Science Education Around the World

The Gravity Discovery Centre: A New Science Education Linked to Research at the Frontier of Physics

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Abstract

This paper describes a new concept for a science education centre, which is designed to provide resources closely linked to the needs of young people today. It combines science with art and links physical science, cosmology, and biodiversity under the banner of the big questions of life and the universe. Education modules are all reality based. Video and computer simulations are avoided. Large scale exhibits support physical observation and experimentation. Computer technology is reserved for recording (digital photography, microscopy, and astronomy) presentation and communication. Students create Power-point, reports which are sent back to school for follow-up work and presentation.

1. Introduction

Today science education, and particularly physical science education, is seen to be in need of major rejuvenation. Video experience has replaced reality for many students and the enormous range of video experience leaves teachers little opportunity to excite students and reward them with new knowledge. UNESCO has identified four major needs for the rejuvenation of science education. (Webb2003)[1] These are: (1) The urgent need for *"revitalisation of the system for teaching science."* (2) That the teaching of science should be based on *observation and experimentation.* (3) That there is a need to provide *assistance and support for science teachers.* (4) That science teaching should have *local relevance* and should respond to *local needs.*

This paper describes a new science education centre, which has been developed in response to locally perceived needs, to capitalise on the unique location and scientific endeavour in

1. J Webb. ICASE 2003 World Conference on Science and Technology Education

Western Australia. Although it was developed without reference to UNESCO policy, it closely matches the needs summarized above. Indeed two of its main focus areas match UNESCO's global priorities: *space education* and *biodiversity education.* The centre has been developed by a broad based community organization with substantial funding by business donors. It is presented here, because it may provide a model and an inspiration to others seeking to revitalize science education in their region.

This paper is structured as follows. First, we summarise current problems in science education as we have identified them. Many of the problems are likely to be common to other OECD countries, but may be less relevant to some developing countries. Second, we present the concept for our education centre, which has been developed around the specific science resources and opportunities we have available to us. Third, we briefly discuss the public response to our concept, and the process by which the concept was developed into a detailed plan. Finally, we summarise the education modules, which have been developed around particular exhibits and facilities in the centre.

At the time of writing the centre is partially complete. Prototype exhibits and trial programmes have been used to test out and develop ideas.

Problems with Science Education Today

In recent years, it is apparent that there has been a decline in interest in science and technology careers, especially amongst high achievers[2]. Students identify physical science as either too difficult or boring[3,4]. Entry requirements for tertiary science are generally far below those required in other disciplines, such as medicine and law. Tertiary teachers complain that they have to lower the level of courses to retain adequate pass rates. Combined with this has been the low rate of graduate physicists and chemists entering the science teaching profession and the consequent rise in the average age of physical science teachers[5]. It is apparent that in a few years there will be a serious shortage of supply of adequately trained physics and chemistry teachers. This can lead to a downward spiral. There is also disquiet amongst members of the engineering industry, who are concerned to maintain an adequately trained pool of potential employees[6].

The cause of these problems may be found in societal change. Many people suggest that the major change is *video experience.* Children today are deluged with video experience. By a very young age children have seen everything from space walking to multiple murders, from sex in all forms to vicious warfare, both real and fictional, and a vast array of exotic places and exotic wildlife. It is ironic that of all these, space science, as opposed to space fiction, which captivated many of the children of the baby boom generation, is today perhaps rather un-exciting, even boring.

The consequence of all this video experience is that children today have *increased expectations and increased needs*[7]. Since these cannot be fulfilled in the classroom alone, there is a need for *specialist learning resources.* Interactive science centres were created to try to fulfil this need, and there is no doubt that they play a significant role. However, many interactive science centres have been forced by commercial pressures to become more like science funfairs than learning centres. Teachers comment[8] that although students have fun, they do not appear to have had a significant learning experience. Specific criticism is that an environment with too much stimulation is not conducive to thoughtfulness and learning.

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The Concept of the Gravity Discovery Centre
The concept of the Gravity Discovery Centre grew out of the imperative that a research centre into gravitational wave detection should contribute much more to its local community than its research output alone, especially when its research was fundamental, even esoteric, and not of immediate relevance to the average person.

It was immediately clear that the areas of science education and the promotion of science were those areas in which the centre could make a significant contribution to society as a whole. An education centre called The Gravity Discovery Centre was proposed.

Planning: To develop detailed concepts for the Gravity Discovery Centre, a Steering Committee was formed which brought together a broad range of interest groups including representatives from government departments responsible for education, tourism, and commerce, as well as local government representation. Other representatives included people from the art community, universities, business, science education, an interactive science centre, and political parties. The steering committee developed strategies for funding, a business plan, and a set of concepts for the centre. A fundraising feasibility study strongly endorsed the possibility that the centre could be funded from a diversity of government and non-government sources. The business plan endorsed the concept of a mostly selffunded centre designed to have a small staff and low maintenance and running costs. The last key planning component by the GDC Steering Committee was the creation of the Gravity Discovery Centre Foundation (GDCF) as a charitable foundation devoted to education and the promotion of science, supervised by a broad based Board of Management.

Attributes: The next step was to identify the specific areas in which the centre could best contribute. To do this the steering committee identified the special attributes of the centre and its site. These are summarized below:

a) The research centre was being established in an isolated location in the Shire of Gingin, about one hour's drive from the major population centre of Perth.
b) The research on the detection of gravitational waves is linked to fascinating but difficult concepts, such as the curvature of space, the nature of black holes, the dimensionality of space, and various topics in astrophysics.
c) The research is also linked to a range of innovative frontier technologies, such as high power lasers, quantum optics, super precise measurements, and the use of supermagnets. For more details on the research see www.gravity.uwa.edu.au.
d) The research project is in close collaboration with The European Gravitational Observatory at Pisa, Italy, and The Laser Interferometer Gravitational Observatory run by Caltech and MIT in the USA.
e) The research centre is located in pristine bushland within a proposed nature reserve containing a significant number of rare plants. The entire region is within one of the Earth's biodiversity hot spots. It is estimated that within one square kilometre there are more plant species than in all of Great Britain.
f) The site is far enough from the city that it offers clear dark night skies for astronomy.
g) The site contains places of Aboriginal cultural significance as well as plants traditionally used by Aboriginal people.
h) Huge areas of West Australian bushland have been seriously degraded by the invasion of introduced environmental weeds. To maintain the pristine biodiversity of the site, it is essential to maintain active ongoing efforts for environmental protection and preservation.
i) Prior to requesting permission to use the site for gravitational wave astronomy, the researchers requested permission for land use from the traditional Aboriginal elders, which led to an agreement that included strong environmental safeguards, and an agreement to include Aboriginal people in the development and operation of the centre.

2. Guiding Principles for a new Science Education Centre

The next step was to develop a set of guiding principles for the GDC. These were developed prior to initiating a fundraising campaign. They were developed through consultation with the steering committee, university academics, science teachers, tourism operators, and professional fundraisers. They are summarized below.

a) *Architecture:* To utilize impressive architecture, large physical scale, and powerful art to convey significance and a sense of awe and beauty. See Figure 1.

b) *Science and Art:* To ensure that displays have striking qualities that make them accessible as art objects as well as having scientific significance.

c) *The Big Questions:* To maintain a focus on the big questions of life and the universe: what is space and time, how did it begin, what is the future for life, our planet and the universe, the origins of life and are we alone in the universe?

d) *Focused Displays:* To develop a relatively small set of large scale and semi-interactive displays clearly related to education modules (see below) linked to the school curriculum.

e) *Self-promoting Icon:* To develop at least one stunning icon exhibit that would ensure that the centre became widely known and would be self publicizing. Due to the research links with Pisa and its links to Galileo and gravity, the icon was chosen to be "The Leaning Tower of Gingin", which would allow students to repeat Galileo's famous experiments. See Figure 2.

f) *Understanding Research:* To develop programs and displays that allow student and public participation in the process of research, including recognition of the nature and difficulties of research, its slow progress and occasional breakthroughs.

g) *Reality first, technology where useful:* To avoid high tech exhibits, such as video simulations, but to use technology where it is useful for data gathering and communication. Specifically it was proposed to use digital cameras for data collection, and Powerpoint for students to create draft presentations to email back to school for follow up activity.

h) *Stewardship:* To develop programs that relate to the biodiversity of the site, stewardship and preservation of the site and which link to the human stewardship of the planet.

i) *Astronomy and Culture:* To develop displays and programs that relate to astronomy, and which include Aboriginal astronomy.

j) *Modern Physics:* To develop sculptural physics exhibits that relate to gravity, curved space, waves and acoustics, lasers and supermagnets.

k) *Innovation:* To showcase local innovations with the aim of encouraging young people by example to pursue innovation and wealth creation through science and technology. To show that an isolated community can compete in a competitive world.

l) *Multicultural astronomy:* To present multicultural cosmology in which cultural cosmological beliefs (Dreamtime creation myths and the Seven Days of Creation) are presented alongside scientific cosmology.

m) *Wilderness experience:* To provide a wilderness experience, not a city experience, utilizing outdoor resources as much as possible.

n) *Education modules.* To create education modules which begin before the visit to the centre, and which provide follow up work after the visit and which include specific support material for teachers.

o) *Cross Promotion:* To cross-promote visits to other science centres and to avoid material which duplicates resources at schools or other science centres.

In summary, the concept for adding value to research was to create a science education centre closely linked to research, and one which combined inspirational architecture, with art, science, and the environment in harmony with

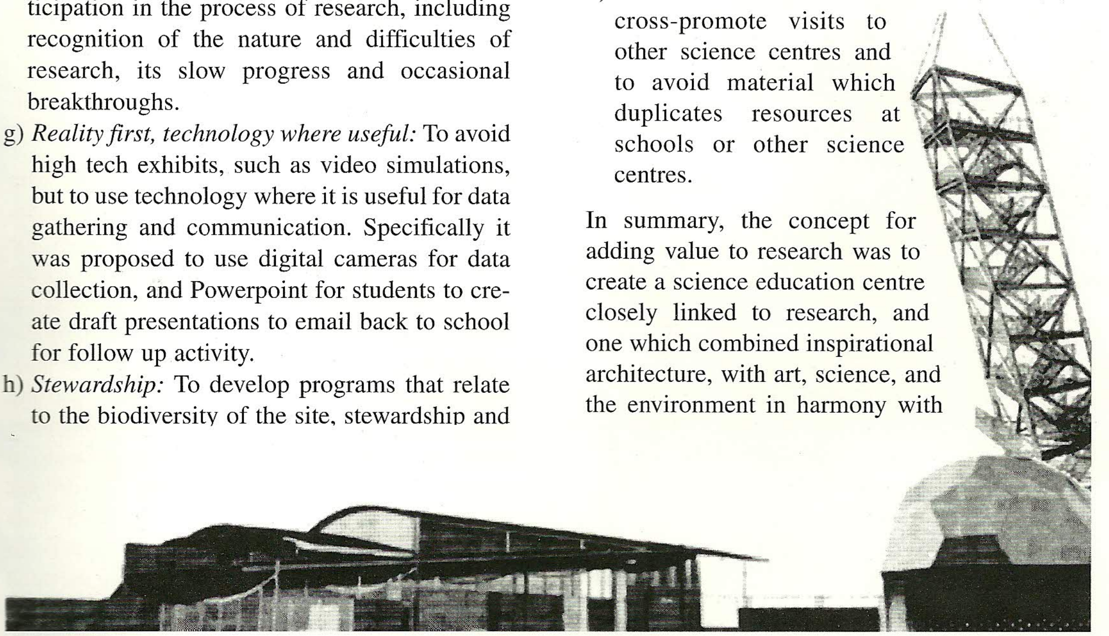


Figure 1a: The Gravity Discovery Centre and the Cosmology Gallery.

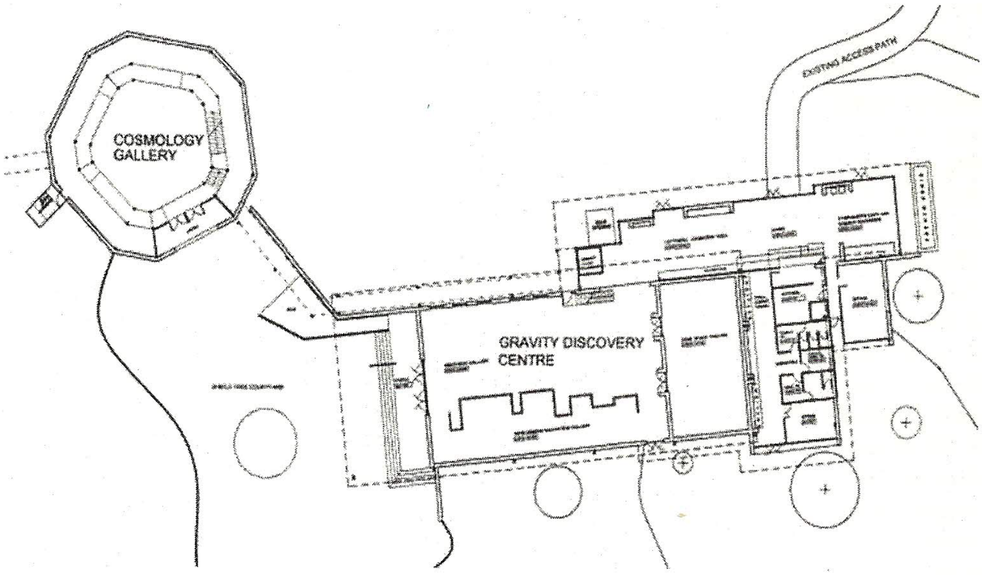


Figure 1b: *The Gravity Discovery Centre floor plan showing the Discovery Gallery, the Innovation Gallery and the Cosmology Gallery*

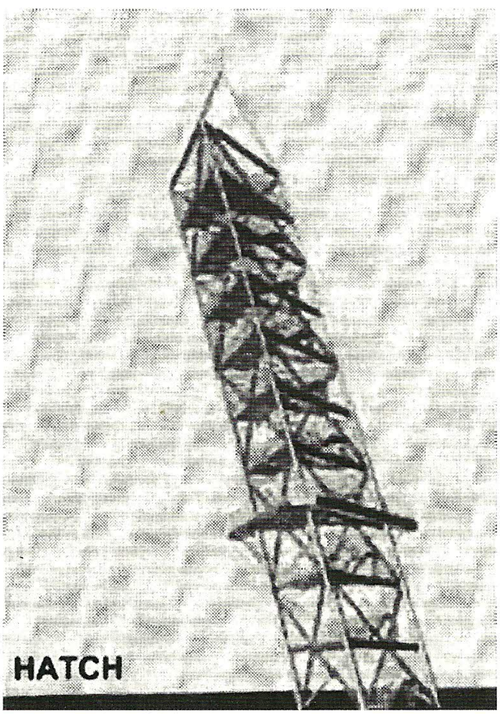
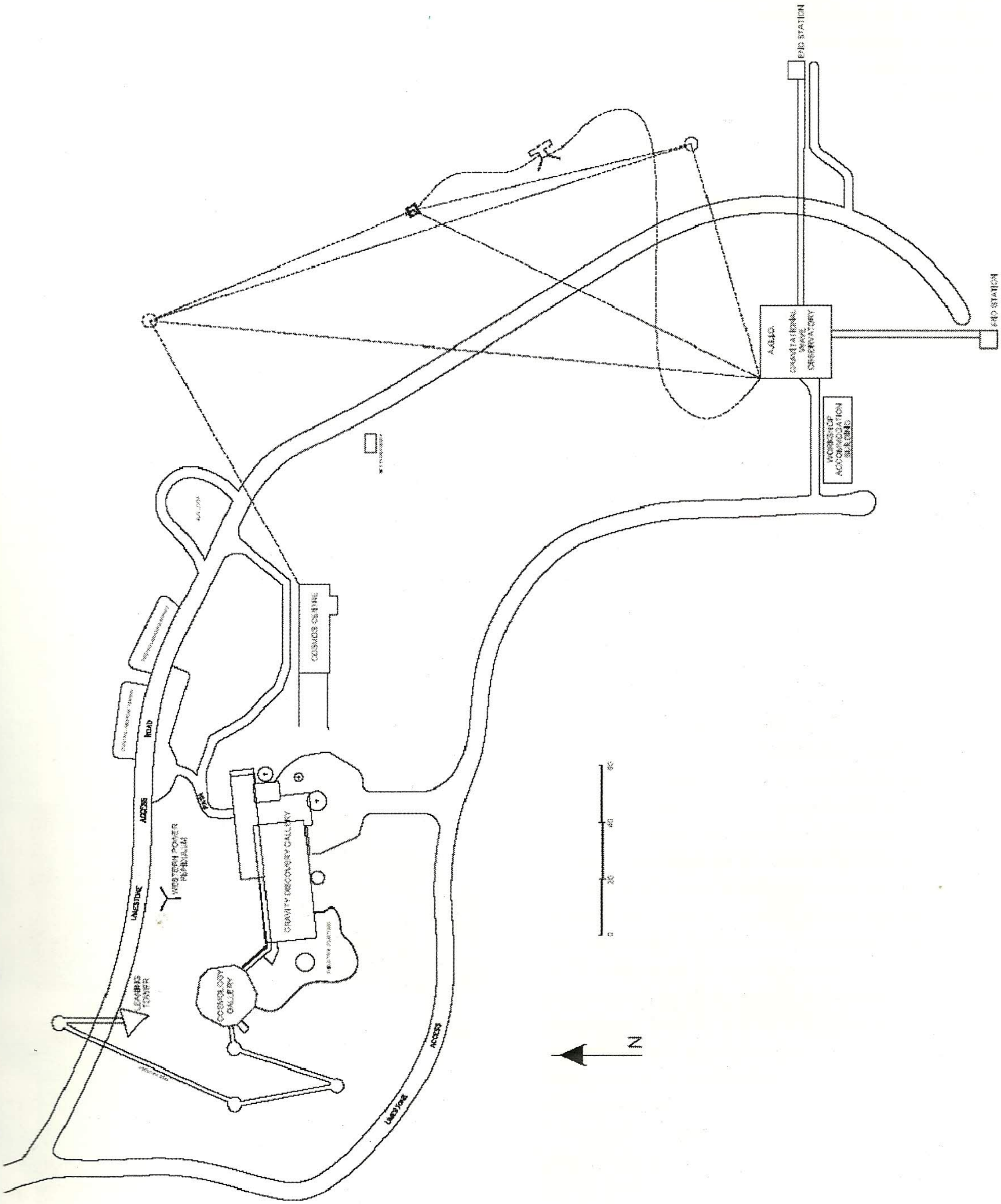


Figure 2: *Engineering design of the Leanin Tower of Gingin. Its height is 40 metres.*

people and technology. The focus was on the big questions of life and the universe, including multicultural cosmology and scientific cosmology. Our goal was to provide students and adults with a thoughtful and awe inspiring experience that would take them beyond the mundane and the video experiences of modern life.

3. Public support and the process of development

Fundraising: The concepts described above were turned into a fundraising brochure and a video. Two years of considerable effort gave us the funds to turn the concepts into reality. The success of the fundraising venture demonstrated the public support for the concept and particularly the widely held recognition that science and technology education was in need of support. Strong support was provided especially by companies based in Western Australia. It was difficult to secure contributions from companies who did not have their head office in Western Australia. This demonstrates how internationalization acts to weaken community, further emphasizing the need to create resources, which can nurture innovation and create wealth at a local level.


END STATION
END STATION
A.I.G.O.
GRAVITATIONAL WAVE OBSERVATORY
WORKSHOP ACCOMMODATION BUILDING
COSMOS CENTRE
GRAVITY DISCOVERY GALLERY
COSMOLOGY GALLERY
LEANING TOWER
WESTERN POWER PENDULUM
LIMESTONE ACCESS ROAD
PATH
LIMESTONE ACCESS
N

Science-Art Concept Testing: To test the concept of using art as a means of interpreting and illustrating scientific concepts, the GDC organized an art exhibition entitled Gravitate[9]. A group of artists were recruited, who participated in workshops with physicists in which the modern concepts of gravity, space and time, and gravitational waves were explored. They then developed works, which included explorations of curved space, non-Euclidean geometry, gravity, and Einstein's Special and General theories of Relativity. Several works presented interpretations of gravitational lensing. One exhibit was a vivid presentation of the relativistic distortion of objects when they travel close to the speed of light. Another work was on the nature of space. Another was on the concept of action at a distance. The exhibition was very popular, and drew large attendances despite the difficult concepts which were presented.

The works from the Gravitate exhibition provided the foundation concepts for many exhibits at the GDC and led to successful funding applications for large scale permanent exhibits.

Public Astronomy: The second project of the GDC was the construction of a public astronomy centre entitled The Centenary of Federation Southern Cross Cosmos Centre, illustrated in Figure 3. This centre allowed the GDCF to confirm the financial viability of a remote science centre. In addition, it provided the base and the nucleus for developing, testing, and evaluating education programs of the type planned for the GDC. The special feature of the Cosmos Centre is a 20m long motorized roll-off roof which opens a large viewing area to the sky. In this area 7 tracking and/or computer controlled telescopes are now located, allowing groups of more than 50 to share in a viewing evening. A 25 inch telescope allowed exceptional viewing of low brightness objects, such as the Orion Nebula. An auditorium allows objects to be simultaneously projected onto a large screen, and specialized software such as Starry Night[10] and Deep Space Explorer[11] allow orientation sessions to take place before viewing. Projected images of the moon allow detailed guided tours of the moon to take place in real time. Average attendance at the Cosmos Centre in its first two years of operation is about 40 people per evening session. The operation of the Cosmos Centre has been commercially viable. It is managed by an amateur astronomer with good presentation skills, supported by several helpers who supervise telescope operation.

Trial Education Programs: The concept of the GDC was developed in close liaison with science teachers. Several workshops were presented at science teachers conferences in which teacher feedback was used to develop various aspects of the centre. Prototype exhibits were discussed and the building layout. In parallel with these activities, the Cosmos Centre was used to develop trial one-day education programs that included astronomy, solar astronomy, biodiversity studies, and physics experiences based on prototype display material. Once these were trialled, it became possible to plan education modules in readiness for the opening of the centre. This in turn, made it possible to present the full concept to science teachers and to get feedback, which allowed the fine tuning of many of the practical issues associated with the centre. Following teacher suggestions, we arranged for a bunkhouse to be set up on a nearby farm. This allowed school groups to stay overnight. The 1km walk to the bunkhouse was turned into a solar system walk (scale model of the solar system) using ceramic planets made by a craftsman potter. This walk

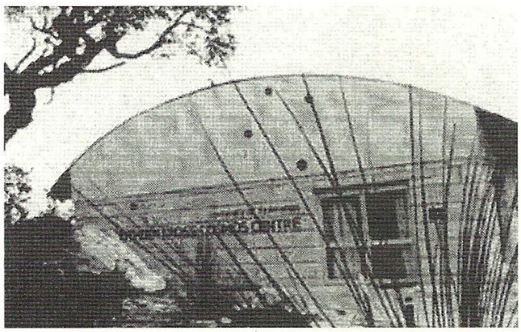


Figure3a: *The Southern Cross Cosmos Centre: external view*

9. Gravitate - Lawrence Wilson Art Gallery, University of Western Australia, Nov 2000. Curated by M Grey-Smith.

10. Starry Night

11. Deep Space Explorer

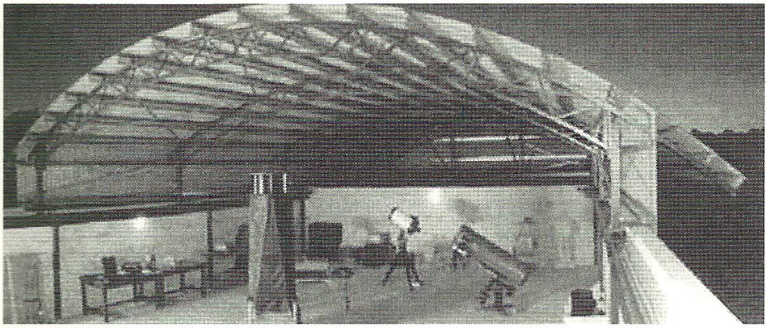


Figure3b: View of the SCCC with roof open showing the telescope viewing area.

allows students to experience the solar system to a scale of 1 to 8 billion, while the planets are displayed on a scale of 1 to 40 million. This walk also serves as a location for biodiversity studies and insect collection.

Teachers' suggestions also allowed the architecture of the GDCF to be fine tuned to teachers needs by providing several separate "confinement areas", which facilitiate control of class groups, allowing several classes to use the centre at a time.

4. Education Modules and Exhibits

The education modules for the GDC have been designed by members of the GDC Education Committee consisting mainly of Primary, Secondary, and Tertiary teachers and educators. They have been designed in two sets, one set for late primary (years 4-7), the other for early secondary (years 8-10). Each module includes an abstract and background information for teachers. Pre-visit activities are then presented, followed by on-site activities, and follow up activities. All of the education modules are designed to allow a modern outcomes based assessment of student performance. Each module worksheet provides a framework for assessment within this paradigm. The education modules can be summarised under three categories.

A) *Space, Time and Cosmology (STC): Nine modules covering space and time, and Einstein's theories, astronomy, cosmology, and multicultural cosmology.*

B) *Forces, Waves and Innovation (FWI): Seven modules covering physics, the forces of nature, technology, and innovation.*

C) *Biodiversity (BIO): Twelve module covering aspects of biodiversity, plant specialisation, sampling, and discovery of new invertebrate species.*

All the planned modules are summarized in Table 1. Details of most of them can be found on the GDC web site.[12] Every module is based on one or more exhibits and each one involves digital imaging as the primary means of recording. Low cost digital cameras capable of taking short video clips will be used in most modules, while others require use of a digital microscope or a digital telescope image. Following the summary in Table 1, we will give a fuller description of some of these modules.

Space and Forces Modules: Underlying many of the STC and FWI modules are concepts of Einstein's General Theory of Relativity. Traditionally this material is considered too difficult for school. However, although the mathematical details are difficult the concepts are simple, and easy to demonstrate. They are as central to the understanding of space and the universe as the concept of evolution is to the study of species and life. Each set of exhibits is designed to be used at various levels. For example, even *Einstein,* the most difficult module, is supported by a delightful children's book designed for ages 8-10. Thus, every exhibit may be used for both primary and secondary education, as well as being a fascinating sculptural object linked to the principles of physics.

The *curved space and geometry* module allows teachers to enrich mathematics education, while introducing the idea first discussed by Gauss almost 200 years ago that the geometry of space

12. GDC web site

Table 1

Theme	Title	Exhibits	Descriptions
STC	Curved Space Geometry	Line drawing car on spherical white board, Dynamic Mirrors. Gravitational lenses +Poster, Curved space artworks Laser beam triangles	Explore non-Euclidean geometry on a spherical white board and examine its implications through observing other exhibits. Do 3-dimensional geometry with laser beams+ smoke generator
	Black Holes: Orbits, Gravity and Geometry	Big Black Hole Orbits in Flat space and Curved Space Space is elastic (poster and small black hole)	Measure orbital period of orbiting balls for different radii on the 5 meter diameter black hole. Interpret and record orbital artworks
	Vacuums and Space	Clear vacuum tank, pump Magnetically weighted Parachutes, Radio	Observe loss of wind resistance and absence of sound propagation as pressure reduces. Light, magnetism unaffected
	Our Star the Sun	Solar Astronomy, Solar system walk, Solar Spectra.	Image and record sunspots Use previous days data to estimate solar rotation period
	The Planets	Planetary astronomy (both day and night) Solar system walk Solar system databank Model solar system	Observe one or more of the 5 easily seen planets. Compare with scale model of solar system and small scale model to determine earth-sun-planet positions
	Einstein and Relativity	Storybook: Albert Einstein. Slowed light artwork. Microwave Doppler effect. Poster: why does a ball fall? Freefall waterjet tank Poster: Physics is simple in freefall	Experiment with the Doppler effect. Digital video with sound. Explain slowed light artwork. Observe freefall water drop trajectories
	Cosmology: How Many Galaxies and Stars in the Universe	Star and galaxy counting at SCCC Hubble Deep Field Posters Deep space images	Estimate number of galaxies in photo. Calculate the number of galaxies in the universe. Then calculate total number of stars and atoms
	Cosmology: Telescopes and Time Machines	1km Sound tube Telescope time travel poster Cosmic Background images Cable waves Water waves	Listen to yourself 5 seconds in the past down a 1km sound tube and measure time delay. Record cable wave travel time and ripple tank wave speed.
	Multicultural Cosmology	Artworks with posters Dreamtime cosmology The seven days of creation Buddhist Cosmology Big Bang Cosmology	Comparison of different cultural interpretations of the universe in relation to modern scientific knowledge.
FWI	Forces of the Universe	The Four forces poster, Cosmic Ray Detector, Tesla Coil, Magnetic Force	Measure magnetic forces from supermagnets Count the cosmic rays Observe forces from electric discharge

Table 1 (continued)

	Magnetic Mollasses	Magnetic skateboard Magnetic pendulum Magnetic parachute Lenz's Law poster	Feel the forces Measure Force-velocity graph. Photograph pendulum for different conductors and spacings
	Pendulums	Zero length spring pendulum Parametric pendulum Foucault pendulum Gorilla Pendulum Coupled Pendulum	Measure, photograph, observe behaviour of different types of pendulum Play with the gorilla pendulum
	Water waves Wire waves, Sound waves and Gravity waves	Solar ripple tank Cable waves Aeolian Harp wire waves Sound pipe Gravity wave facility Gravity wave distortion	Send waves down wave cable Observe reflections, interference, resonance. Repeat in sound pipe. Listen to wind induced wire waves Visit gravitational wave facility
	Gravity	Galileo Free fall experiment Gravity Glass Elevator Free fall waterjet experiment	Compare fall of balls of different composition. Wind resistance. Image waterjet in free fall Measure free fall of people in a water counterbalanced lift.
	Lasers and Light	Solar prisms Solar pinhole camera, Gratings	Photograph solar spectra from gratings and prism. Compare with laser light. Photograph pinhole image
	Innovation	Sapphire oscillators Orbital engine Weeds Australia Supermagnets	Research the ideas and the benefits. Invent new uses for supermagnets
BIO	Introducing Biodiversity	Plants and insects of the sand plain. Image database.	Photographic collection. Invertebrate collection from pitfall traps. Species counts.
	Nasty Creepy Crawlies	Tick collection Tick attractant/repellent experiments	Collect ticks and study their behaviour. Attraction to humans, effect of repellents.
	Who eats who?	Invertebrate collection Drop traps and light traps, posters. Find a new species	Photograph and identify invertebrates. Search against reference collection. Expect to discover ~300 new species.
	Banksias	Four species of Banksia Banksias poster.	Compare and contrast the dominant species on the sand plain: flowers, nuts, leaves, bark and insects.
	Finding Fruit	Nuts, pods and other fruiting bodies	Explore the amazing variety of nuts, pods and seed cases, and how they protect themselves
	Floral Attractions	Flowers in season Book: Extraordinary Plants Flower image database	Find and record flowers. Identify them and describe them
	Leaves Fight Back	Leaves Book: Extraordinary Plants Leaves Poster	Create photo document of various leaf types with different protection mechanisms.

Table 1 (continued)

	Firefighters	Fire damaged plants Fireproofing with bark Fireproof nuts and bark	Find and record fire damaged trees. Explore fire history of the site
	Carnivorous plants	Reference photo collection, posters, Book: Extraordinary Plants	Photograph and identify various sundews
	Active Pollinators	Orchids and Trigger Plants Reference photo collection, poster	Find and Photograph plants, observe and time trigger reset.
	What is a weed?	Weed display, environmental weeds. Weeds Australia display	Identification, photography, roadside searching and collection,
	Plants for Life	Plants of Aboriginal cultural significance	Tours led by indigenous experts. Photographic recording

should be studied experimentally and not taken on faith from the works of Aristotle and Euclid. On a spherical whiteboard, using a special line drawing car, students will be able to prove that the sum of the angles of a triangle is not equal to 180 degrees and that the area of a circle is not exactly πr^2. They will learn that the geometry we do on flat paper is a special case of a much more general type of geometry.

Using laser beams, they will be able to create triangles in 3 dimensional space and learn that space is sufficiently flat that the Euclidean results are a useful approximation.

These ideas are taken further in *Einstein* and *Gravity*. In Einstein, fundamental but simple ideas, which underlie Einstein's discoveries, are introduced. In particular, a simple experiment using water jets in a freely falling transparent ball is used to demonstrate the idea that "physics is simple in free fall." Gravity is the force you have to exert to prevent the natural motion of objects, which is free fall. To understand this, it is necessary to understand that objects fall, because their path in space time is extended, if they do not fall. This happens because time depends on gravity. All these ideas have been successfully tested with young people, who are remarkably more receptive than adults to the new ideas. In *Vacuum and Space,* students will test free fall in vacuum, repeating the famous feather and hammer free fall demonstration performed by Apollo astronauts on the Moon. They will also observe that sound does not propagate through space, but that light and magnetism do.

The finite velocity of all waves is explored in *Waves.* The implications of finite wave velocity for study of the universe is explored in *Telescopes are Time Machines.* A 90 metre long cable wave exhibit and a one kilometre long sound pipe allow students to create waves and measure their velocity and to experience the concept of seeing or listening into the past. This links to the scale of the universe and our ability to look back to the time when the universe was very young. Students will also recognize that our entire experience of life is in the past.

Waves also link to the search for gravitational waves and the technology which is used. This includes long pendulums in gravitational wave research used for vibration isolation. The *Pendulums* module allows students to explore a

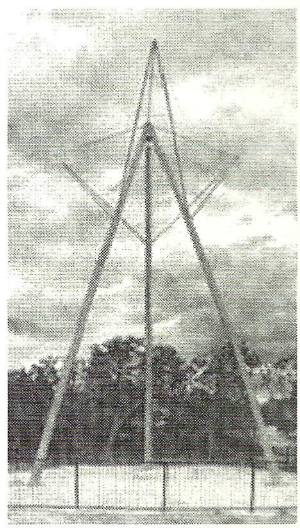


Figure 4: *The Western Power Pendulum Tower which supports four 15 metre length pendulums of various types.*

variety of very large pendulums suspended from a 15 metre special purpose pendulum tower. See figure 4. A Foucault pendulum measures the rotation of the earth, while others display remarkable behaviour. The zero length pendulum displays spherical orbits, while the coupled pendulum shows dramatic beat phenomena.

Biodiversity Modules: Many of the biodiversity modules are designed to relate to the spectacular biodiversity of the site. They are intended to instil an appreciation of the spectacular local environment of which most Western Australians are largely unaware. They offer the real possibility for students to discover a new species, as well as to examine in detail many extraordinary plants.

To provide long term scientific value the GDC plans to create a reference collection of invertebrate species from the site. This will be combined with a database of digital images. Collaboration with government, museum and conservation staff will facilitate identification. Because of the threat of invading weed species, a database will also be maintained of weed species, which will help the GDC to manage the site with minimal environmental damage.

The Limits of Knowledge: A very important aspect of the GDC Education Modules will be the presentation of the limits to human knowledge. It is disempowering, and indeed misleading, to present science as having all the answers. Every module should also teach students what we do not know, and indicate the frontier where our knowledge stops. Here we give a few examples which span the age of the universe.

- Recent images of the very early universe show that it began in a state of high uniformity, but with random fluctuations of about 10 parts per million. We do not know where these came from, but without these fluctuations, galaxies and stars would never have formed.
- Modern cosmology tells us that the universe is dominated today by invisible dark matter and dark energy. We do not know what these things are.
- Our sun has sunspots, which vary over an 11-year cycle. We do not know the cause of either the sunspots or of the 11-year cycle.
- The Earth's magnetic field is generally said to be due to dynamo currents in its core. However the precise mechanism for this is unknown. The reason for the field reversing direction every million or so years is also unknown.
- The weird behaviour of matter in the quantum regime is beyond our comprehension, and yet may soon be harnessed to create vastly more powerful than modern computers.
- Quantum physics is incompatible with Einstein's theory of gravitation, yet both are correct to the limits of modern measurements.
- The entire spectrum of gravitational waves is undetected and itself offers a century of scientific exploration.
- The reason for the structure of our solar system is unknown, and it is unknown whether there is life on other planets, and whether extraterrestrial civilizations exist.
- The reason for the origin of life is unknown.
- Tiny organism-like structures in deep rock may be alive or may be lifeless mineral structures. The answer is unknown.
- Huge numbers of species have yet to be discovered. Human impact on the planet is likely to bring many of these species to extinction before they are even discovered.
- We do not know how to steward the planet for future generations. We do not know how to live in harmony as a species, let alone with the 30 million other species on the planet.

The scientific method has given us the means of tackling our ignorance. The key component of the scientific method is scepticism. It is therefore important that the GDC education programs should emphasise critical observation and not blind acceptance. They should also emphasise scientific integrity. Science poses questions. Through experiment and observation nature provides the answers. False answers and interpretations will always be discovered eventually. All education modules at the GDC are designed to accommodate these components.

Conclusion

The most remarkable thing about science is that it works! That we are able to continually pose new and sensible questions and understand the answers is astonishing! We do not know if the human mind provides a limit to our ability to understand the universe. However, we do know that knowledge obtained through science and applied with wisdom offers us the greatest possibility of understanding our place in the universe. Such knowledge is essential if the human race is to create a rich future for itself and its planet. Fundamental research into gravitational waves has provided an opportunity to create an education centre that is designed to be a small contribution towards this goal.

More particularly, The Gravity Discovery Centre is designed to show bright young people that there is a huge future for science and exploration. It is designed to allow students to experience the joy of finding things out for themselves-the joy of knowledge and understanding. It is designed to encourage young people to be the scientists and technologists of tomorrow, while contributing to society's broader deeper understanding of science.

Simultaneously through its art and science approach, the GDC will be an art gallery in its own right that will attract and appeal to non-scientifically minded people. The artistic interpretation of science will give an added dimension to the centre, which will enable it to counter the view that science is boring. The art gallery environment is also designed to be conducive to quiet thinking and observation.

Acknowledgements:
The project described here was made possible by donations from the following individuals, companies, and organisations.

Archistone
ArtsWA
Awesome Festival – Healthway
BGC Group
BHP Billiton Petroleum
BHP Billiton Sheet & Coil
Lady Jean Brodie-Hall
Sir Laurence Brodie-Hall
Mr John Budge
Mr Russell Chandler
Centenary of Federation
Cheriton Lodge
Clough Engineering
Di Candilo & Sons
The Education Department of WA
Everett-Smith & Co Pty Ltd
Grant Transformers
Hatch Associates
Mr Simon Hibbert
Highline Construction
Iluka Resources
Jarrah Computers
Kellogg Joint Venture
Kingstream
Kott Gunning
Mr Chris Lane
Lotterywest (formerly Lotteries WA)
Perilya Ltd
PIHA
Probedrill
Public Education Endowment Trust
Regional Assistance Program
Regional Infrastructure Funding Program
Dr Jim Ross / Renewable Energy Corporation
School of Physics, UWA
Chris & Felicity Scott
Sherwood Overseas Ltd
Shire of Gingin
Simms Metal
Soil & Rock Engineering
Spowers Architects
Titan Resources
Tiwest Joint Venture
United Group
The University of Western Australia
Urbanstone
Wesfarmers Limited
Western Power

The GDC Foundation is greatly indebted for their support.