3D online education

Broadband enabling STEM

Gavin Walker, Brett Grandbois, Kazys Stepanas, Dennis Frousheger, David Haddon, Fletcher Talbot, Chris Gunn, Shlomo Berkovsky, Jane Li, Matt Adcock, Stuart Anderson, Belinda Ward, Christian Richter, Fred Pauling, Tom Lowe, Paul Flick, Daniel Keogh

EP157166
23 September 2015

Department of Communications
Contents

Acknowledgments........................................................................................................ iv
Executive summary ..................................................................................................... v
1 Introduction .............................................................................................................. 8
   1.1 Previous CSIRO work ......................................................................................... 8
   1.2 IntoScience ........................................................................................................ 12
   1.3 Objectives .......................................................................................................... 12
2 Activities ................................................................................................................ 13
   2.1 3D education platform ...................................................................................... 13
   2.2 Panommersion system ..................................................................................... 24
   2.3 Interaction between the 3D environment and the Panommersion system .......... 35
3 Evaluation ............................................................................................................... 38
   3.1 Approach and methodology ............................................................................. 38
   3.2 Evaluation of the 3D system ............................................................................. 38
   3.3 Evaluation of the Panommersion system ........................................................... 41
   3.4 Whole of project analyses ............................................................................. 45
   3.5 Future directions .............................................................................................. 51
4 Conclusion ............................................................................................................. 53
   4.1 High-speed broadband ..................................................................................... 53
   4.2 Engagement in science, technology, engineering and mathematics (STEM) .... 53
   4.3 Online 3D learning environment ..................................................................... 53
   4.4 Collaborations .................................................................................................. 54
   4.5 Closing remarks ............................................................................................... 54
Appendix A Evaluation questionnaire results .......................................................... 55
Appendix B Evaluation questionnaires ..................................................................... 57
Appendix C Evaluation usage results ...................................................................... 67
Appendix D Panommersion potential commercialisation partners ......................... 68
References ............................................................................................................... 71
Figures

Figure 1 Museum robot at the National Museum of Australia....................................................... 8
Figure 2 Museum robot interactions.................................................................................................. 9
Figure 3 Map of museum generated by the robot ............................................................................... 10
Figure 4 Each user chooses their own view from the panorama....................................................... 10
Figure 5 a) Zebedee laser scanner and b) Projection of Pisa scan .................................................. 11
Figure 6 Insect scan apparatus ......................................................................................................... 12
Figure 7 Captured point cloud........................................................................................................... 14
Figure 9 Auto-generated mesh ......................................................................................................... 14
Figure 9 Tool for video frame lookup from point cloud...................................................................... 14
Figure 10 An illustration of the issues facing point cloud data reconstruction.................................... 15
Figure 11 General comparisons between the custom algorithms (top) and a commercial product (middle). Video images are provided for reference (bottom). Both meshes contain comparable triangle counts......................................................................................................................... 17
Figure 12 Scans of items similar to those collected by Joseph Banks .............................................. 19
Figure 13 Scans of bud inside and out.............................................................................................. 19
Figure 14 IntoScience Jenolan Caves .............................................................................................. 21
Figure 15 a) Jenolan journal finding Zebedee b) Jenolan investigation............................................... 21
Figure 16 a) Instruments and b) Challenges...................................................................................... 22
Figure 17 a) Upper deck and b) Afterfall with Joseph Banks samples............................................... 23
Figure 18 Panommersion system diagram........................................................................................ 25
Figure 19 The default lesson view .................................................................................................... 28
Figure 20 The active visitor view ..................................................................................................... 29
Figure 21 Capturing panoramic stills via a web interface................................................................ 30
Figure 23 User icons ....................................................................................................................... 31
Figure 23 Collaborating with icons a) Gavin’s screen and b) Anne’s screen ................................... 32
Figure 24 Interactions of panommersion system .......................................................................... 33
Figure 25 a) ANMM replica lantern b) Ladybug camera c) project replica lantern with ladybug..... 33
Figure 26 a) Replica blanket box right next to ANMM box b) inside box with camera and processor c) box ventilation......................................................................................................................... 34
Figure 28 3D model of foredeck camera mast .............................................................................. 35
Figure 28 Pannodes on deck of Endeavour model with scheduled tour ............................................ 36
Figure 29 Pannode glowing to show user can step through to panorama ........................................ 37
Tables

Table 1 Summary of 3D product results against targets .......................................................... 39
Table 2 Panommersion results against targets ........................................................................ 41
Table 3 Percentage of student with knowledge better than random .................................... 49
Table 4 Average attitude towards science measures in four conditions ................................. 55
Table 5 Average Combined Interest in Science measure against gender ................................. 55
Table 6 Combined Interest in Science measure against school years .................................... 55
Table 7 Combined Interest in Science measure against ICSEA .............................................. 56
Table 8 Knowledge questionnaires results in four conditions ................................................ 56
Table 9 Absolute knowledge attainment from experiences ...................................................... 56
Table 10 Number of classes for IntoScience Jenolan Caves ................................................... 67
Table 11 Students for IntoScience Jenolan Caves ................................................................. 67
Table 12 Lessons run per school year ....................................................................................... 67
Acknowledgments

This is an Australian Government funded project. It is a collaboration between CSIRO, the Department of Communications and 3P Learning, with assistance from the Australian National Maritime Museum. The project acknowledges the help of the Jenolan Caves Trust in supporting scanning of the caves. The authors wish to thank Robert Zlot and Elliot Duff from CSIRO for their work on the project. Also Lynda Kelly and Anne Doran from the Australian National Maritime Museum for their support and Heath Knott for IT help. They also acknowledge Tim Power, Luke Tomes, Sally Miles and Ben Colenso from 3P Learning for their contributions to the project. Finally thank you to Ben Macklin and Anne Gane from the Department of Communications.
Executive summary

The 3D Online Education project was a joint project between the Federal Department of Communications, CSIRO and 3P Learning, with assistance from the Australian National Maritime Museum (ANMM). It set out four objectives:

- Demonstrate innovative uses of high-speed broadband and digital technologies in the delivery of learning via new online education services.
- Increase engagement amongst school students in science, technology, engineering and mathematics (STEM) areas.
- Provide an engaging, supported and effective online 3D learning environment for students and citizens.
- Establish the collaborative relationships with schools and commercial partners that will enable technologies developed under this project to become self-sustaining at the conclusion of the Commonwealth funding.

To satisfy these objective two products were built. The first was an extension to 3P Learning’s IntoScience project containing two 3D learning environments, the Jenolan Caves and the ANMM’s HMB Endeavour. The second product was the panommersion telepresence system, providing live immersive video tours of the HMB Endeavour over high-speed broadband. The project also demonstrated a way of walking between the virtual 3D world and immersive tours.

3P Learning took laser scans from CSIRO’s Zebedee handheld scanner, improved with custom CSIRO algorithms and built 3D environments in which to run STEM lessons. Some of these lessons included 3D insects and plants, scanned by CSIRO’s InsectScan system. The IntoScience Jenolan Caves environment has been provided to hundreds of schools around the country and brought excitement to thousands of students. The HMB Endeavour environment is due for release next year.

At the same time CSIRO took the previous Museum Robot system and re-engineered it to be robot free. The Museum Robot system allowed a guide to provide live, interactive, video conferencing with up to 15 participants while each participant was able to independently look around the panoramic video streaming from the robot. CSIRO took the panoramic camera off the robot and installed three panoramic video cameras on the HMB Endeavour in fixed locations. Each camera was paired with its own processor to create the panoramic video. This allowed live 360 degree video to accompany video conference features from an iPad during live online guided tours of the Endeavour. The panommersion system was successfully tested with schools.

An evaluation of student attitudes to STEM careers and learning outcomes was conducted for the two systems. The resulting data had too much variability to draw any significant conclusions.

Advanced 3D meshing algorithms now make it easier to build environments for IntoScience from Zebedee scans of the real world. The scanning and meshing process is more suited to natural, not constructed, environments where the natural irregularity hides the noise in the laser scans.
CSIRO’s InsectScan technology was further developed. InsectScan takes thousands of photographs to build detailed and colour rich 3D models of very small things. CSIRO worked with the Australian National Insect Collection and the Australian National Botanic Gardens to scan specimens like the ones Joseph Banks collected. These were made part of the Endeavours lessons.

The panommersion system demonstrated what can be done with high-speed broadband in Australia, requiring 5-10 Mbps download and 2 Mbps upload for a satisfactory experience. The software requirements are in line with the 25 Mbps download and 2 Mbps upload recommended for high-speed broadband in the USA. Testing revealed that bandwidth is not enough however, closer work with schools is needed to tailor its use to the teaching environment. IT infrastructure at schools must be properly configured for high-speed broadband applications to function effectively. More flexibility in bandwidth requirements and the latest web standards for video, WebGL and WebRTC, may help alleviate the difficulties faced.

The Australian National Maritime Museum is eager to continue use of the panommersion system. It is seeking more schools to be involved. 3P Learning is also excited about what has been achieved. It is already looking forward to include more real world environments, in line with its product cycle. Both technologies have significant potential to lift the technology base of online education and exploit high-speed broadband as it is rolled out.
1 Introduction

Science, technology, engineering and mathematics (STEM) are important skills for participation in the digital economy, and employer demand for these skills is outpacing supply. Meanwhile, enrolments in STEM subjects in secondary schools and universities have declined over the past few years while less than 10 per cent of Year 4 and Year 8 students in Australia achieved advanced performance benchmarks in mathematics and science, a lower percentage than that achieved by many of Australia’s Asian neighbours. New and innovative ways of teaching STEM subjects in school are needed to increase interest and encourage participation.

The Australian Government committed $2.5 million (GST exclusive) to CSIRO over two years to support a $4.0 million project to demonstrate innovative uses of high-speed broadband and digital technologies in the delivery of learning—particularly in science, technology, engineering and mathematics subjects.

In order to meet the objectives of the project, CSIRO needed to subcontract a third party and called for Expressions of Interest from the Australian education industry. The role of the third party was to collaborate on the development of 3D Immersive Technologies for online education purposes and to commercialise the outcomes of such collaboration. 3P Learning was selected as the preferred partner, and CSIRO and 3P Learning signed an agreement to obtain the services of 3P Learning. 3P Learning is an Australian educational software provider with expertise in developing and deploying 3D game-based education software. 3P Learning has an established relationship with a number of schools that were selected to participate in the project.

1.1 Previous CSIRO work

CSIRO has developed and patented technology that enables 3D simulations of real world environments using Zebedee - hand held laser based simultaneous localisation and mapping of physical environments such as a building, campus or natural environment. While Zebedee quickly scans objects by walking around the InsectScan system can populate that 3D environment with the tiniest of creatures. CSIRO has also developed an immersive telepresence system for education (Panommmersion technology) that was used in

Figure 1 Museum robot at the National Museum of Australia
the previous Museum Robot (mbot) project (CSIRO 2015).

1.1.1 Museum robot

A visit to a museum can be a real eye-opener. But for some, such as students in rural areas of Australia, the aged in care facilities and those unable to leave their homes, a physical visit can be an impossibility no matter how much they’d like to go.

The museum robot project was a trial of remote telepresence at the National Museum of Australia. The robot accompanies education staff through the museum’s galleries, taking remote visitors on a virtual tour using a high-speed broadband connection that allows remote visitors to interact with a human educator in the museum. The human educator guides the robot through the museum and the remote visitors use a panoramic camera to look around and explore items in the exhibit.

Virtual visitors are able to hear and see the educator with a webcam mounted on the robot and interact with educators on a range of experiences such as multiple-choice questions and polling. Educators are able to gauge visitor responses in real time. The can also look around the museum to see and interact with information about each of the objects on display.

![Figure 2 Museum robot interactions](image)

The robot generates a map during setup and uses that, with its laser guided base, to navigate to set locations in the museum where goals or topics are setup.
Each visitor is sent a spherical video. They can then pan around that video seamlessly, quickly and independent of the other visitors.

Figure 3 Map of museum generated by the robot

Figure 4 Each user chooses their own view from the panorama
1.1.2 Zebedee

Zebedee (CSIRO 2015a) is a handheld laser scanner that creates 3D maps of difficult environments in the time it takes to walk through them. It doesn’t rely on GPS, making it suitable for a range of scientific and commercial applications.

Simple to use, Zebedee creates 3D laser maps continuously, quickly, reliably, and cost-effectively. The system is suitable for 3D mapping applications in indoor, underground and outdoor environments, including locations previously inaccessible to larger scanning equipment. And unlike wheeled mobile systems, Zebedee can operate on stairways and rough terrain.

1.1.3 InsectScan

Scanning small things needs a precision rig. The CSIRO rig, shown in Figure 6 below, captures about 4500 high resolution 2D photographs; tens of gigabytes of data. After reconstruction, the resulting 3D models are around 10 MB in size; small enough to be easily stored and shared.

InsectScan (Nguyen et al 2014) was developed because there was no similar solution in the market. With scientific applications in mind, CSIRO developed the system using low cost, off the shelf components, to put it within reach of researchers, collections and museums.

The hardware and software costs are under $10,000.
3P Learning has developed an online science learning resource called IntoScience (IntoScience 2015). Based on the Unity gaming engine (a powerful rendering engine and development suite that supports the creation and publishing of interactive 3D content), the IntoScience educational platform allows students to enter into a (rendered) 3D world to discover, experiment, learn, play and recall scientific knowledge and skills. Students perform these activities in imaginary environments. This project has demonstrated innovation by constructing new learning environments that are accurate replicas of real-world locations.

The objectives of the 3D Online Education project are to:

- Demonstrate innovative uses of high-speed broadband and digital technologies in the delivery of learning via new online education services.
- Increase engagement amongst school students in science, technology, engineering and mathematics (STEM) areas.
- Provide an engaging, supported and effective online 3D learning environment for students and citizens.
- Establish the collaborative relationships with schools and commercial partners that will enable technologies developed under this project to become self-sustaining at the conclusion of the Commonwealth funding.
2 Activities

The activity of the project is to create two independent, but related education experiences:
3D Education. Build 3D education modules, for two sites, based on real world places.
Immersive telepresence. For the same two sites build immersive telepresence installations.

With two outstanding education tools the project also explored how they could be connected.

2.1 3D education platform

The current environments used as the settings for lessons in IntoScience are fantasy environments; they are imaginary spaces that have been created by designers at 3P Learning. This project has constructed new learning environments that are accurate replicas of real-world locations.

The basis for the shape of these replica environments is the point cloud data generated using CSIRO’s Zebedee hand-held laser scanning technology. Using Zebedee technology to bring realism to 3D game-based learning environments provides improved learning opportunities in STEM subjects to Australian students and a technological advancement relevant for online education systems in general. CSIRO has developed methods for speeding up the process of constructing replica environments from Zebedee data.

The environment provides the context in which the learning takes place. CSIRO has improved the InsectScan technology to make it easier to scan small, fragile or short lived things to enrich the education experience.

3P Learning has pulled all of these elements together to build educational environments for the Jenolan Caves and the HMB Endeavour. They have crafted activity focused learning modules to exploit the richness of the environments.

2.1.1 Zebedee laser scan

The CSIRO developed Zebedee handheld laser scanner was used to record three dimensional maps of environments of interest for use, together with the associated video footage. The generated map is later converted to a usable mesh format for use by the education software.

In this case, the scanned areas were the Endeavour replica ship in Sydney and large areas of the Jenolan cave system in the Blue Mountains, NSW.

Conduct

The scans are produced by walking through the area being mapped with the device and moving in order to observe as much of the environment of interest as possible. The device records 40,000 points per second. After processing each point represents the location where the laser beam intersects the environment. This accurate three-dimensional map of millions of points is then a fixed record from which useful mesh representations can be constructed. Multiple datasets were
taken for each environment and the maps were merged together during processing using custom built place-recognition software. Video footage is also recorded from the device.

Outcomes

Software was built to interpret the point cloud into a mesh format. This mesh is then textured based on information in both the associated video footage from Zebedee and separate high resolution photographs. A custom-built web application was also made available for optimising the task of finding video footage for an area of the map, which reduces the workload of texturing the generated mesh.

![Figure 7 Captured point cloud](image1.png)

![Figure 9 Auto-generated mesh](image2.png)

Benefits

Point clouds provide a high accuracy record of an existing environment from which meshes suited to any virtual world style can be built. This real-world scan provides authenticity to the virtual replica and produces maps that would be very difficult or impossible to generate reliably by other means. Zebedee is ideal for the chosen environments because it is portable, fast to scan, low cost, allows merging of multiple maps and has good global accuracy, plus it can work underground.

![Figure 8 Tool for video frame lookup from point cloud](image3.png)
The associated video footage with the scan provides a high resolution record of the real location, allowing finer objects to be discerned, and captures dynamic features and sounds which a laser scan cannot do. These are all useful in recreating the scene in a virtual world.

2.1.2 Building a 3D Mesh of the environment

The 3D scanning of environments is something which has long been imagined in various films and fiction. The utility of being able to easily scan and capture a 3D environment for visualisation and analysis is readily apparent, as the alternatives are painstaking and meticulous measurements followed by manual reconstruction.

3D scanning techniques are currently increasing, including laser based LiDAR scanning, stereoscopic cameras, structured light or time of flight cameras such and visual structure from motion using standard cameras. While each of these provides various advantages and disadvantages, all most commonly generate data sets referred to point cloud data. These consist of millions of 3D points representing where data samples were attained in 3D space.

Point clouds are relatively easy to visualise on modern computers, but difficult to understand and difficult to extract information from. Point cloud scenes often appear cluttered and require the user to move around the scene in order to interpret the original environment. Additionally, the scanning processes are far from perfect and point cloud data often suffer from three key issues: noise, outliers and coverage. These are illustrated in Figure 10.

![Image of point cloud data issues](image.png)

**Figure 10** An illustration of the issues facing point cloud data reconstruction

This has led to a large body of research into converting point cloud data into more traditional triangle based 3D meshes for visualisation and processing. 3D meshes are used in most computer graphics visualisations including technical and architectural visualisations, games and films.
Converting point clouds to 3D meshes continues to be an active field of research as separating good data from bad and dealing with missing data pose particularly challenging problems.

Within the context of the 3D Online Learning project, the goal was to scan real world environments – the Jenolan caves and the Endeavour – using the Zebedee scanner, then create a virtual 3D visualisation of the environment within 3P Learning’s Into Science product. This has the added difficulty of generating a 3D mesh which is sufficiently succinct for use in Into Science.

**Conduct**

Zebedee is a highly portable laser based, LiDAR scanner. The primary advantage of Zebedee is the ease with which a scan can be performed and a point cloud generated. As with all scanning techniques, Zebedee data have particular advantages and shortcomings. Development efforts have focused on catering for these shortcomings to a sufficient degree to generate a viable mesh for 3P Learning.

Note that any mesh generated by an automated process would always require manual, human intervention in order to meet the stringent requirements of the Into Science product. In particular, the final mesh must:

- Be a succinct description of the real environment. In technical terms, the mesh requires a low number of triangles or rendering performance suffers significantly.
- Be appropriately coloured to match the visualised environment. Mesh triangles generally have no colour information on them and textures are “painted” onto the mesh to add colour.
- Represent only the primary environment. Objects in the environment, such as clutter on tables, chairs, cannons on the ship, etc., are represented by separated meshes.

All these processes either require human judgement because of the complexity of the task, or to fill in data simply not present in the Zebedee scan, as in the case of texturing the mesh.

Research began by evaluating existing tools and techniques for converting a Zebedee point cloud to a mesh. Several commercial products were considered, including VRMesh (VRMesh 2015), Geomagic Wrap (Geomagic 2015) and 3DReshaper (3DReshaper 2015). Each tool was evaluated for the both quality of the resulting mesh and for the viability of using the mesh to create the artistic mesh for use in Into Science.

The Jenolan caves mesh was originally generated using 3DReshaper. It was then extensively edited by hand to address failings in the reconstruction, especially with respect to holes where insufficient data was present, to reduce the number of triangles and add textures (colour information). This proved to be a laborious and sometimes tedious process.

After scanning the Endeavour, the research focus shifted to provide a better initial mesh and reduce the amount of time spent fixing the scanned mesh. The Endeavour proved to be a particularly challenging environment due to the detail of the ship, many cramped spaces, the high level of clutter and even the motion of the ship on the water during scanning. Custom algorithms were created and these were able to:

- Greatly reduce or eliminate the number of holes in the generated mesh.
- Better represent two sided surfaces with some thickness such as walls and floor/ceiling.
- Preserve fine detail in the original scan.
The results are shown in Figure 11. Research has continued in order to further improve the results of these techniques.

**Outcomes**

The Jenolan caves scan has resulted in a 3D visualisation of the 690m long Chifley cave system in 3P Learning’s Into Science product. Without the Zebedee scan, attaining a reasonable, nuanced representation of the cave system would have taken many more person months of measurements, reference photography and modelling. This is despite the time spent fixing issues in the automatically generated mesh.

The custom algorithms were used to generate the Endeavour mesh removed the need for so much fixing and patching of the automatically generated mesh. Instead, efforts turned immediately to constructing the succinct model of the Endeavour and adding the coloured textures to the model. Due to the geometrically regular nature of constructed environments (as opposed to natural ones) the precision of the automated mesh was not satisfactory for use. Instead, the generated mesh was used to help guide accurate references of scale and position of items within, and features of the ship. These features were created by IntoScience 3D artists with reference to technical and historical documentation of the ship’s construction.

**Benefits**

The custom algorithms developed as part of this project are suited to reconstructing any kind of environment and specifically address shortcomings in Zebedee scans, such as non-uniform coverage. These algorithms also serve to preserve fine detail in the scanned environment, such as being able to preserve the ropes and part of the ship’s rigging. Had they been available, these...
algorithms would have saved significant effort in reconstructing the Jenolan caves. These algorithms are likely to assist in future scans of natural environments.

2.1.3 Scanning small 3D objects

CSIRO has developed a prototype system for 3D scanning tiny objects in natural colour — called InsectScan — it is the first such scanner in the world (Nguyen, et al 2014). This technology has been improved on and adapted for use in the 3D Online Education Project in order to bring scientific specimens into the student’s 3D lesson environment.

Conduct

The original InsectScan system relied heavily on specific off-the-shelf hardware, some of which has since been discontinued. Throughout this project we have made a range of upgrades and improvements. The biggest of these is the switch from a hardware controller with a cumbersome user interface to a more versatile computer software controlled system that can be operated from a standard windows desktop.

CSIRO trialled alternative optical capture systems, and written new software to interface with them. In addition, some specimens have been scanned in two complementary modalities – InsectScan for the coloured 3D surface and computed tomography (X-ray CT) for the internal structures.

Outcomes

Partnerships have been built with the Australian National Insect Collection (ANIC) and the Australian National Botanic Gardens (ANBG) in order to borrow and, in the case of ANGB, be licensed to take cuttings of relevant specimens.

A range of small and fragile ‘Banks specimens’ have been scanned and examples can be seen below. These include two views of a blue/black Chrysolophus Spectabilis beetle, two views of a red/black Cimex Armatus beetle, the underside of a Mycalesis Treminus butterfly, a sprig of Eustrephus Latifolius with a more detailed close up of one of its fruit, and three views of a sprig of Trema Tormentosa leaves and fruit.
A new web-based 3D graphics rendering prototype was developed that is capable of displaying both the coloured outer surface and the internal detail. Examples from our early prototype,
depicting the internals of a flower bud, are shown below. These are screen captures from a web viewer that uses open standards and runs in most modern browsers without plug-ins.

**Benefits**

Joseph Banks and other crew members on the HMB Endeavour made the first known collections of Australian insects and plants during their exploration of Australia in 1770. The actual insect specimens collected are now housed in the British Museum. The plant specimens originally collected by the crew have since been pressed, dehydrated, and are split between various herbaria in Australia and the UK.

Though the development and use of the new 3D scanning technologies, interactive online lessons can now include relevant objects such as plants and insects that were otherwise quite difficult to access.

**2.1.4 Building a 3D Education environment**

The creation of a 3D replica environment of the Jenolan Caves from point cloud data collected by the Zebedee scanner was conducted in Q3 2014. The environment, intended for use in an educational setting as part of the IntoScience platform, was created using a combination of point cloud data, 3D photogrammetry and photographic images. The environment and the embedded learning activities were completed in July 2014 and delivered to schools the following month.

**Conduct**

During the project, teams from CSIRO and IntoScience visited both the Jenolan Caves and the HMB Endeavour sites. On these visits a test site was chosen, technical trials were conducted and a full scan of the selected environments were conducted.

The output of these visits was a significant amount of data in the form of point cloud data, photogrammetric information and reference images. A 3D modeller from IntoScience used these outputs to create a 3D mesh of the Jenolan environment with sufficient detail of key features, including calcium carbonate crystals, cavern structures, sails and rigging, along with textural information of the scanned surfaces. The output of these efforts was a complete 3D environment of a major section of the Chifley cave system, and a reconstruction of the HMB Endeavour as high detail models.

While the detail of these produced models could perform well on high-end computers, through experiments it was determined that such detail would lead to significant performance issues on standard school infrastructure. In order to have these environments deliver a reliable experience across a range of platforms the detail of these models had to be reduced. Optimisation of these 3D models was needed to significantly reduce detail in terms of polygon counts while maintaining accuracy and authenticity of the original models. These optimised models were of sufficient quality to import into the Unity game engine and subsequently, the IntoScience platform. In these environments 3P Learning built learning modules or activities.

**Jenolan Caves**

The Jenolan Caves learning module in IntoScience is an integrated guided inquiry investigation that’s primary purpose is to help students to identify how the caves and their crystal structures
have formed. Through the interaction of a number of activities distributed throughout the Jenolan environment, along with items collected within the space that interact with these activities, students investigate samples in the environment, record environmental data, combine and separate samples and explore the chemistry of the formation of stalactites and stalagmites through crystallisation processes.

**Figure 14 IntoScience Jenolan Caves**

*Jenolan Journal – science inquiry and chemistry*

This activity gives a guided structure to the student’s investigation. Each segment of the activity begins with guiding questions, such as “investigate how rainwater and limestone contribute to cave formation”, and takes on a predict, observe, record, explain structure. Through this activity

**Figure 15 a) Jenolan journal finding Zebedee b) Jenolan investigation**

students primarily learn science inquiry skills of recording information, explaining observations and making predictions based on evidence.
The Journal also serves as a space to record and collect other observations tangential to the main chemistry questions. Here students can collect findings about the local ecology, historically significant artefacts and items of technology used to create the 3D environment.

**Investigation Program – chemistry and physics**

Throughout the cave environment students are able to collect samples of rocks, liquids and gases found in the cave environment. Students bring these samples back to sample stations distributed around the 3D space which takes them to the Investigation program. In the investigation program the students are able to analyse the samples for their chemical and physical properties, test their acidity and analyse their chemical composition. Further in the lesson students can begin mixing samples to check for different types of changes, as well as perform separation techniques in order to extract some specific chemicals. This activity covers many areas of chemistry and physics through years 6 – 9.

![Figure 16 a) Instruments and b) Challenges](image)

**Instruments – science inquiry and equipment**

Distributed amongst the caves are sample stations that students must activate. When activated the students must arrange a number of scientific devices, including thermometers, hygrometers and CO2 readers in order to make observations of the surrounding environment. The data from these devices is later used to draw conclusions about where stalactites typically form. These activities teach science skills based outcomes aimed primarily at scientific equipment.

**Mid / End Challenges**

These challenges are quiz-based summative assessments of the learning outcomes within the Jenolan Caves environments. The Mid Challenge has six random multiple-choice questions and the End challenge contains fifteen such questions.

**Endeavour**

The educational content in the Endeavour environment is much less complex than those in the Jenolan Caves lessons due primarily to the lack of development time. The content is less inquiry-based in general and is instead focuses on direct instruction. The environment is divided into three
separate areas explained below. The embedded lesson reward students for discovering all the points of interest.

![Image: Upper deck and Afterfall with Joseph Banks samples](image)

**Figure 17 a) Upper deck and b) Afterfall with Joseph Banks samples**

**Upper Deck - physics**

The students can explore various features on deck including: the ships bell, the cannons, the steering wheel and the associated navigational instruments, double block pulleys and a telescope. Through these areas of interest students learn the historical and scientific significance of these items.

**Mess hall - health**

Here students can explore the ship’s interior and discover sauerkraut, cured beef and other food in order to learn about the significance of hygiene and health on board the ship.

**Afterfall – geography and biology**

In the captain’s area of the ship students are able to discover: the ship’s map as well as biological samples collected by Joseph Banks. These samples are demonstrations of the InsectScan technology embedded in the 3D environment. Through these items of interest the student learns the significance of Bank’s discoveries and the journey of the Endeavour.

**Outcomes**

The 3D educational environments were used to create expansive inquiry-based science investigations that were both aligned to the Australian Curriculum and relevant to the given context. The Jenolan caves environment targets learning outcomes in chemistry, earth sciences and ecology, while the Endeavour environment targets learning outcomes in physics, technology and science and human endeavour.

Activities created in these environments were designed to measure and demonstrate learning outcomes through data collected on student engagement, completion, and a summative test in the form of 15 multiple choice and text entry questions.
The Jenolan caves environment was delivered to the public in August 2014 and has been operational in the IntoScience platform for over a year. The Endeavour environment and educational content have been privately released to a select number of schools for beta testing.

**Benefits**

The outputs of these activities were used to create new opportunities for the delivery of innovative educational experiences to teachers and students. The outcomes led to a series of benefits:

- Grounding a science investigation in a real life environment, giving students a greater understanding of the applicability of outcomes learned in school
- Making a popular school excursion site in NSW accessible to regional, interstate and international schools which would not typically be able to visit.
- Providing students a 3D environment which they can navigate and explore using a 3D avatar, giving the context of the learning outcomes a spatial element similar to a real tour of the environment.

In all the outcomes produced many benefits for learning, however, despite collected data on participation there is a need for more evaluation on the educational and attitudinal impact of the experience for students.

### 2.2 Panommersion system

Initially developed as part of the Mobile Telepresence for Museums Initiative, CSIRO’s Panommersion technology enables students to participate - via a computer in their school, home, or local library - in live, immersive, interactive lessons delivered by an educator from a remote location such as a laboratory, or other educational setting. The Panommersion system requires a broadband internet connection at each end to stream panoramic video from an omni-directional camera, allowing multiple students (or classes of students sharing a connection—for example in front of their classroom Smartboard) to connect at the same time, but each have a unique visual experience. Using a standard PC, headset and web-camera, the students use a browser-based interface to look around the laboratory/environment by panning and zooming within the panoramic image. They can click on highlighted objects within their field of view to explore digital content that has been linked to those objects, and are challenged to respond to real-time quizzes posed by an educator. The students can see, hear, and interact with the educator and other students via a video-chat system that is integrated into the browser-based interface - just as if they were together in the laboratory.

The original implementation of the Panommersion system on a mobile robot placed a number of constraints on the system which could now be relaxed. CSIRO was able to improve the resolution of the system (from 2k to 4k), which provides an enhanced visual experience for remote students (or visitors). The project enhanced the educational potential of the Panommersion system by providing visitors with the ability to add annotations to objects they can see in the panoramic vision, and for these annotations to be immediately published to other online students.
The Panommersive lessons provide an opportunity for students with a high-speed broadband internet connection to participate in lessons provided by expert educators they would not otherwise be exposed to, and set in locations they would not otherwise be able to access.

Unfortunately the first site (Jenolan Caves) was unsuitable for the panommersion system due to the lack of high-speed broadband. The panommersion system has been installed in the HMB Endeavour, where the internet is access by a fibre optic cable while at the dock and distributed via the Australian National Maritime Museums gigabit AARNET connection.

2.2.1 System architecture

The panommersion system built upon elements of the Museum Robot system described in Section 1. Key differences include using a fixed instead of mobile panoramic platform and physically separating the guide application from the panoramic platform. The Museum Robot system has a single panoramic camera mounted on the robot and connected to the panoramic computer on-board the robot. This computer has a touch screen interface that enables the guide to control the tour, see and talk to remote visitors and command the robot to move between waypoints. Streaming of the panoramic camera video, control of the tour and interaction with remote visitors therefore all occurs from the single computer and is directly controlled by the Guide software running on that computer.

![Diagram of the panommersion system](https://example.com/diagram.png)

**Figure 18 Panommersion system diagram**

In the panommersion system there are multiple stationary cameras and a single portable device providing the guide with a user interface to control the system and interact with remote visitors.
This portable device has no direct connection with the panoramic cameras as in the museum robot system and can therefore not perform the panoramic streaming. Each panoramic camera therefore requires its own streaming computer and new software to enable the portable device to control the streaming remotely. The control of the tour also differs as a tour no longer consists of moving the robot between waypoints, but now of starting and stopping different panoramic cameras and providing these different panoramic video streams to the remote visitors.

The development of the pannonmersion system therefore required development and extension of the following system components:

1. Pano servers that connect to the panoramic cameras and stream the panoramic video as directed by the Guide app.
2. The Guide app that runs on a tablet computer and provides the guide with the user interface to control the tour and interact with remote visitors.
3. The back end servers that provide the website, database and media server functionality.
4. The remote visitor web browser interface.

2.2.2 Pano servers

The Pano Streamer system primarily consists of a paired panoramic camera and streaming PC. The firewire connected PC processes the raw panoramic image it receives from its paired camera and delivers the processed image to CSIRO servers via a physical on-ship internet connection. The streaming PC also connects wirelessly to the guide tablet and receives instructions from educators regarding the tour.

Conduct

The process of design and research of the Pano Streamer system can be broken up into three main sections: Camera parameter optimisation; PC processing performance profiling; and PC hardware and form factor design.

There is an obvious trade-off between panoramic stream quality and the processing power required to stream the feed. Extensive testing of different camera parameter configurations was undertaken in order to optimise the quality of the panoramic stream. It was during this testing phase that optimal values for parameters such as bit-rate, resolution, colour processing were determined.

Once there was a benchmark for the requirements of the processing power of the streaming PC, the design of the PC could be undertaken. Various hardware components were individually tested for adequate performance characteristics and then tested again in specific PC build configurations. This process also informed previous decisions made regarding camera parameters and stream performance and the viability of those design choices.

The limitations of the design of the PC streamer primarily consisted of a physical size constraint and connectivity to various other elements of the system. In order to preserve the requirements of portability and modularity of the system, several design choices were made in order to produce a PC streamer system which was as physically small as possible.
Ultimately, over several iterations of PC hardware builds and system profiling, a suitable final design was chosen which gave the best possible processing performance whilst remaining compact.

**Outcomes**

From the chosen configuration five systems were built, with three packaged and deployed on the Endeavour and two kept for spares and testing.

**Benefits**

The final Pano Streamer system is able to locally process raw panoramic data and stream a quality panoramic feed from the panoramic camera to CSIRO servers over the internet. Having the panoramic images of the camera processed locally makes the system portable and modular and allows for more processing power per camera than other alternative designs. The portability of the design consequently allows for the installation of such systems into environments with minimal effort and minimal impact on the environment itself. Increased modularity of the system design makes it easier to install several connected Pano Streamers in a setting, which ultimately provides more content for tours. The installation of three such systems aboard the HMB Endeavour shows that the final design of the Pano Streamer system is robust enough for quite difficult operating environments.

**2.2.3 Guide app**

The guide application provides a user interface to the guide and enables them to coordinate the running of the tour and interact with the remote visitors. This activity is about re-engineering the guide application, extending the software from the Museum Robot project to work with the panoramic streamers to start and stop different panoramic cameras as the tour progresses. The new application also needed to work on a tablet computer, iPad, and operate as a purely touchscreen application that fits within the iPad user interface requirements and available computing resources.

**Conduct**

The guide application is implemented in Adobe Flash for AIR (Adobe Integrated Runtime), which allows the application to be packaged and run on different platforms including iOS, Android, OSX and Windows. The primary release of the software is on iOS for iPad, but testing has also been conducted on Windows 8 based tablets.

The key tasks to develop the guide application were:

- Restructure the application code to utilise the mobile optimised components of Flash, which provide a better experience on touch screen based devices.
- Implement new software components to communicate with and control the panoramic streaming computers.
- Re-implement the lesson controls to progress the tour between panoramic streamers in response to guide inputs.
- Implement pausing and restarting of the lesson to enable the guide to disconnect from the lesson when walking between panoramic cameras on the HMB Endeavour.
• Implement new “skins” for the application so that the visual style and layout conforms with current mobile application design guidelines.
• Configure continuous integration building of the software so that release packages of the latest software version are automatically generated and ready for installation on iOS and Windows.

**Outcomes**

The guide application was completed and released for iPad and Windows. The application initially presents the guide with a lesson setup view where they will see a list of any lessons that are scheduled to begin in the next 30 minutes. The details of the lesson can be seen, and further detail on the topics within the lesson can be selected.

When the guide is ready they will connect to the lesson and the application will move to the lesson view as shown in Figure 19. In this view the guide can see a silhouette for each remote visitor in the lesson, the view from one of the tablet’s cameras, start (or pause) and stop buttons, buttons for each topic in the lesson and buttons to ask the visitors questions. When the application has finished connecting to the first camera the guide can start the lesson which will begin the panoramic camera and the iPad camera streaming to the remote visitors.

![Figure 19 The default lesson view](image)

During the lesson the guide can speak with one of the visitors by touching the visitor’s silhouette. The active visitor view will be shown as in Figure 20 and the guide will be able to see and hear the remote visitor. All other visitors will also be able to see and hear the active remote visitor until the guide ends the connection with them.

When it is time to move to the next topic of the lesson the guide can press the next button, or alternatively select a specific topic from the list to move straight to it. If the topic is associated
with a different panoramic camera then this new camera will be started and the remote visitors will be able to see the new stream. The topic may instead be a static topic with only a static image instead of a camera stream, in which case the remote visitors will see the panoramic image while still being able to see and hear the guide.

During the lesson the guide can press the “Y/N” button or the “ABC” button to enable all of the remote visitors to be able to answer a question. The guide will ask the question and depending on which button was pressed the visitors will see either yes/no buttons or A, B, C buttons. Each answer will be shown next to the visitor’s silhouette so the guide can quickly see everyone’s answers.

As the application requires a continuous network connection to stream the guide video to the visitors, if when moving between cameras the guide will pass through an area with no or poor WiFi coverage they will need to pause the lesson. When this is done the guide camera will stop, but the panoramic camera will continue to run, so visitors can continue to look around the panorama and click on hotspots. Once the guide has arrived at the next camera the guide can recommence the lesson and again be seen and heard by the remote visitors.

![Figure 20 The active visitor view](image)

**Benefits**

The guide application provides an easy to use and effective interface to control the lesson and interact with remote visitors. By using Adobe Flash and Adobe Air to implement the application it is versatile in what operating system it runs on and makes use of the strong media streaming capabilities of Adobe Flash. Having been tested on iPad and Windows 8 tablets, with the future possibility of also using Android tablets the application is not constrained to a single device type.
2.2.4  Configuration web services

Web pages and services are used to:

- configure the system
- manage user accounts
- book tours
- set up tour content
- service non-video content to the visitors
- provide the public presence and control when joining a tour

Conduct

The bulk of the web pages and services were brought across from the museum robot project. The physical nature of the robot constrained the way tours operated and how the panoramas were captured.

The panoramic camera sat on top of the robot and the interface to capture images was onboard. This interface was first moved to the iPad guide app. This proved unsuccessful due to limitations with the video processing interface on the iPad. The decision was made to switch the capture to the web pages where a PC could be used.

An activity to capture, store and reuse panoramic video was started. The goal was to be able to play back pre-recorded panoramas where a live stream was impractical due to network considerations. The initial capture was successful, however there were insufficient resources to complete the file management and guide display interfaces required for its effective use.

Support services were required for transitioning from the 3D environment to the panommersion environment. Tours were once tied only to a map as the robot generated 3D maps of its environment. This was extended to allow tours to bind also to a 3D scene. The scene is developed offline and imported into the service interface. For tours attached to the scene additional services provided locations and schedules where tours would start.
Finally, bugs were fixed in both the old and the new system.

**Outcomes**

The web-based image capture is used to obtain static panoramas. These enable the setting up of hotspots for the live tour, in locations which will match the video stream. From the 3D support services panodes (see section 2.3) could be located in the 3D scene and a list of ticketed tours could be displayed.

**Benefits**

Capturing static images is of critical benefit to the system. The static panoramas for the base of topics (or goals), which are the learning modules of the system. The hotspots setup provide valuable detailed information for visitors.

The panodes and ticketed tour list provides a transition from the 3D environment to the panommersion system.

**2.2.5 Collaborative environment**

For visitors in the museum robot the main interaction was with the guide. Apart from hearing others conversations with the guide there was no interactions between visitors. To enhance the group experience on the endeavour a visitor annotation system has been added.

**Conduct**

Visitors now have access to an icon and text annotation system. For each panoramic topic a visitor can add up to five icons. At each icon the visitor can add a short multiline text message. The icons are stuck on the panorama. That is as the panorama rotates the icons rotate with the panorama. Icons can be moved and removed. If the guide takes the tour to a new topic the icons for that topic are hidden. If the guide returns the icons reappear.

Icons and text from other visitors are visible on each other’s panoramas. So visitors can see other icons and read their text. Icons are assigned to visitors on a first come first served basis. There are 15 unique icons, all from the public domain (Figure 23).

There is no filtering on the text messages. If they are getting out of hand the guide can turn the whole system off from the guide app settings.

**Outcomes**

Visitors can use the icons to point out interesting features. Text associated with icons allows visitors to communicate directly with each other. Figure 23a (left) shows Gavin looking at Anne’s note with his icon in the background and Figure 23b (right) shows Anne looking at Gavin’s note with Anne’s icon in the foreground.
**Benefits**

The panoramic video provides context to the guide's talk. Visitors can use the panoramic video to communicate with the guide. In a real tour environment there is a back story. Students would be pointing at things and whispering to each other about interesting things they see around them. The collaboration enhancements allow students to replicate part of that experience.

![Collaborating with icons a) Gavin's screen and b) Anne's screen](image)

---

### 2.2.6 Panommmersion and the HMB Endeavour

The HMB Endeavour is in the care of the Australian National Maritime Museum. It was chosen as a site of the panommmersion system due to its uniqueness and widespread recognition. With uneven surfaces and plenty of stairs it also suited a non-robot approach.

**Conduct**

The panommmersion system used on the HMB Endeavour has been developed to provide remote students with a similar, if not better, educational experience while not affecting visitors on the ship. In order to achieve this, much time and discussion was put into how the cameras and systems could be installed on the HMB without being obvious to the ‘live’ visitors. The position of cameras was decided on by the significance of what was in view and the ease of installation and use by an educator. The Great Cabin was high on this list due to the historical and scientific significance. The mid-ship position with a view of the main cooking area and mess showed how life was for the rest of the crew. The foredeck gives a view of the masts and rigging and the ‘seat of ease’ which is always an interesting topic. (Figure 24)

**Panoramic cameras**

The main problem was in the 18th Century look of the Endeavour and how a five sided, black anodized camera (Ladybug) would fit in without looking out of place. The most obvious solution for the cameras in the Great Cabin and the Galley were to put the cameras inside something that would not affect the picture quality of the online visitors. This was made possible by recreating the copper lanterns that are used on the ship to provide light (Figure 25a).
Figure 24 Interactions of panommersion system

The Ladybug camera (Figure 25b) is essential to the delivery of a panoramic video experience. This camera is made by Point Grey and features six, two Megapixel cameras in a pentagonal shape, with one camera on top. In order for the camera to work inside the lantern, the camera has been turned upside down so it is hanging from the ceiling.

Figure 25 a) ANMM replica lantern b) Ladybug camera c) project replica lantern with ladybug

The lanterns used on the HMB were made using copper in roughly the same way as they would have been in the 18th century when the original Endeavour was built. When asked if a camera could be placed in one, the ANMM were not forthcoming as they cost approximately $4000 each to have made. Instead custom replicas were made out of aluminum.
The design was drawn up in CAD and made by the metal workshop at QCAT. The original lamps had rivets holding them together which we were not available in aluminum. This was overcome by using TIG welding a lump over each join to look like the head of a rivet. To hold the camera in place, a 3D printed ABS cage was made to connect the camera to the main support bolt, which held the ring on top.

The finished lanterns (Figure 25c) were anodized in a copper colour to give the authentic look if the black paint is scraped away. A perspex tube was used to protect the camera. The end result was very acceptable to the ANMM and the shipkeeper was impressed with how well they looked like the original.

For the external foredeck camera, there was no way to hide what it was and nothing nearby to hang it off. The decision was made to make a mount that could clamp onto a beam on the foredeck. This would not look 18th century at all, so no attempt was made to hide it.

Pano Server Installation

The computer systems used for the panoramic streaming (PC) were installed into protective boxes that enable the systems to be brought onto the ship with relative ease. Given that the PCs needed to do a lot of processing, the enclosure design required ventilation. The Great Cabin is a special place on the ship. It required a special box that was similar to the other blanket boxes that were already there. A custom ‘blanket box’ was made that was ventilated and able to hold the PC and the panoramic camera ‘lantern’ when not in use.

Each box employs an Ethernet over Power (EOP) adapter to provide network connectivity without the need for additional cables. This enabled the cabin box to only require an IEC power cord to a hidden power point for the system to have power and network connectivity.

The other two panoramic servers were installed in waterproof Pelican cases with space to hold the camera and mount (lantern for the mid-ship and the post for the foredeck). These boxes are not ventilated to maintain the watertight seal. As they are not on public display, they can be left open while in use. This is enough to provide adequate cooling for the PC.

The midships box was relatively simple with only space for the PC, EOP adapter and lantern needed. The Foredeck camera was a more complex problem which needed a post to be designed that would meet with the following criteria.

1. Easy for educators to assemble/disassemble with no tools needed.
2. High tolerance to positioning error so camera is always in the same spot.
3. Have camera at 1.6m above deck so items of interest are visible.
5. Must mount securely to ship without causing damage.

These constraints were all met with a design that used a clamping system onto a main bearer on the foredeck. This clamp held the post which had a swivelled, extendable section to reach the desired height. Pieces were held in place using cam lock levers that require no tools and are easy to use. The post was designed in SolidWorks (CAD) with the CSIRO QCAT workshop making the post. The whole post is made from aluminium with stainless steel bolts and fittings used. A foam tape was used on the underside of the clamp to ensure the woodwork and paint on the ship was not damaged.

The final design needed to have a wedge inserted under the clamp to bring the post closer to vertical. This was due to an error in measurement when originally scoping the position of the post.

The post has been installed and removed on the ship many times and shown that an educator can do it with relative ease.

**Outcomes**

The pano server units were installed on the HMB Endeavour from March through to May 2015. ANMM staff were able to unpack and pack the equipment as required and it could be easily removed from the ship when it sailed.

**Benefits**

Simple and historically sensitive equipment helps preserve the ambience of the live visit to the Endeavour. Should the ANMM adopt the equipment longer term the camera cable could be built into the ship and the below deck camera left up all the time. This has been done for existing electrical wiring to the ANMM lanterns. A rapid deployment would then be possible for the guides.

### 2.3 Interaction between the 3D environment and the Panommersion system

This project encompasses both a 3D virtual world and a panommersion system. A key goal of the work is to explore how transitions can be made from one system to the other.

#### 2.3.1 Panodes

A prototype transitions from the 3D environment to the panommersion system via panodes. Kazys Stepanas coined the term panode for the spheres, painted with a scaled down static
panoramic image. They are panoramic nodes in the 3D environment. The image is used in other parts of the system to create hotspots and as a backup if the panoramic camera goes down.

**Conduct**

The 3D model is an environment in which activities can take place. To utilise that environment an interaction engine is required. 3P Learning uses the Unity engine for their IntoScience product, so it made sense to use that also for the demonstration environment. Panodes were added to the base 3D model, within the Unity engine to act as portals to the panomersion system.

Service pages for creating topics were extended to allow a Z coordinate, on top of the standard map based two coordinates. This information is normally populated by the robot. In the 3D environment controls were added to all selection of points for panodes.

Tours are not always running, they are dependent on a guide being available. To provide the crosswalk without the guides, point of interest panodes were created. These transitioned to a simple static panorama with a hotspot viewer.

![Figure 28 Pannodes on deck of Endeavour model with scheduled tour](image)

**Outcomes**

This system demonstrated the ability to traverse a 3D environment and enter a panoramic space through the panode portal. The initial environments were generated directly from the Zebedee scan and meshing tools, allowing exploration of both the mesh and the transition. Later environments (shown) contain the model developed by 3P Learning.
Benefits

The panode demonstration was able to show 3P Learning what was possible in a couple of months work. Being able to transition from a 3D simulated world to a real world anecdotally increases the excitement about both experiences. It also allows the contrast of differences between the 3D and real world. The 3D model is based on the best understanding of what the Endeavour was really like. The panommersion experience shows the ship as built. With allowances for modern seafaring and the vagaries of the builder.
3 Evaluation

3.1 Approach and methodology

The project is being evaluated through two main strategies:

1. The gathering of usage statistics from the logs of 3P Learning’s IntoScience product. The statistics are being reported against metrics which are described in detail in the appendices. The metrics where largely listed in the project implementation plan and any undefined requirements clarified by the steering committee.

2. A set of studies to evaluate the impact of the outputs of the project on students and teachers.

3.2 Evaluation of the 3D system

IntoScience publically launched the Jenolan Caves 3D environment during Australian National Science Week 2014 (16-23 August). The event engaged 625 schools and over 16 000 students in the learning modules. These statistics were captured on 3Ps user tracking software which collects data on student, class and school logins.

3.2.1 Approach and methodology

The IntoScience platform records data at the level of individual students, classes of students and schools. For individual students there are measures of engagement, completion and performance in educational topic areas within IntoScience. For classes and schools there exists data on the number of classes registered to that school, each class year group and the number of students they contain. For the purposes of this evaluation the IntoScience profile services were interrogated for any school, class or student participation in the Jenolan Caves activities.

3.2.2 Results

The results cover two periods of investigation: a launch event, and a long-term record of activity during the year since its release.

IntoScience publically launched the Jenolan Caves 3D environment during Australian National Science Week 2014 (16-23 August). The event saw 625 schools register for participation and over 16 000 students taking part in the learning modules.

In the target period of ‘Australia’s Biggest School Excursion’ the following outcomes were recorded:

- 16 179 students participated in activities within the Jenolan Caves 3D environment.
- 1 431 classes enrolled students in the activities.
- 625 school registered interest in participating in these launch events.
The event itself led to valuable outcomes in the form of new subscribers to the IntoScience platform. It also attracted local and national media and was officially launched by the then Minister for Communications, Malcolm Turnbull, at Scots College, Sydney.

Table 1 Summary of 3D product results against targets

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target</th>
<th>Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of STEM lessons delivered</td>
<td>100 STEM subject lessons</td>
<td>762</td>
<td>See Table 12 in Appendix C.1</td>
</tr>
<tr>
<td>Number of students participating in STEM lessons</td>
<td>7500 students across 550 schools participating in STEM subject lessons</td>
<td>45755 students across 705 schools</td>
<td>See Table 11 in Appendix C.1</td>
</tr>
<tr>
<td>Number of students participated in STEM lessons from home</td>
<td>1700 students participating from home</td>
<td>Unknown</td>
<td>Unfortunately IntoScience does not yet have capability to record time stamped data, nor IP address to the above mentioned statistics. This makes analysing where and when students recorded points for participation impossible. As a result there are no reliable figures on home usage.</td>
</tr>
<tr>
<td>Number of students contributing to the design and creation of the 3D environment</td>
<td>150 students participating in testing</td>
<td>300 Students</td>
<td>Number of students involved in alpha and beta testing. 175 testing the Jenolan Caves environment. 125 testing the HMB Endeavour environment.</td>
</tr>
<tr>
<td>Number of teachers contributing to the design and creation of the 3D environment</td>
<td>20 teachers contributing to the design and creation of the 3D environment.</td>
<td>15 Teachers</td>
<td>Number of teachers involved in alpha and beta testing. 9 testing the Jenolan Caves environment. 6 testing the HMB Endeavour environment.</td>
</tr>
<tr>
<td>Number of schools contributing to the design and creation of the 3D environment</td>
<td>3 high-speed broadband schools participating in testing</td>
<td>5 Schools</td>
<td>Number of schools involved in alpha and beta testing. NOTE: high-speed broadband connection is not a requirement to use IntoScience. 3 testing the Jenolan caves environment. 2 testing the HMB Endeavour environment.</td>
</tr>
<tr>
<td>Number of real world sites mapped</td>
<td>2 real world environments mapped</td>
<td>2 environments</td>
<td>The Jenolan Caves and the HMB Endeavour</td>
</tr>
<tr>
<td>Number of STEM learning module developed</td>
<td>7 STEM modules developed</td>
<td>7 modules</td>
<td>As agreed in March 2015 the modules considered the same as IntoScience activities. There are seven activities given in section 2.1.4.</td>
</tr>
<tr>
<td>Number of 3rd party products and services adopting these modules</td>
<td>2 Commercial adopters of the platform</td>
<td>2 adopters</td>
<td>3P Learning is the adopter of the IntoScience platform and is continuing to develop it. The Australian National Maritime Museum has adopted the panomersion platform and is seeking sponsorship to maintain it</td>
</tr>
</tbody>
</table>

Collected data from the year to date after the public release has shown that:

- 705 unique schools with registered classes have taken part in these activities
• 2,982 classes have recorded participation in these activities, with 90% of these classes being from years 7, 8 and 9.
• 45,755 students have recorded engagement with these activities.

Table 1 gives a brief comparison of the Jenolan Caves IntoScience data against the required metrics.

Evaluation of criteria on the student satisfaction and learning outcomes is covered in Section 3.4.1 and Section 3.4.2 respectively.

See Appendix C for finer detail on usage statistics.

3.2.3 Sustainability and scalability

The outputs of these activities proved valuable to the evaluation of delivering innovative 3D environments in an educational setting. Not only did the event lead to increased business interest, importantly it demonstrated a desire for schools and teachers to deliver memorable and unique experiences to students, especially around events that celebrate the role of science in society.

Commercial direction for IntoScience

Looking forward, the two scanning technologies, the Zebedee scanner and the InsectScan, represent immense value to future projects integrating real-world environments and historically accurate samples. With the assistance of these technologies a small team have demonstrated that they can produce a highly accurate digital replica of a real life environment in relatively short time.

These scanning technologies hold great potential for future projects involving the IntoScience educational platform. They make available many opportunities to allow students to explore and examine everything from precious and fragile artefacts, to dangerous or inaccessible environments and using these simulations to create unique teaching moments that could not be created in person. That these technologies cover both the macro and the micro leads to a great variety of options for digitisation. The team at IntoScience are keen to explore future projects using the InsectScan technology and an improved Zebedee scanning technology.

Key factors for sustainability

In this project a total of two high detail environments, featuring elaborate educational content was produced within a four to six month period each. While this represents a scalable approach to delivering a consistent suite of immersive learning experiences while remaining a small workforce, further improvements to the processes and algorithms of the technology would help to limit manual work, production costs and delivery times.

The primary impediment to greater scalability surrounds the accuracy of the Zebedee’s recorded point cloud, and the lack of textural or colour information available from the Zebedee scanner. A mass of person-hours are spent manually repairing holes in meshes, or recreating features of the environment that are of a medium to small size that the Zebedee is not accurate enough to detect. Pairing the Zebedee point cloud with other data sources, such as photogrammetry, may provide more accurate recreations of objects, environments and their colour and textural information. This would significantly cut down manual labour and would see greater sustainability of producing such 3D environment simulations.
3.3 Evaluation of the Panommersion system

The panommersion system was installed only for the HMB Endeavour as the Jenolan Caves, had very limited internet connectivity. The direct evaluation of the panommersion system was carried out by collecting usage statistics. The teachers involved in the tours were interviewed to support the argument that the technology baseline for the education sector was improved (see Section 3.3.4 for the analysis).

3.3.1 Usage of panommersion system

Tours on the HMB Endeavour included lessons in physics (pulleys), mathematics (time) and health (preventative medicine and hygiene). All lessons included all parts.

In the end three lessons were delivered at one school for year 7, 8 and 9 classes of roughly 20 students each.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 STEM lessons by panommersion.</td>
<td>3 STEM</td>
<td>It was difficult to arrange lessons. Lining up network connectivity, ship availability and class availability was challenging. The nature of the evaluation study with pre and post experience questionnaires meant everything needed to work first time for the classes. Seven lessons across three schools were scheduled for delivery. Of those three schools one had firewall issues and on other had bandwidth issues.</td>
</tr>
<tr>
<td>10 students in each lesson</td>
<td>25 students year 7</td>
<td>Lessons were given in front of a whole class.</td>
</tr>
<tr>
<td></td>
<td>15 students year 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 students year 9</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Panommersion results against targets

The panommersion system was included in the study of learning outcomes and student satisfaction. The analysis can be seen in Sections 3.4.2 and 3.4.1 respectively.

3.3.2 Approach and methodology to interviews

We planned to conduct semi-structured interviews with the science teachers, who were present at the virtual visit and whose students interacted with the Panommersion platform. The goal of the interviews was to understand:

- Students’ participation and interaction in the virtual visit as perceived by the science teachers based on the teachers’ observations.

- Teachers’ views and beliefs about the potential benefit of using immersive telepresence technology for education delivery.

Due to technical issues, only one school successfully completed the virtual visit. We interviewed the science teacher from that school. The interview was completed two weeks after the virtual
visits. The telephone interview lasted around 25 minutes and was undertaken by two CSIRO researchers. The interview was audio recorded and transcribed.

The interview participant was asked to elaborate on the experiences, observations and reflections in relation to the use of panommersion platform for learning and teaching. The interview participant was encouraged to discuss in detail the benefits and shortcomings of the Panommersion technology and the innovative approach to deliver online education services supported by the high-speed broadband network (see examples of interview questions in Appendix B).

3.3.3 Results of interview

The teacher we interviewed involved in two virtual tour sessions for their year 7 and year 8 students. One session had 25 students and a second session had 15 students. Each session lasted around 70 minutes. Both sessions were held in the learning centre of the school. A laptop was setup to allow the students to interact with the guide at the museum. One student operated the Panommersive platform through the laptop, while the screen of the laptop was projected to a large screen for other students.

Students’ interaction and learning experience

The teacher we interviewed had positive feedback on the students’ interaction experience and learning experience in the virtual tour. They felt that students’ participation and interaction were the same as those of normal teaching lessons. When asked how the virtual tour compared to being physically present in the museum, they felt that it was the same. The positive feedback can be exemplified by the following comments:

“They were very interested because it's - it was the novelty of it and being able to interact on the computer, so, yeah, they were quite fascinated with it.”

“The positive aspect is that you still have the students in a controlled environment and they are very much engaged and they feel it’s a very unusual interactive thing where they are virtually out of the classroom.”

“They did very much like the interactive aspect, that they could - that the one student on the laptop could work the cursor to move the camera and - or that they could talk to that person in Sydney who would just answer their questions and walked around and zoom into things for them, so this aspect made it very real for them.”

They found that the teaching material delivered by the museum was very interesting and engaging. However, they suggested that the learning goal for the lesson needed to be discussed and communicated between the teacher and the museum guide before the virtual tour, to make sure the lesson would be tied in well with the learning goal.

Technical issues

The teacher mentioned that there were three short-term transmission breakdowns in one of the sessions. This could have been due to a network connection problem and the lesson was stopped for a couple of minutes before the connection was re-established.

They also pointed out that only one laptop was used at the school site and the ability of individual navigation was limited. The panommersion platform allows multiple simultaneous connections.
and the teacher expressed her desire to allow more computers for the class if the network bandwidth issue can be solved:

“That is probably the only thing they do not have on – when we do an interactive like that there is one guide out there talking to the whole class, there is no individual choice whether the individual child now wants to look at that or maybe just want to look at a different label.”

Overall satisfaction with the class teaching using the panommersion platform

They were satisfied with the teaching using the panommersive platform in general, although they would use it as a complementary tool in teaching. They explained that:

“It’s just that I think learning should be using several means of teaching a student and this would be one tool amongst a number of tools I would like to use to teach a student…. So, for the activity, just rating the activity, so it’s an excellent activity and is very satisfied, but if I use it - I would not use it all the time, it can be only one tool amongst many different tools in teaching.”

They also suggested an audio-video recording of the session so that the same group of students could do a follow-on study as an extension of the virtual tour.

They stated that they would recommend the use of the panommersion platform to other teachers and they would like to use the platform for teaching in the future.

The benefit of using immersive telepresence technology for education delivery

The teacher highlighted the remote interaction and engagement experience enriched by the platform. They commented:

“Because the students can get in contact with the outside world around them and they can visit places they can’t go to usually and they’re still very interactive, actively engaged in visiting these places by allowing them to interact with people that are there and talking to them.”

They also pointed out that the telepresence technology could be valuable in the teaching of science and other subjects and can become one of the components of the overall teaching experience.

3.3.4 Sustainability and scalability

This section looks at where the opportunities are for increasing adoption of the panommersive technology.

Broaden the outreach and visibility in education

Enhancements to the panommmersion system since the museum robot project has not substantially changed the look and feel. What has significantly happened is the guide and panoramic interfaces have been separated from the robot. Free from the robot guidance and power constraints, more challenging environments and higher quality immersive imaging has been achieved. It was possible to install the system on an ocean capable ship of significant celebrity, the HMB Endeavour.

Adding iconic structures to the list of immersive telepresence installations is certain to increase visibility of and engagement with immersive telepresence. However there exist many barriers to the adoption of new technologies in classrooms. Primary barriers typically relate to the
technology’s ease of use, the teachers confidence and competence with the technology and the amount of support, both educational and technical, that is available. Teachers may be time-poor and many will not have the experience, confidence or time to manage new technologies.

The panommmersive system experienced difficulties when attempting to integrate within the classroom environment, in part due to bandwidth issues, but also due to technical difficulties related to school IT infrastructure, firewall permissions, significant setup time and preparation.

Further development of the technology should be conducted alongside research into the realities of the classroom and school environments and the demands of teachers from a practical and educational point of view. In order for this technology to be sustainable it must seek to increase its compatibility with the classroom infrastructure, improve its ease of use and overcome its perceived barriers to adoption. Teachers of all three schools scheduled for tours continue to be enthusiastic about the new technology. If these issue can be ironed out there is great potential for future tours.
Commercialisation

The initial market survey to identify prospect entities for commercialization has led to a broad field of firms, headquartered in Australia and overseas (see Appendix D). Due to the tight integration of the 3D environment and the Panommersion system, a commercialization to any of these firms is limited by their interest in both technologies, at the same time. This limits the application and target market significantly, and the following areas have been identified for a broader technology push:

Education

A synergy of the two technologies maximise the educational benefit. While 3D environments allow rapid creation and exploration of new environments, the Panommersion offers a direct way of collaboration, interaction and remote presence within such environments.

Construction

The construction industry relies on 3D and geo-referenced information on a day-to-day basis. Combined with Panommersion, the ability to “pan in” on the site via installed security cameras, dedicated camera systems or mobile video stream resources offers significant opportunities for workers to share a common understanding at the strategic level. An example is for engineers to evaluate progress live and guide suppliers and contractors according to new information. In addition, the visual feedback through 3D and Panommersion creates a common understanding among contractors and suppliers with different domain knowledge, easing collaboration and communication. Due to the digital content, access can be given to remote experts from across the world, e.g. to inspect the building plan of a large-scale construction while inspecting the site immersive via video.

Based on the engagement with 3P Learning throughout the initiative, it is expected that an increasing interest and consequent uptake of the technology will take place. Especially the implementation of the Endeavour allows project staff to present a first product prototype to interested parties and firms while receiving continuous feedback on how to improve the system to meet market demands.

3.4 Whole of project analyses

Some parts of the evaluation apply to both the 3D and the panommersion system. The project examined how the two systems affected student attitude to a career in STEM and their learning outcomes.

3.4.1 Improved interest in STEM

Approach and methodology

CSIRO has conducted an evaluation study aiming to understand how the delivery of lessons using the Panommersion platform impacts the attitude of students towards science and technology. The instrument used to assess the students’ attitude was a scientifically validated questionnaire specifically aimed at measuring student attitude towards science (see Appendix B.2) (Kind, et al 2011). The questionnaire was developed and validated by researchers at Durham University, UK, and subsequently applied in a number of studies in a variety of settings and environments.
The questionnaire consists of 37 questions, addressing six constructs of attitude towards science: learning science in school (6 questions), self-concept in science (7 questions), practical work in science (8 questions), science outside of school (6 questions), future participation in science (5 questions), and importance of science (5 questions). The student answers the questions on a 5-Likert scale and an aggregated attitude score is computed out of the individual construct scores. For comparison purposes, we collected students’ self-reported measures with regard to these aspects twice: approximately two weeks before and after the experience. In addition, basic demographic information about the students (see Appendix B.1) were collected in both questionnaires.

To single out the impact of the panommmersive technology and the implications of using various modalities of the experience, we studied the change of student attitude towards science in four experimental conditions:

- **Real visit to the site and direct interaction with the exhibits and content.** This involved a visit to the HMB Endeavour at the Australian National Maritime Museum. The lessons at the Endeavour were delivered by qualified museum guides.

- **Virtual visit using the 3P IntoScience content only (no panommmersion platform).** This virtual tour involved the use of the interactive IntoScience content developed by 3P Learning. The students used personal computers to explore topics similar to the topics presented at the real visits to the HMB Endeavour or Jenolan Caves.

- **Virtual visit using the panommmersion platform only (no 3P IntoScience content).** Virtual tour was conducted by using the platform with network connections between the schools and the Australian National Maritime Museum. During the virtual tour, the students had the opportunity to talk to the museum guide and watch high-definition video transmitted from the HMB Endeavour.

- **Static teaching.** Normal classroom lessons focused on the topics similar to the topics presented at the visits to the HMB Endeavour. The lessons were accompanied by printed and multimedia content, but were delivered in an offline mode.

We planned to recruit 3-4 high schools for each experimental condition, aiming to assign 70-100 year 7/8 students in each school to the above conditions. Note that all the students from a school participated in the evaluation were assigned to the same condition. All the students from the classes selected for the evaluation participated in the experience, as per the condition to which the school was assigned. However, only the students who returned to the school a consent form signed by their parents or guardians were allowed to fill the two questionnaires. We planned to keep gender, age, and socio-economic distribution of students across the four conditions as uniform as possible.

The pre- and post-experience questionnaires were completed online and stored securely by 3P Learning. The scores of attitude towards science were computed and the differences between the pre- and post-experience scores were analysed. We examined the differences against the year, gender and socio-economic level of the students. The data collected by both questionnaires was anonymised, such that no individually recognisable data was collected.
**Results**

The data presented in this report is based on the available cases at the time of writing. The number of schools and students who participated in the evaluation was lower than planned, primarily due to difficulties in recruiting schools and students, sticking to the time line of consent forms and questionnaires, and the busy schedule of the HMB Endeavour exhibition. As the number of participants was lower than planned, particularly in the panommmersive condition, the evaluation cannot draw out clear and conclusive results. However, we will highlight here the main trends observed in the evaluation, while the detailed results are presented in Appendix A.1 and Appendix B.

Table 4 in Appendix A.1 shows the mean scores achieved by the evaluation participants in each of the six constructs of the attitude toward science questionnaire, namely Learning science in school, Self-concept in science, Practical work in science, Science outside of school, Future participation in science, and Importance of science. In addition to these, we computed the “Combined Interest in Science” score. All the scores were computed on a 1-to-5 point scale, where 5 was the highest possible score.

We observed that the overall attitude towards science decreased slightly, from 3.09 (N=509) to 2.97 (N=307), which accounts to 3.88%. This should be considered in the context of a greater variability of results, since the number of participating students was lower and the standard deviation increased by about 20%. This practically means that the questionnaire responses were noisy and no strong claims about the statistical significance of the results can be made. This finding holds if breaking the combined score into the individual constraints of attitude. The mean scores of only four out of the six constraints decreased (at most by 9.8%) and scores of two constructs were stable. However, the observed standard deviation was significantly higher, which undermines the validity of the results.

Considering individual experimental conditions and the combined attitude score, we observed an increase of 7.0% in the classroom condition, decrease of 20.7% in the panommmersive system, increase of 1.9% in the site visit condition, and decrease of 3.9% in the Jenolan condition. Again, the variability of the results was too high to draw clear conclusions. Focusing on the construct referring to future participation in science, we observed no difference across the four conditions, while in the individual conditions this construct increased by 5.4% in the classroom condition, decreased by 14.1% in the panommmersive system, increased by 4.8% in the site visit condition, and decreased by 1.0% in the Jenolan condition.

We conducted gender-based analysis and re-computed the construct scores and the combined attitude scores for female and male students separately. This is reported in Table 5 in Appendix A.1. Overall, the trends were very similar to those listed in the overall analysis, with little of the observed difference being attributable to the gender of the students. Considering the combined science attitude scores, female students slightly outperformed males, achieving the scores 3.02 vs 2.97, respectively. This gives 1.7% higher scores by female students. Within the four experimental conditions, the most prominent differences of 7.5% and 5.6% were observed in the classroom and panommmersive conditions, respectively. As pointed out in the overall analysis, the observed gender differences were too small to exhibit statistical significance.
We also conducted an age-based analysis and separated the attitude towards science results obtained by Year 7 and Year 8 students (see Table 6 in Appendix A). As one could expect, the Combined attitude score of Year 8 students was higher than that of Year 7 students, 3.22 vs 3.03, respectively. This matches closely to 6.3% higher scores achieved by Year 8 students and reflects a greater emphasis on science topics in the curriculum of Year 8. Within the four experimental conditions, the most prominent difference of 22.3% was observed in the site visit condition. Considering the individual constructs, in which the greatest change in attitude was observed, we highlight the science outside schools and future participation in science constructs, each scoring between 7% and 8% improvement for Year 7 and Year 8 students.

Finally, we grouped the schools according to their average ICSEA (Index of Community Socio-Educational Advantage) score. The ICSEA scores were obtained from a public database (ref) and the participating schools were split into three groups: below-average, about-average, and above-average ICSEA. The overall Combined Interest in Science score are reported in Table 7 in Appendix A. The attitude scores were found to positively correlate with the ICSEA score and for the three groups it was 3.04, 3.14, and 3.19, respectively. Considering the scores within each bucket, we observed very slight increases in the below-average and about-average groups (0.8% and 0.9%, respectively) and very slight decrease of 2.1% in the above-average group. Again, these results may be attributed to noise and insufficiently high number of students rather than to statistically significant differences.

**Key findings**

Overall, little change was observed in the experimental evaluation. In the classroom and site visit conditions we found minor improvements in the Combined Interest in Science score. An improvement in the attitude towards Future participation in science was also observed in these two conditions. The gender comparison did not yield strong results, with female and male students achieving comparable scores of Combined Interest in Science.

Some differences were observed in the age-based comparison, where Year 8 students scored higher than Year 7 students, particularly with regards to the science outside schools and future participation in science constructs. The ICSEA-based analysis showed that students in the schools with higher ICSEA scores achieved higher scores in Combined Interest in Science than those in schools with lower ICSEA scores.

The project sought to find a 20% improvement in interest in STEM career, particularly from the IntoScience system. The result was not strong enough to indicate any significant movement.

### 3.4.2 Improved learning outcomes

**Approach and methodology**

We conducted an evaluation of the learning outcomes by using questionnaires developed by museum educators and domain experts from ANMM and 3P Learning. We used only the post-visit knowledge questionnaire since the students were unlikely to correctly answer the knowledge questions before the visit. The questionnaire contained 10 multiple-choice questions referring to the knowledge of the topics covered by the experience (see Appendix B). The correct answer to each question was worth 1 point and the total score of each questionnaire was based on the sum of the 10 questions and ranged from 0 to 10.
**Results**

The average knowledge score was 4.91 in the classroom condition, 5.33 in the panommerision condition, and 5.16 in the site visit condition. Overall, the knowledge scores obtained in the conditions were comparable, with a slight superiority of the panommerision condition. Again, the number of students completing the knowledge questionnaires was too small to draw statistically significant conclusions or analyse the outcomes with regards to gender, age, or socio-economic level of the students. Also, the socio-economic level of students in the conditions was quite different, which does not allow us to directly compare the conditions.

In the Jenolan condition, the average knowledge score was 5.97, although this referred to a different knowledge questionnaire and was not directly comparable to the other three conditions. Detailed results of the learning outcome are presented in Table 8 in Appendix A.2.

The knowledge questionnaires were also looked at for an absolute learning outcome. That is, did the students retain any of the content in the lesson? For a 10 question multiple choice exam where each question has four possible answers a random set off answers will on average get 25% of the questions right or 3 out of 10. In Table 3 below it can been seen that in all experiences over 80% of students retained knowledge better than a random result. Full figures are in Table 9 in Appendix A.2.

<table>
<thead>
<tr>
<th>Number correct</th>
<th>Classroom</th>
<th>Panommerision</th>
<th>Site Visit</th>
<th>Jenolan</th>
</tr>
</thead>
<tbody>
<tr>
<td>% better than 3+</td>
<td>0.83</td>
<td>1.00</td>
<td>0.85</td>
<td>0.95</td>
</tr>
</tbody>
</table>

**Key findings**

The knowledge scores observed in the different conditions were comparable. However, this should be considered in the context of the small number of students and substantial differences between the conditions. Thus, we are not able to clearly draw conclusions about the relationship between the conditions and knowledge outcomes. Across all experiences more than 80% of students retained some knowledge from the lessons. The classroom was the worse of the experiences with the two virtual visits being the best. The number of students who completed the questionnaire in the panommerision case is too small for a reliable result (only 12 students).

### 3.4.3 High-speed broadband

*Degree to which the 3D software demonstrates the capabilities of Australia’s high-speed broadband infrastructure*

The USA Federal Communications Commission (FCC) defines broadband as internet access at speed significantly faster than dial-up modems. (FCC 2015)

In 2010 the FCC defined broadband as having a minimum download speed of 4 Mbps (megabits per second) and a minimum upload speed of 1 Mbps, or 4/1 Mbps. In 2015 the FCC revised the definition to be 25/3 Mbps. (Wigfield 2015)

In Australia broadband is provided over a variety of mechanisms including (commsau 2013):
• **ADSL2+:** Over copper via the telephone exchange. Theoretical speeds of 24/3.3 Mbps are possible. More than half however have download speeds less than 9 Mbps and most upload speeds are less than 1 Mbps.

• **HFC:** Hybrid Fibre Coaxial cable can deliver 110/2.4 Mbps with upgrade paths. Bandwidth is shared amongst premises so contention can degrade the throughput.

• **FTTP:** Fibre to the premises can deliver 2500/1200 Mbps over 32 premises with 100/40 Mbps being the highest plan commonly offered by NBN.

• **FTTN:** iiNet in Canberra offers a fibre to the node service of up to 80/20 Mbps. (iiNet 2015)

• **4G Mobile:** Multiband LTE based systems are capable of 100/40 Mbps but the bandwidth is shared and prone to contention by other mobile users.

• **NBN Fixed wireless:** A 4G mobile technology with a fixed number of users delivering 25/5 Mbps.

• **Satellite:** Offering 6/1 Mbps now and 25/5 when new satellites are operations. Latency (or lag) is high.

The 3D online education project produced two distinct products with different characteristics. 3P Learning’s IntoScience product provides a 3D learning experience in virtual worlds including Jenolan Caves. The HMB Endeavour virtual world is in alpha release. The product has been optimised to be small enough to run on an iPad 2 and download over a home connection (mostly ADSL2+).

The optimization produced a dramatic reduction in quality. For example the HMB Endeavour model derived from the Zebedee scan was 8 million triangles whereas the one used in the alpha system is 250 thousand triangles, a 30:1 reduction. Should high-speed broadband become commonplace then a much more detailed model (and richer experience) could be provided for certain platforms.

The pannommersion product from CSIRO requires download of streaming high resolution (4k) spherical video, two way video conferencing and shared object synchronisation. The version of the system installed at the National Museum of Australia required 10/2 Mbps. The high upload is due to the video conference and shared object synchronisation.

Initially it was thought the new installation at the Australian National Maritime Museum would require higher 15/2 Mbps. However after testing a lower 5/2 Mbps was found to be acceptable because the panoramic cameras are in fixed locations on the ship, instead of moving around on the robot. The reduced movement in the video means less bandwidth is required. As it stands it is the upload capacity that constrains the pannommersion system. It can only run where there is 2 Mbps upload available which rules out most common form of broadband ADSL2+.

An evaluation of the pannommersion system was conducted with Australian secondary schools. It was challenging to find schools with the bandwidth requirements. Other schools wanted to have multiple schools connect simultaneously, significantly increasing the bandwidth needed. In the end the pannommersion system was tested by three schools. All had 100 Mbps connections to the school.

• School one could not go ahead because the software used ports that are commonly blocked by schools. Schools block these internet ports to stop students using up school bandwidth by
downloading videos. Video, of course, one of the primary drivers for high-speed broadband. Permission to open the ports had to be sought from the state Department of Education.

- School two encountered quality issues which could have occurred at a variety of points between the school and the cameras.
- School three initially experienced bandwidth issues and the system testing was then performed over a 4G modem. 4G devices are fairly new and limited bandwidth contention was experienced. This may not always be the case. Later tests found router settings at the schools were not favourable to video transmission. Contention with other school internet traffic was causing reduced quality.

These tests show that many factors are involved in the successful use of high bandwidth technology. Only with the whole ecosystem geared toward the use of high bandwidth applications do we get effective use of high-speed broadband.

The panommersion system, requiring 5/2 Mbps, is a good example of software that requires high-speed broadband infrastructure. It is particularly suited to the new infrastructure being rolled out as part of National Broadband Network. It needs networks that comply with the new USA FCC definition of broadband 25/3 Mbps.

This application though is just the tip of the iceberg. Over the last year there has been significant investment in panoramic video requiring high bandwidth. Google has developed the jump processor for panoramic video and, together with GoPro, has developed high resolution cameras producing stereoscopic panoramic video at over 150 Mbps. (GoPro 2015; Google 2015) Video including panoramic video will really drive the broad need for high-speed broadband.

3.5 Future directions

This section will look at the key technologies development in this project and explore where each technology could go individually and together.

3.5.1 Immersive telepresence

These technologies immerse users in the content. The project has made a real time panoramic video stream available but to be truly immersive more consideration needs to be given to the user context. During testing with schools it was clear that just have high-speed broadband available is not enough. The panommersion system was developed to deliver immersive lessons to individuals on separate high-speed broadband connections. In school context however this is often not the case. Used in a group setting a lot of the immersive aspects are lost. Additionally there were institutional issues reducing its broad appeal.

Future work on this system could include:

- Gaining a deeper understand as to how teachers would prefer to use immersive systems.
- Updating to new web technologies such as WebGL (web graphics) and WebRTC (web real time chat) to open up access through institutional barriers.
- Adjust system output dynamically to real life broadband constraints.
- Develop a peer to peer or multicast form for multiple users with a single broadband connection.
• Open up the video stream to a wider audience.
• Support a broader set of user devices (iPads, VR systems).

3.5.2 3D virtual worlds

The original premise was that by using Zebedee and advanced meshing algorithms the building of real world 3D environments for education could be made possible. The project has shown this, but it has also shown that the current process is not well suited to constructed objects (like the Endeavour). Future work could focus on:

• Being able to identify, semiautomatically, which surfaces are meant to be smooth and therefore focus on provision of detail on irregular surfaces.
• Be able to properly track voids in the scanning. A reconstruction would know then that there is definitely nothing in that spot (rather that it just not being scanned).
• Tie photogrammetry in with scanning.

Better use could be made of the high resolution 3D model produced by the project. Possibly with an interactive exhibit at the Australian National Maritime Museum.

3.5.3 3D and immersive technologies

There are opportunities to use the technologies together. Firstly the 3D models could be used to augment the reality of the live tours. Educators can visually reconstruct some parts of the panoramic picture to show historical dynamic features such as how an item was used or how a ship was damaged. Secondly panoramic video or stills could be used create a back drop to a 3D experience. Such as showing what it was really like at sea.
4 Conclusion

The project had four objectives which were delivered as described in the following sections.

4.1 High-speed broadband

*Demonstrate innovative uses of high-speed broadband and digital technologies in the delivery of learning via new online education services.*

3P Learning have added two new sites to their education platform IntoScience, the Jenolan Caves and the HMB Endeavour. 3P Learning delivers the IntoScience platform online, either directly into classrooms for via local services. Innovative scanning technology allowed the recreation of real world environments and inclusion of high detailed plants and insects. The IntoScience virtual excursion won the NSW iAward for education services.

At the same time panoramic cameras were installed on the HMB Endeavour and a tablet based app written for immersive telepresence lessons from the Endeavour. New forms of high-speed broadband were crucial for the delivery of the lessons into classrooms.

4.2 Engagement in science, technology, engineering and mathematics (STEM)

*Increase engagement amongst school students in science, technology, engineering and mathematics (STEM) areas.*

The products developed by this project were evaluated in a school context. Measures of engagement in STEM were compared across classroom, 3D IntoScience, Panommersion and live visit experiences. Unfortunately no strong conclusions could be drawn from the evaluation. However schools and students were eager to be involved with both the IntoScience and panommersion products.

4.3 Online 3D learning environment

*Provide an engaging, supported and effective online 3D learning environment for students and citizens.*

In recruiting schools for the project it was found many were eager to be involved with the 3D IntoScience project and panommersion system. The technical requirements for the latter did make it difficult to turn that eagerness into participation. 3P Learning continues to support the use of the Jenolan Caves site in the IntoScience product and will also support the Endeavour site when it is released in 2016. The Australian National Maritime Museum is eager to reach out to students and citizens with the panommersion system on the Endeavour. The knowledge assessment in the evaluation did not show any strong learning benefit for the technologies, however they were still effective in teaching student STEM material.
4.4 Collaborations

Establish the collaborative relationships with schools and commercial partners that will enable technologies developed under this project to become self-sustaining at the conclusion of the Commonwealth funding.

3P Learning has integrated the work on the Jenolan Caves and the HMB Endeavour into their IntoScience product. This product has engagement from schools across Australia. They have indicated a willingness to look at further sites as it fits their product cycle. The ANMM is pursuing commercial supporters to fund continuing use of the panommersion platform and is eager to leverage the technology to engage across Australia using high-speed broadband. Schools contacted for panommersion trials are eager to continue engagement with the ANMM. A commercial partner for the panommersion system is being sought.

4.5 Closing remarks

The 3D online education project has succeeded in producing two 3D education tools and one immersive telepresence system. The 3D system has been based on two real world sites, the Jenolan Caves and the HMB Endeavour. Scanning with the Zebedee hand held scanner was more effective for the more natural site, the Jenolan Caves, where the natural variation disguised the noise of the instrument. Partners 3P Learning released the IntoScience product containing STEM lessons in Jenolan Caves in August 2014 where it has been used by thousands of students. The Endeavour site in IntoScience has been through initial testing with a full release due in 2016. CSIRO has scanned plants and insects which were similar to the ones collected by Joseph Banks on Cook’s voyage on the Endeavour. The technology allows looking at the inside and outside of specimens, opening up access to the small and fragile. Scans have been included in alpha release of the Endeavour IntoScience product.

On board the HMB Endeavour at the Australian National Maritime Museum (ANMM) three, live, streaming, panoramic cameras have been installed. A non-robot panommersion system has been used to deliver virtual tours and STEM lessons to schools. The ANMM is eager to leverage the technology to engage across Australia using high-speed broadband. The panommersion system is still early technology and relies heavily on infrastructure that is not yet fully deployed. Like many early technologies refreshing and reshaping the technology is essential as it finds the right timing for wide spread adoption.

While the product evaluation did not indicate a strong learning benefit from using advanced technologies in classrooms some of the results were inconclusive. Both products certainly generated smiles and enthusiasm in their use. Continued investment in advanced learning technologies will deliver many more.
## Appendix A Evaluation questionnaire results

### A.1 Result for interest in STEM career

**Table 4 Average attitude towards science measures in four conditions**

<table>
<thead>
<tr>
<th>Measures</th>
<th>Classroom - Before</th>
<th>Classroom - After</th>
<th>Panommersion - Before</th>
<th>Panommersion - After</th>
<th>Site Visit - Before</th>
<th>Site Visit - After</th>
<th>Average scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N=43)</td>
<td>(N=45)</td>
<td>(N=44)</td>
<td>(N=12)</td>
<td>(N=207)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning science in school</td>
<td>3.37</td>
<td>3.28</td>
<td>3.64</td>
<td>2.53</td>
<td>3.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-concept in science</td>
<td>2.98</td>
<td>3.19</td>
<td>3.48</td>
<td>3.24</td>
<td>3.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practical work in science</td>
<td>4.12</td>
<td>3.85</td>
<td>4.22</td>
<td>3.49</td>
<td>4.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science outside of school</td>
<td>2.69</td>
<td>3.09</td>
<td>3.08</td>
<td>2.61</td>
<td>3.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future participation in science</td>
<td>2.46</td>
<td>2.74</td>
<td>2.70</td>
<td>2.32</td>
<td>2.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of science</td>
<td>3.64</td>
<td>3.04</td>
<td>3.67</td>
<td>3.43</td>
<td>3.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined Interest in Science</td>
<td>2.84</td>
<td>3.04</td>
<td>3.14</td>
<td>2.49</td>
<td>3.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5 Average Combined Interest in Science measure against gender**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Classroom</th>
<th>Panommersion</th>
<th>Site Visit</th>
<th>Jenolan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male before</td>
<td>2.83</td>
<td>2.87</td>
<td>3.14</td>
<td>3.22</td>
</tr>
<tr>
<td>Male after</td>
<td>2.84</td>
<td>2.49</td>
<td>3.20</td>
<td>3.15</td>
</tr>
<tr>
<td>Female before</td>
<td>3.05</td>
<td>3.09</td>
<td>3.14</td>
<td>-</td>
</tr>
<tr>
<td>Female after</td>
<td>3.04</td>
<td>2.57</td>
<td>3.20</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 6 Combined Interest in Science measure against school years**

<table>
<thead>
<tr>
<th>School year</th>
<th>Classroom</th>
<th>Panommersion</th>
<th>Site Visit</th>
<th>Jenolan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y7-Before</td>
<td>-</td>
<td>3.14</td>
<td>3.02</td>
<td>3.32</td>
</tr>
<tr>
<td>Y7-After</td>
<td>-</td>
<td>2.49</td>
<td>3.00</td>
<td>3.24</td>
</tr>
<tr>
<td>Y8-Before</td>
<td>2.84</td>
<td>-</td>
<td>3.59</td>
<td>3.12</td>
</tr>
<tr>
<td>Y8-After</td>
<td>3.04</td>
<td>-</td>
<td>3.76</td>
<td>3.00</td>
</tr>
</tbody>
</table>
Table 7 Combined Interest in Science measure against ICSEA

<table>
<thead>
<tr>
<th>Interaction Mode</th>
<th>ICSEA</th>
<th>N before</th>
<th>N after</th>
<th>Average measure - Before</th>
</tr>
</thead>
<tbody>
<tr>
<td>School 1</td>
<td>Classroom</td>
<td>903</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>School 2</td>
<td>Site Visit</td>
<td>922</td>
<td>82</td>
<td>38</td>
</tr>
<tr>
<td>School 3</td>
<td>Site Visit</td>
<td>1017</td>
<td>81</td>
<td>46</td>
</tr>
<tr>
<td>School 4</td>
<td>Site Visit</td>
<td>1027</td>
<td>44</td>
<td>31</td>
</tr>
<tr>
<td>School 5</td>
<td>Panommersion</td>
<td>1111</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>School 6</td>
<td>Panommersion</td>
<td>1118</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>School 7</td>
<td>Panommersion</td>
<td>1159</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>School 8</td>
<td>Jenolan</td>
<td>1203</td>
<td>215</td>
<td>135</td>
</tr>
</tbody>
</table>

A.2 Results for knowledge questions

Table 8 Knowledge questionnaires results in four conditions

<table>
<thead>
<tr>
<th>Classroom (N=46)</th>
<th>Panommersive (N=12)</th>
<th>Site Visit (N=140)</th>
<th>Jenolan (N=147)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average score</td>
<td>4.53</td>
<td>5.08</td>
<td>5.11</td>
</tr>
</tbody>
</table>

Table 9 Absolute knowledge attainment from experiences

<table>
<thead>
<tr>
<th>Number correct</th>
<th>Classroom (N=46)</th>
<th>Panommersive (N=12)</th>
<th>Site Visit (N=140)</th>
<th>Jenolan (N=147)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>0</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>1</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>3</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>2</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>4</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>1</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>1</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Number with 3+ correct | 38                | 12                  | 119               | 140             |
Total students          | 46                | 12                  | 140               | 147             |
% better than 3+        | 0.83              | 1.00                | 0.85              | 0.95            |
Appendix B  Evaluation questionnaires

B.1  Demographic questionnaire

Please select the answers that best describes you.

1. Name of your school
   -- list of schools participating in the study --

2. What is your Gender?
   ☐ Male  ☐ Female

3. What is your year group?
   ☐ Year 7  ☐ Year 8  ☐ Year 9

4. Have you visited Jenolan Caves / The Endeavour before?
   ☐ Yes  ☐ No

5. How much experience do you have using 3D computer game for either study or personal use?
   ☐ No experience  ☐ Some experience  ☐ Regular experience  ☐ Daily experience
### B.2 Attitude towards science questionnaire

Please specify the extent to which you agree/disagree with the following statements.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. We learn interesting things in science lessons.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I look forward to my science lessons.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Science lessons are exciting.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I would like to do more science at school.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I like Science better than most other subjects at school.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Science is boring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I find science difficult.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I am just not good at Science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. I get good marks in Science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I learn Science quickly.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Science is one of my best subjects.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. I feel helpless when doing Science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. In my Science class, I understand everything.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Practical work in science is exciting.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. I like science practical work because you don’t know what will happen.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Practical work in science is good because I can work with my friends.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I like practical work in science because I can decide what to do myself.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I would like more practical work in my science lessons.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. We learn science better when we do practical work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. I look forward to doing science practicals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Practical work in science is boring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
22. I would like to join a science club.
23. I like watching science programs on TV.
24. I like to visit science museums.
25. I would like to do more science activities outside school.
26. I like reading science magazines and books.
27. It is exciting to learn about things happening in science.
28. I would like to study more science in the future.
29. I would like to study science at university.
30. I would like to have a job working with science.
31. I would like to become a science teacher.
32. I would like to become a scientist.
33. Science and technology is important for society.
34. Science and technology makes our lives easier and comfortable.
35. The benefits of science are greater than the harmful effects.
36. Science and technology are helping the poor.
37. There are exciting things happening in science and technology.
### B.3 Example questions used in the interviews with science teachers

*We would like to know how you feel about the students’ learning experience in the virtual tour based on your observations.*

<table>
<thead>
<tr>
<th></th>
<th>Much worse</th>
<th>Worse</th>
<th>Similar</th>
<th>Better</th>
<th>Much better</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How were the students’ participation and interaction compared to those of normal teaching lessons</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. From learning perspective, how did the virtual tour compare to being physically present in the museum?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

*We would like to know your overall satisfaction with the virtual tour using the pannomersive platform.*

<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Overall I was satisfied with the use of the pannomersive platform for teaching purposes</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. I would recommend the pannomersive platform to other teachers</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. I would like to use the pannomersive platform for teaching purposes in the future</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
6. In your opinion, what are the benefits of using immersive telepresence technology for education delivery?

7. What were the issues you observed during the virtual tour?

8. Please make any other comments or suggestions related to the delivery of online education services through the panommersive platform and high-speed broadband network.
B.4 Knowledge questionnaire – The Endeavour

1. **The single and double blocks on deck are used to**
   a) raise and lower sails
   b) decorate the masts
   c) help sailors to climb the masts
   d) balance the ship

2. **The masts stay upright on the deck because of the**
   a) dead eyes
   b) hearts
   c) a) and b)
   d) none of the above

3. **The ship’s bell rang every 30 minutes. A sailor knew that his 4 hour shift on deck had finished when he heard the bell ring**
   a) 4 times
   b) 8 times
   c) 12 times
   d) 16 times

4. **Conservation practices were used on the Endeavour. Items that were reused included**
   a) frayed ropes at the ‘seats of ease’
   b) old cheese was carved into buttons
   c) frayed ropes for wiping hands at meals
   d) all of the above

5. **Hanging kegs above the mess tables contained vinegar for wiping down the tables after meals. This was done to**
   a) keep the tables shiny
   b) kill germs to prevent disease
   c) make the mess smell sweet
   d) preserve the wood from damage

6. **Captain Cook included sauerkraut in the food served on board so that the men would not get**
   a) chicken pox
   b) food poisoning
   c) scurvy
d) measles

7. **Sailors who disobeyed rules were punished by whipping with the**
   a) rat o’ four ears
   b) snake o’ three eyes
   c) cat o’ nine tails
   d) dog o’ six legs

8. **All men except one slept in hammocks instead of bunks because hammocks**
   a) take up less space
   b) are more comfortable
   c) stop men falling out onto the deck below
   d) all of the above

9. **Sydney Parkinson was one of the men brought on the voyage by Joseph Banks. Sydney was**
   a) an artist
   b) an astronomer
   c) a secretary
   d) none of the above

10. **Before the last trunnel was nailed into Endeavour, it was**
    a) taken up on top of the Sydney Harbour Bridge
    b) displayed in maritime museums around Australia
    c) taken around the world on a Navy ship
    d) carried into space aboard Space Shuttle Endeavour
B.5 Knowledge questionnaire – Jenolan Caves

Limestone is an example of which type of rock?

- □ Igneous
- □ Particulated
- □ Metazoic
- □ Sedimentary
- □ Metamorphic

You are performing a litmus test on a liquid. You notice that the blue litmus paper turns red when some of the liquid is dropped on. From this you can conclude the liquid is:

- □ Acidic
- □ Basic
- □ Red
- □ Hot
- □ Plasmic

Above is a particle model representing a substance. What state is this substance in?

- □ Gasious
- □ Confused
- □ Liquid
- □ Solid
- □ Water

Which of the following is typically NOT involved in the formation of caves?

- □ Water
• Carbon Dioxide
• Limestone
• Sulphuric Acid
• Calcium Carbonate

You think that a rock you have is a sample of limestone. What test should you perform to check whether this was true?

• Check if it fractures into sheets
• React it with an acidic substance
• See if it leaves a black streak when rubbed on paper
• Test whether it tastes salty
• Burn it under a bunsen burner

Above are the chemical components of a substance. This substance is best classified as a:

• Element
• Chemical formula
• Compound
• Mixture
• Conglomerate

You find a calcium carbonate crystal hanging from the roof of a cave. What is this cave formation typically called?

• A roof spear
• A hanging cave crystal
• A stalactite
• A stalagmite
A swagnamite

Which of these sets of conditions would best describe a cave environment?

- High humidity and a stable temperature
- High wind speeds and low salinity
- High temperatures and very dry
- Low carbon dioxide concentration and sub zero temperatures
- High rainfall and highly variable temperatures

Which of the following are examples of sedimentary rocks?

- Conglomerate, limestone, chalk
- Gold, silver, nickel
- Slate, marble, gneiss
- Led Zeppelin, AC/DC, Pink Floyd

Which ingredient might make a bottle of pop drink slightly acidic?

- The carbon dioxide used to make it fizzy
- The sugar used to make it tasty
- The plastic from the bottle around it
- The purified water used to dilute the cordial
- None of the above
Appendix C Evaluation usage results

A breakdown of the metrics by system and the results. Note a list of schools will be omitted for privacy reasons. Only the number of schools will be given. The Department can request a list of schools for internal use only.

C.1 IntoScience 3D Education Platform

Statistics have been extracted from log files of the IntoScience platform and other data held by 3P Learning.

Table 10 Number of classes for IntoScience Jenolan Caves

<table>
<thead>
<tr>
<th>School Year</th>
<th>10 and up</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5 - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 and up</td>
<td>89</td>
<td>261</td>
<td>1123</td>
<td>1334</td>
<td>97</td>
<td>78</td>
</tr>
</tbody>
</table>

Table 11 Students for IntoScience Jenolan Caves

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of Participating Students Per Year Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School Year</strong></td>
<td><strong>10 - 12</strong></td>
</tr>
<tr>
<td><strong>Investigation Program</strong></td>
<td>223</td>
</tr>
<tr>
<td>Aligned to chemistry and physics outcomes</td>
<td></td>
</tr>
<tr>
<td><strong>Jenolan Journal</strong></td>
<td>140</td>
</tr>
<tr>
<td>Aligned to science inquiry skills and chemistry outcomes</td>
<td></td>
</tr>
<tr>
<td><strong>Sampling Instruments</strong></td>
<td>339</td>
</tr>
<tr>
<td>Aligned to science inquiry skills and equipment</td>
<td></td>
</tr>
<tr>
<td><strong>End Challenge</strong></td>
<td>12</td>
</tr>
<tr>
<td>Summative assessment quiz aligned to above topics</td>
<td></td>
</tr>
<tr>
<td><strong>Average result (Max 15)</strong></td>
<td>6</td>
</tr>
</tbody>
</table>

Table 12 Lessons run per school year

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of Lessons Run Per Age Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School Year</strong></td>
<td><strong>10 and up</strong></td>
</tr>
<tr>
<td><strong>10 and up</strong></td>
<td>22</td>
</tr>
</tbody>
</table>
Appendix D Panommersion potential commercialisation partners

This document presents a series of potential commercial partners to engage with in order to increase the impact of the Panommersive technology developed as part of the 3D online education project. This list excludes the current partner of the project, 3P Learning, as close collaboration is already in place.

Whilst the target sector for the 3D online education project is STEM educators and more broadly Australian schools, the following list includes potential partners beyond this sector for two specific reasons. Firstly, many technology providers offer their products to the education sector as a whole and don’t narrow their scope to schools only in order to maximize revenue opportunities. Secondly, the progression of the technology within the education sector as a whole will ultimately result in the adoption of it by schools. As the technology development itself presents an advancement of the productivity for this sector, immersive technology may become a key success factor in the industry going forward. This presents a catalyst for the adoption within schools over the long-term as the industry adopts the technology more broadly.

D.1 TAFE Institutes in general & Open Colleges

With the enrolment of many thousands of students in TAFE courses, the Panommersive system offers the possibility to further extend specific courses to remotely participating students. Especially in areas such as construction, the immersion into a 3D world with a shared environment amongst students offers a strong value proposition. Extending this proposition with 3D worlds in which manipulations of a virtual artefact are an effective simulation of actions in the real world present a unique learning environment for future students.

With Open Colleges already offering an online platform for online learning, the integration of Panommersive technology alongside existing courses would incur minimal costs while increasing the value proposition of the platform as a whole. Viewed from a competitive point of view, this could further enhance the platforms ability to compete with international open online course providers such as Khan Academy (http://www.khanacademy.org/) and coursera (http://www.coursera.org/) for example.

D.2 eVideo

Sydney, Suite 27-28, Level 2, 330 Wattle Street, Ultimo NSW 2007

eVideo has a broad range of video conferencing and Tele-presence systems, but does lack truly immersive systems. Consequently, a value proposition can be put forward to add significant immersion possibilities to their product range by integrating the Panommersion system developed by CSIRO.
Especially the SCOPIA XT Tele-presence Platform may benefit from the ability to fuse virtual “game alike” environments through immersion in order to offer targeted immersion possibilities, for example in the construction industry for example. Specific value propositions range from inspecting a virtual representation of a construction site to simulation of new business and operational processes in the virtual model to collectively discuss the implications in a board-room setting with remote participants.

D.3 Vantage Systems Pty Ltd

Level 9, 10 Queens Road, Melbourne VIC 3004

Vantage Systems offers a series of products, broken down in areas by the medium of conferencing. With vMeeting video, the firm aims to enable the connection of multiple end-points, real-time collaboration and business process integration amongst other features.

The small scale of the firms operations may allow the proposition of a completely new product range in addition to their current systems, fully based on the current Panommersive system. However, the financial capacity of the firm may be limited and thus a licensing scheme may be more favourable to achieve a commercialization of the system.

D.4 Polycom

With a large range of offerings and dedicated solutions proposed for the education sector (http://www.polycom.com.au/solutions/solutions-by-industry/education.html), Polycom would be an ideal partner with international reach in order to commercialize aspects of the technology more broadly. Especially the Polycom Content Access Program (PCAP) may offer an ideal product range to be complemented by the Panommersive system, enhancing the breadth and scope of the offering while providing additional features for increased differentiation of the firm.

D.5 Desire2Learn Australia Pty Ltd

1 Queens Road, Suite 1144, Melbourne, VIC 3004

Desire2Learn offers a learning environment formed by multiple products that are hosted through software-as-a-service environments. In addition to these solutions, the firm offers a comprehensive API to the solution. By using this API, a connection between the solution and the Panommersive system could be established in order to enhance the presentation abilities of the Capture product via immersive 360-degree recordings. This could form an additional product under the umbrella of Desire2Learn or also be advertised as a 3rd party extension to the system.

D.6 UniQuest Pty Ltd

UniQuest is closely related to the University of Queensland and specializes in the commercialization of research outcomes in a general sense. With a dedicated portfolio in the education and training area, an opportunity to commercialize the Panommersion system together with other products or systems may exist.
D.7 NetSpot Pty Ltd

With offering managed hosting, professional services and a help desk, NetSpot is well positioned to horizontally integrate additional offerings such as the Panommersion system. While most of the firm is focused on supporting Moodle and Blackboard installations for education institutions, the proposition to add a truly immersive service offering may exist, but could be risky for a firm of such scale.

D.8 Smart Sparrow Pty Ltd

SmartSparrow offers an adaptive eLearning solution, aimed to assist students individually to progress their studies by challenging them appropriately based on past progress. Rich simulations and adaptive content complement this key differentiator. Adding the Panommersion system to complement the simulations or content could offer additional differentiation for the firm.

D.9 For the record (FTR) Pty Ltd

Level 6, 179 Turbot St, Brisbane, QLD 4000

http://www.fortherecord.com/ provides tailored solutions for capturing evidence in courts and to digitize as well as record and archive the material.

The Panommersion system offers a potential advancement of their current product suite by offering a comprehensive view of the court and a larger variety of individual viewpoints. While not a key differentiator for the firm, it may offer a distinct add-on to existing products.
References


AT CSIRO WE SHAPE THE FUTURE
We do this by using science to solve real issues. Our research makes a difference to industry, people and the planet.

As Australia’s national science agency we’ve been pushing the edge of what’s possible for over 85 years. Today we have more than 5,000 talented people working out of 50-plus centres in Australia and internationally. Our people work closely with industry and communities to leave a lasting legacy. Collectively, our innovation and excellence places us in the top ten applied research agencies in the world.

WE ASK, WE SEEK AND WE SOLVE