave some information, when the Mission Commander and the astronauts also provided information. In discussion about where useful information came from, students mentioned the Mission Commander, the astronauts and their own data, but did not seem to perceive AMIE as giving useful information. Somehow, the students perceived the avatar as holding less authority and status that the Mission Commander, and indeed, most times he had to specifically direct their attention to her or repeat information she gave. This may be because she could not respond as immediately, or with the same content detail or with the same personal responses as the commander, and perhaps was therefore 'less real' than the commander and the dynamic video clips.

CONCLUSION

It is clear that students enjoyed taking part in Space Mission: Ice Moon and worked hard to achieve a successful resolution to the situation. Four case studies showed some of the ways in which a simulation such as Space Mission can support KS3 students' understandings of science and raised further implications for using this technology for learning more generally.

Role play and authentic context

Taking on imagined roles within a powerful narrative emerged as a critical factor in this simulation. By pretending to be scientists in an Emergency Response Team, students were able to think and act as scientists. They had to take responsibility for their decisions, and consider the consequences of their actions as if they were scientists. The roles, and associated attitudes, which learners adopt in any particular context, and how this enables (or disables) them to achieve certain goals, or to act and think in certain ways, can be seen as a critical factor in designing learning experiences.

The immediacy of the two-way communication with the Mission Commander and the dynamic use of 'as live' video clips were crucial elements in supporting students' suspension of disbelief, which allowed them to immerse themselves in their roles and relate to the experience as an authentic situation. This provided a coherent context and a purpose for students' activities including data interpretation and problem-solving.

Collaboration

Defining individuals' roles within teams helped students organise their work and cooperate effectively. However, they also needed enough autonomy and flexibility to adapt roles to suit changing circumstances; when roles were too rigidly defined, for example by an adult outside their team, cooperation broke down as individuals remained focused on their individual tasks rather than adapting to suit the needs of the team. Students understood that they could only solve problems by working cooperatively and knowing that team mates were relying on them was a motivating factor in completing work.

Each team's activities gave them only a partial view of the overall situation; in order to understand the bigger picture, members from different teams communicated with each other to build a shared understanding of what was happening to the astronauts and often collaborated to decide what action to take.

Layout of the room also emerged as a significant factor in facilitating cooperative work. In such large team-based collaborative activities, consideration needs to be given to room layout in order to facilitate equal and shared access to team and video-conference display screens, identification of team bases, and ease of movement through the space.

Scientific literacy

With a range of modes of representation and communication available (graphs, maps, post-it notes, data etc), students were able to translate information between modes and decide upon the most effective modes to use in different circumstances. Much communication used shared reference points developed from artefacts such as graphs and maps as a commonly understood shorthand, and used these original artefacts to lend authority to a message or help communicate a complex explanation. In making choices from a range of possible modes students weighed up the benefits in order to select the quickest and clearest way of conveying their message.

Interpreting data

With training, most students were able to competently handle and process data as necessary and interpret this information to explain events. By constructing explanations from the ground up, students experienced an authentic knowledge-producing activity, similar to the process of real science. However, the Mission Commander was credited with holding the 'correct' interpretation, and his knowledge was trusted far beyond the students' own explanations. The Mission Commander's perceived teacher-like authority may have encouraged this attitude, familiar to students from school where teachers ask questions to which they already know the answer. It may be that the Mission Commander could in some cases hold back from giving interpretations in order to encourage students to work further with their own interpretations.

A few students were moving towards using data to judge the validity of explanations. The Mission Commander was able to support these students by questioning further on this line. To develop and extend these skills further, additional problems could be included on the timeline that would specifically require students to adjudicate between competing explanations by comparing validity of data.

Students appeared not to grasp that data that is more recent is more valid in determining the astronauts' current situation, often appearing to choose to complete work on out-of-date downloads before requesting updates. The value they placed on thorough completion of tasks (perhaps carried across from school) appears to have overridden considerations of validity in several cases.

Problem-solving

The problem-based approach of the mission saw students identifying questions and goals, and sourcing relevant information and resources in order to rescue the astronauts. Recommendations for action revealed that students were working with underlying hypotheses that they adjusted over time. However, these were not made explicit and were not tested methodically. The problem-solving process was often collaborative, drawing in information from the perspectives of different teams. Such problem-solving skills are similar to the processes of scientific inquiry followed by research scientists and students gained experience of creating solutions and new knowledge for themselves.

Taking part in Space Mission: Ice Moon was an enjoyable and valuable experience for the students involved. Further development should be undertaken to develop the prototype created to a stage where it can be more widely disseminated and greater numbers of learners can benefit from taking part.

FURTHER RESEARCH QUESTIONS ARISING FROM THIS STUDY

This study has identified several interesting themes beyond this particular project that would reward further research.

The expert scientist identity that students adopted proved highly significant to their learning experience. Further investigation into how students' roles and identities can affect their learning would be very useful. For example, is it possible for students to take on expert roles in other situations such as the 'normal' classroom, and does this enable them to think, act and learn differently? Related to this question, it would also be useful to explore learners' ideas of what 'experts' are in different domains, where they get these ideas from, and how this affects what they do when asked to take on the role of experts.

Aside from taking on roles as experts, it would be interesting to look at how asking learners to take on other roles in other imagined or real situations may allow them to access different ways of thinking and acting. Perhaps even more importantly, it is learners' conceptions of their own identities as learners that may most affect how they approach learning. If learners can become reflective about their identity as learners, and possibly adapt to suit different contexts then they may be empowered to have greater control over their own learning.

The authentic, even though fictitious, context of the scenario was important in that it provided coherence and a purpose for students' activities. It would be possible with these kinds of technologies for learners to link up to scientists and experts in other domains engaging with real, current problems and explore the real forefront of knowledge production, perhaps even making some kind of meaningful contribution to the work of real scientists and researchers.

This study shows that authenticity is important to learners' engagement and understanding; research into how to bring authenticity to other learning experiences would be useful. This may be, as in the case of Space Mission, through an imaginative suspension of disbelief in a fictitious scenario, or possibly more powerfully, working in the authentic context of learners' own lives. Learners could decide on their own problems to investigate and solve, effectively writing their own missions to carry out with peers. They could choose experts to link to over video-conferencing, which could include bringing in people from their own community as well as other experts from communities and institutions relevant to their problem.

FURTHER RESEARCH AND DEVELOPMENT OF SPACE MISSION: ICE MOON

Long-term development and research opportunities specific to the Space Mission project are summarised here.

Distributed dissemination and development

Responsibility for hosting the Space Mission: Ice Moon simulation currently rests with the National Space Centre, which provides training, technical support and staff. Larger scale take-up of the project amongst more schools will depend either on the National Space Centre increasing the resources it can devote to this project, or adopting an 'open source' model to dissemination and development. Participating institutions such as schools, CLCs and science centres could be given responsibility and training enabling them to host missions themselves, and even contribute further events to the timelines. As well as institutions, students themselves could participate in developing the mission for other users. Students would then also be engaged in reflecting on and articulating what they had learnt during the mission.

A further development would be for students in multiple locations to work together during a mission, communicating by webcams, instant messenger or multiple video-conference connections. Teamwork, communication and collaborative decision-making would need further support, but opportunities for sharing knowledge and decision-making across different boundaries could be a valuable learning experience worthy of further research.

Classroom context

This study was not able to follow up on students' learning back in the science classroom after the mission. A period of reflection following the active and immersive experience of participation in the mission may support students in making their learning more explicit and therefore enabling them to draw upon it on other contexts such as the science classroom and other problem-solving situations. Follow-up or debrief materials may be necessary. This could perhaps take the form of a report from the Mission Commander or materials for teachers to use when back in the classroom. For this reason, teachers should also be encouraged to attend the missions with their students.

Further research about how students' school science experiences before and after the mission influence their understanding of what they have learnt would provide a deeper understanding of any lasting benefits of Space Mission.

Differentiation of outcome

Providing a range of more and less successful outcomes to the scenario, dependent on students' actions, should be considered. Providing different outcomes may create a more explicit link between students' actions, and the consequences for the astronauts. This could support students in critically reflecting on their actions during the mission. It may also help engage those students who are not imaginatively immersed by giving them a game-like structure of cause and effect to work within. Further research into how differentiating outcomes promotes reflection on consequences of actions may be useful in investigating the ways in which multiple outcomes could be used and their effects.

Training session

The training session that students undertake prior to the mission needs further development and consideration will need to be given on how best to train classroom teachers to run this part of the experience.

Students should be actively engaged with the information to be learnt, practicing using it rather than simply being given a wealth of information to memorise in a short period.

The training session should equip students with:

- an understanding of the current scenario on Europa
- relevant scientific knowledge about Europa and the information they are analysing
- familiarity with their role and others' roles within their team and the whole Emergency Response Team (one possibility would be to ask each team to undertake the training relevant to them, and to present back to the wider group; this may also result in more 'ownership' of team information)
- science and maths data handling skills needed to complete their tasks
- familiarity with their software interfaces (a scaled-down version of the software used in the mission should be used in the training session, allowing students to become familiar with the interface, so they can focus more on their tasks and on problem-solving during the mission).

Space Mission: Ice Moon provided an engaging learning experience for Key Stage 3 students. They were immersed in a gripping narrative, taking on the role and identity of expert scientists, taking decisions and analysing data in order to achieve their goal of saving a group of stranded astronauts. Thrown largely onto their own resources, students relied on each other, collaborating and working closely together in order to create explanations and solutions. The video-conference connection provided a window onto another world, which reflected back into the classroom, transforming that familiar space into a Mission Control. The classroom became a space in which children could use their imagination to participate in an immersive experience, engaging in an authentic way with scientific concepts and skills. These types of technologies and approaches may have an important part to play in future learning environments in creating immersive simulations that allow students to take on new learning identities and transforming familiar learning spaces by making connections with real and imagined worlds.

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APPENDICES

Observation schedule example

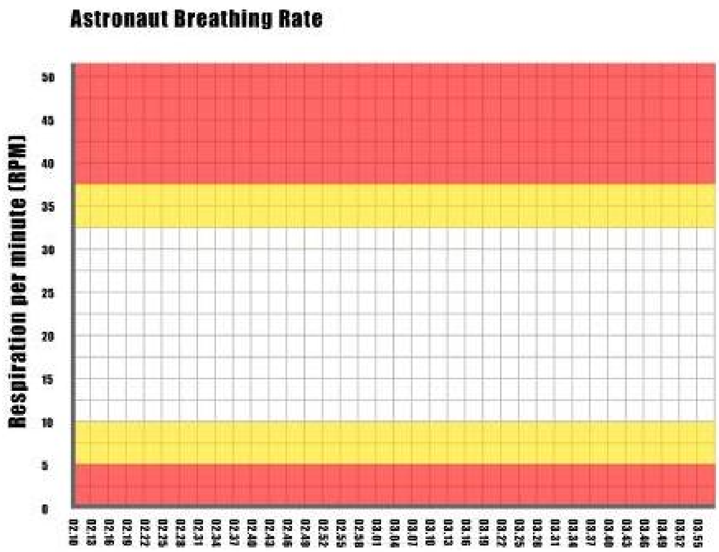
Time: 0-5 minutes			
Time	Participants	Lng. Int. no*	Actions and speech

* Learning Intention number – researchers were asked to note if their records related directly to one of the four main research focuses.

Video analysis transcription example

Time	Observation – speech and behaviour	Categories
02:27	One team member going through procedure and roles with others: "you work out the time on Europa, the first sensor… the second sensor…" General discussion about who's going to do what.	Organising roles

Example graph



Example status table

Astronaut_________________ Medical Status Records

Yellow Zone = -10 Red Zone = -20 Initial status – Total effects = Health status

Time on Europa	Initial status	Heart rate	Body temperature	O_2 saturation	Breathing rate	Blood pressure	Total effects from Red or Yellow zones	Current health status
	100%							
	100%							
	100%							
	100%							
	100%							
	100%							
	100%							
	100%							
	100%							
	100%							
	100%							

Questionnaire data

Pre-trial

	Views about science in school	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	I like science more than any other school work	9	17	9	18	5	1	59
2	Science is just too difficult		10	9	23	16	1	59
4	We have to do too much work in science	1	11	16	15	12	4	59
5	School science clubs are a good idea	15	20	15	6	1	2	59
6	We do too much science at school	6	6	15	13	18	1	59
7	You have to be clever to do science.		7	2	20	27	3	59
8	We have to do too much writing in science.	5	15	9	17	11	2	59
9	Doing experiments in science is boring	1	1	1	18	37	1	59
10	There is too much reading to do in science	1	4	16	18	19	1	59
11	It is good to use computers when learning science	29	15	11	1	0	3	59
12	It is easier to understand science when using computers and videos	20	22	12	3	1	1	59

	Views about science in general	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	Science is boring.	2	8	11	18	19	1	59
2	I would like to be a scientist	1	7	16	13	20	2	59
3	I like to read science stories	2	12	12	19	12	2	59
4	I would avoid science programmes on TV	9	19	12	8	10	1	59
5	I would like to be given a science kit as a present	8	10	12	13	15	1	59
6	I like to find out about science by using the internet	14	25	9	6	4	1	59
7	I would like to be given a CD-ROM about a science topic	8	12	18	11	8	2	59

	Views about importance of science	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	Science is good for everybody.	22	18	11	5	2	1	59
2	Lots more money should be spent on science.	15	18	17	5	2	2	59
3	Science can make better and safer medicines.	39	13	5	1		1	59
4	TV, telephones and radio have all needed science.	33	12	13			1	59
5	Our food is safer thanks to	30	21	5		1	2	59

	science.							
6	It is important that more people become scientists	14	21	17	3	3	1	59
7	Everybody should know something about science	28	21	5	3	1	1	59

	Views about working with others	**Strongly agree**	**Agree a little**	**Not sure**	**Disagree a little**	**Strongly disagree**	**No answer**	**Total**
1	To get a big job done, we have to work together.	43	13	1			2	59
2	If we have a task to do, we should have a plan.	31	25	1	1		1	59
3	After the job is over, we must check our plans again.	20	23	13	2	1		59
4	It is best to have a leader for a team.	22	25	6	1	5		59
5	You can get more done if you are part of a team.	38	17	2	2			59
6	We must help others in the team if there is a problem.	46	10	3				59
7	We should work out what could go wrong before we start.	29	19	9	2			59

Post-trial

	Views about Space Mission: Ice Moon	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	Space Mission: Ice Moon gave us experience of how scientists work	32	20	5	2			59
2	I would like to do an e-mission like Space Mission: Ice Moon again	36	15	4	2	2		59
3	We learnt about the moon Europa.	42	14	3				59
4	We learnt about how to rescue astronauts from a space disaster.	37	13	5	3		1	59
5	Working in teams during Space Mission: Ice Moon helped us to get the work done.	44	7	6	2			59
6	Talking to the Flight Commander on the videoconferencin g screen was exciting	29	18	5	4	3		59
7	Getting the work done in Space Mission: Ice Moon was stressful	23	25	7	3	1		59
8	Taking part in Space Mission: Ice Moon was boring	4	5	7	10	32	1	59
9	Space Mission: Ice Moon was just too difficult	2	6	10	17	23	1	59

10	It was easy to understand what to do and how to do it	15	26	6	7	2	3	59
11	I would enjoy doing science in school more if it was more like doing a Space Mission	28	18	7	4	1	1	59
12	Space Mission: Ice Moon is a better way to learn science than what we usually do at school	35	10	11	2		1	59
13	Doing Space Mission has made me more interested in science	22	16	11	4	5	1	59

	Views about science in school	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	I like science more than any other school work.	10	16	8	10	14	1	59
2	Science is just too difficult.	3	9	11	20	15	1	59
4	We have to do too much work in science.	10	11	15	8	11	4	59
5	School science clubs are a good idea.	17	14	16	6	4	2	59
6	We do too much science at school.	8	10	14	12	14	1	59
7	You have to be clever to do science.	3	7	7	13	26	3	59

8	We have to do too much writing in science.	11	11	14	15	6	2	59
9	Doing experiments in science is boring	1	2	5	16	34	1	59
10	There is too much reading to do in science	7	10	17	12	12	1	59
11	It is good to use computers when learning science	31	12	12		1	3	59
12	It is easier to understand science when using computers and videos	31	13	10	4		1	59

	Views about science in general	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	Science is boring.	8	6	9	10	25	1	59
2	I would like to be a scientist	5	5	14	9	24	2	59
3	I like to read science stories	4	6	13	11	23	2	59
4	I would avoid science programmes on TV	15	12	9	7	15	1	59
5	I would like to be given a science kit as a present	8	8	13	10	19	1	59
6	I like to find out about science by using the internet	17	16	12	4	9	1	59
7	I would like to be given a CD-ROM about a science topic	9	9	14	13	12	2	59

	Views about importance of science	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	Science is good for everybody.	27	16	12	1	2	1	59
2	Lots more money should be spent on science.	17	27	11		2	2	59
3	Science can make better and safer medicines.	39	8	10	1		1	59
4	TV, telephones and radio have all needed science.	37	12	8	1		1	59
5	Our food is safer thanks to science.	31	11	12	1	2	2	59
6	It is important that more people become scientists	18	17	19	3	1	1	59
7	Everybody should know something about science	29	18	9	2		1	59

	Views about working with others	Strongly agree	Agree a little	Not sure	Disagree a little	Strongly disagree	No answer	Total
1	To get a big job done, we have to work together.	42	10	4	1		2	59
2	If we have a task to do, we should have a plan.	33	16	6	3		1	59
3	After the job is over, we must check our plans again.	29	15	9	6			59
4	It is best to have a leader for a team.	34	16	6	2	1		59

5	You can get more done if you are part of a team.	44	10	4	1		59
6	We must help others in the team if there is a problem.	42	12	3	1	1	59
7	We should work out what could go wrong before we start.	33	16	8	2		59

Training lesson plan

Space Mission: Ice Moon

Pre-mission training lesson plan

Duration: approx 2 hours

Starter activity - 15 mins

Objective – to give pupils a brief idea of the mission scenario and to enable them to discover some facts about Europa to set the scene for the mission

Resources

Smartboard or whiteboard/flipchart
Europa worksheets
Teacher answer sheet
Europa facts sheet
Europa pics
Notes on Europa nasa (explanation of Europa pics)
(These resources can be paper or electronic-based depending on what is available in classroom)
Internet availability for pupils

If possible have a video clip of Europa to show them as they come in:

eg www.solarviews.com (from site map go to Jupiter-Europa-Europa movies-rotation movie)

- Give basic background to mission:

> *Four astronauts have recently set out on a routine exploration of the moon Europa. Commander Susan heads the team with Ajaz, Pierre and Jean. They have failed to report in and are not on their expected route. It is presumed that they are lost and may have other problems too. The Base Commander is trying to regain contact with the expedition party and may need some help once they have been found.*

It will be your job to rescue them.

Do you know where Europa is?

Do you know any facts about Europa?

- Give the students 10 minutes to research basic information using websites provided

REF: europa worksheet.pub, europa worksheet answers.pub

- Record answers – either:

1. Students produce a quick Publisher fact sheet

2. Students find answers and teacher records centrally (on smartboard, whiteboard, flipchart – whichever is available using publisher template available)

REF: europa facts template.pub

- Spend a few minutes going over main facts: (NB: Not all students will find all answers)
- There is more info than can probably be covered in the time but can be useful for questions from students.

REF: europa facts.doc (Facts about Europa), europa pics.ppt (Pictures of Europa) notes on europa nasa.doc

Preparation activities linking to teams – 40-60 mins

Objective – to explain organisation of mission and specific teams and their roles

This is with the whole team because they are all learning more and it gives them a good overview that will improve the mission because they are more aware of what information each team has and therefore encourage them to communicate with each other more.

Setting the scene

- Give the following briefing to set context for mission:

Background story

Europa, a distant moon of Jupiter, has a 100km thick ice crust above a deep ocean. The surface of Europa is barren and bathed in fatal levels of radiation from the strong magnetic field surrounding Jupiter. It is thought that the ocean beneath the ice could be a suitable environment for life to develop.

Europa Base is home to a small research expedition who is exploring the ice tunnels in the region of the base. The base and the explorers are protected from the surface radiation by a layer of ice a minimum of 10 metres thick. The base reached its safe position by melting its way down through the ice, refilling the hole above as it went.

Your role

You are an Emergency Response Team called into action to assist Europa Base. You will be advising the Base Commander, helping to monitor the team of astronauts.

You will be receiving lots of data from the astronauts' suits about their health and the status of the suits. You will also be receiving information to help you to work out where ice tremors are occurring in the ever-shifting ice crust. You will also need to navigate the astronauts back to the base using a map of the ice tunnels.

All the data you receive will have to be downloaded from the satellite orbiting above Europa. Every three minutes you will have the chance to download a limited amount of information from the satellite team. It is vitally important that you keep a track of the information that you will need on the next download and request it each time. There is only a limited amount of data available on each download but there will be lots of important information so you will need to think carefully and prioritise.

In this case it is more important to have an up-to-date record than a complete record of the Health/Life Support for an astronaut, especially if you are worried about any individual astronauts.

- Explain that there are four Monitoring and Planning teams, a Communications team and a Satellite team.
- Explain that you are going to look at the work of each team because it's important to know what everyone does before assigning people to their teams.

Ice conditions – 10-15 mins

- Discuss ice conditions, eg movement of the ice due to movement in land, water beneath and temp changes, crevasses.
- Discuss problems of moving on ice – much as on Earth but here in tunnels under the ice.
- **REF: Europa pics.ppt:** features on Europa, eg screen 11, 15, 16.

How might the ice environment affect the astronauts moving through the tunnels to get back to base? Eg ice tremors resulting in tunnel collapses, movements in the ice cause tunnels to move.

- Discuss Ice team's role: to monitor ice conditions by collecting readings from eight ice sensors and plotting them on a map.
- **REF: electronic version of map for plotting available** (needs 2D Techsoft to run).
- Liaise with Navigation on areas to avoid. Inform Flight Commander via Communications team.

Navigation – 10-15 mins

- Discuss navigation – how we navigate.
- Compass – Europa may not have strong magnetic field, magnetic field may not be polar-based – therefore our compasses would be no good on Europa.
- Stars/sun – astronauts underground so wouldn't see sky and position of stars would be different on Europa.
- Maps – these will change constantly with changing state of ice and will have to be transmitted to astronauts frequently.
- Satellite navigation – this is similar to how the astronauts will be guided on this mission.
- Areas of strong radiation will also cause problems. Discuss how radiation effects human body - sickness, death, long-term effects – cancers. Astronauts need to be under 10 metres of ice to protect them from effects of radiation.
- Discuss Navigation team's role – to plan safe routes for the astronauts through ice tunnels using maps downloaded from the satellite. You must then submit your planned routes to the astronauts and Flight Commander through the computer.
- It is vital you have up-to-date information from the Ice team about ice tremors, tunnel collapses and high radiation areas.
- You will also need to keep in touch with the Life Support Suit team and Medical team to check that the astronauts have enough battery power, oxygen, and are healthy enough to make it through the route that you have suggested.

Medical – 10-15 mins

- Brainstorm needs of human survival – water, oxygen, temp, pressure, food
- Discuss how we measure vital signs:
  Temperature – thermometer or temperature strip, physically feeling forehead. Inside spacesuit a sensor will be stuck to skin.
  Blood pressure – a cuff on wrist or arm attached to electronic reader or cuff and stethoscope. In spacesuit this will be automated cuff.
  Heart rate/pulse – use finger (not thumb because this has pulse itself) and feel pulse in wrist or neck. Count number of beats in 15 secs using watch and multiply by four for pulse/heart rate.
- If possible, do practical demo of taking blood pressure, HR, temperature.
- Discuss Medical team's role – to monitor the vital signs of the four astronauts by downloading information from the satellite team, calculating overall health status and submitting this through the computer every three minutes.
- Health of astronauts will affect how fast they can move. Team will need to liaise with Navigation team on routes to ensure the astronauts can complete the routes particularly if any astronaut ill or injured.

Life Support Suit – 10-15 mins

- Discuss use of Spacesuit (Life Support Suite) to create safe living environment for astronauts.
- **REF: Europa pics.ppt:** components of spacesuit screen 7.
- Discuss what spacesuit is providing the astronauts:
  Oxygen, suitable temperature, suitable pressure, water to drink, waste disposal system, communication system.
- Discuss what it is protecting them from (extremes of temperature, radiation to some extent, atmospheric pressure unsuitable for humans, weighted to overcome light gravity, visors to protect against damage to eyes by sun or radiation.
- Emphasise the difficulty of moving and working in a spacesuit. Very cumbersome, impairs manual dexterity, hearing others is reliant on electronic communication system, visibility impaired – have to move whole body to see side views.
- If possible demo pressure with marshmallow and syringe. Use needleless syringe to inflate marshmallow with air to show what would happen to human body in low pressure atmosphere. Suck air out to show effect on human body of too high an atmospheric pressure.
- If possible demo difficulty of working in a space suit eg making LEGO model with several pairs of thick gloves on.
- Blown up long balloon – show how difficult it is to bend (rather than fold) This is how spacesuit on arms and legs are - difficult to bend – easier with elastic bands or slinky around it to provide moving joints just as spacesuit is designed.
- Discuss Life Support Suit team's task – to monitor status space suit – eg amount of oxygen left, temperature, battery power etc by downloading information, calculating overall status and submitting to Flight Commander through computer every three minutes.
  It is vital to liaise with Medical team – a change in space suit condition will affect medical condition of astronauts and the other way round.

  Also important to keep up to date with Navigation team because a longer safer route may not be possible if not enough oxygen or battery power is left.

Communications – 5 mins

The Flight Commander is in charge of linking all teams and making sure your information gets to the astronauts, so it is vital that all information is relayed to him via the Communications Officer as quickly as possible.

The communications officer is responsible for coordinating messages between the Emergence Response Teams and the Flight Commander. If the teams are slow inputting their data into the computers, the Communications Officer will come and chase up the teams to get cracking!

It is important that messages get through to Rescue team and Base Command as quickly as possible and accurately. Communications team will have to link with all teams and have good overview about what all the teams are doing and finding out and keeping abreast of the current situation.

Satellite – 5 mins

The satellite orbits Europa once every three minutes, which means that there is a window in which you can download the information you need once every three minutes. There is also a limited bandwidth available in this window – so you can't download everything each time. This team will need to get requests for downloads regularly from each of the four teams and if requests exceed space limit they will have to get teams to prioritise requests or make a decision themselves. Downloaded data must be relayed to teams as quickly as possible.

Satellite team needs to have good overview of current situation particularly with regard to health of astronauts – keeping them alive is the objective of the mission.

Specific preparation for teams - 30–40 mins

Ideally four trained staff would be present for this part of the activity. In the absence of this, students should be asked to read the instructions given and staff available should work their way round the class giving support where necessary.

> *You are the Emergency Response Team responsible for rescuing these four lives from the ice moon Europa. You will each be given a team and be fully trained in your role – you are the experts. Only you can save the astronauts now.*

- Divide students into teams

REF: Team roles as a guide to numbers

- Place students in teams for pre-mission training:

1. Medical and life support

2. Navigation team + Communication team

3. Ice team + Satellite team

REFs:

Medical: Instructions, Graphs x 5, Status calculation sheets x 2, ppt

Navigation: Instructions, Practice map x 3, Practice table x 3

Ice: Instructions, Practice map x 4, Practice table x 4, ppt

- Students complete pre-mission tasks as per instructions

Communication and Satellite team to spend 20 minutes with designated teams and then move around to other teams to observe what they are doing. This should give them a reasonable overview of all teams.

- When pre-mission tasks completed, students should elect leaders and decide who will be responsible for what.

REF: Team roles as a guide to roles

All teams need a representative to link directly with Base Commander via VC.

Teachers to work with Communication and Satellite teams before letting them move round groups to get a feel for what other teams are responsible for.

Explain roles as above and show them screen shots to prepare them for format of communications. Explain record sheet for download requests.

The mission

- It is useful to have computers primed ready with URLs so that students just need to press enter at the right time. Unnecessary delay can occur because of misspelled complicated URLs.
- I advise teachers to stay with group they have trained to ensure they can cope with practicalities of task in timed situation. It is then preferable to withdraw and observe - only interfering if absolutely necessary. If students ask you for information or advice direct them to the Flight Commander.
- If students are struggling because of small numbers teachers could take on role of Consultant researchers for teams.
- Ask each team to sit at their desks and read the instructions on their table or screen shots sent by base command. Check that everybody is happy with what they have to do before the mission begins.

REF: 3 x Mission instructions for each team (6), 3 x Quick Reference Sheets for each team (6)

Good luck on your mission. Lives may depend on your decisions.

Mission runs: 90 minutes