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THE DEVELOPMENT OF TECHNOLOGICAL LEARNING ACTIVITIES FOR CSIRO SEC

CSIRO

An Interactive Qualifying Project
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by

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Abstract

This project, performed in Australia with the **C**ommonwealth **S**cientific and **I**ndustrial **R**esearch **O**rganisation's **S**cience **E**ducation **C**entres (CSIRO SEC), was a study of science education in secondary schools. Its goal was to create hands-on activities and cutting-edge demonstrations to expose students to emerging technologies. CSIRO SEC develops interactive learning activities that are meant to pique student interest in the sciences. It will use the outcomes of this project to strengthen its existing programs and develop new programs relating to emerging technologies.

Executive Summary

Australia's **C**ommonwealth **S**cientific and **I**ndustrial **R**esearch **O**rganization **S**cience **E**ducation **C**entres (CSIRO SEC) aim to expose young students to science in the hopes they will become interested and pursue careers in the sciences. One way it accomplishes this is by offering educational programs through which students experience how rewarding and exciting science can be. Schools can purchase one of these programs from CSIRO SEC, and CSIRO Education Officers will travel to the school with all the needed materials. Their programs include topics such as electronics, forensics, physics, chemistry, and biology. Even though this list covers a vast amount of science and technology, the current rate of technological advancement has provided a plethora of new technologies -- such as nanotechnology and photonics -- that are perfect candidates for future CSIRO SEC programs. CSIRO SEC wants to add programs to its repertoire that will expose students to some of these emerging technologies. The SEC sponsored this WPI team to develop a Catalogue of Learning Activities that will help to modernize its repertoire.

Before engaging in a large-scale research project, it is important to understand its environment. This IQP is a study in science education. Its environment is the Australian school curriculum, and in Victoria, the curriculum is governed by the Victorian Curriculum Assessment Authority (VCAA). The **C**urriculum **S**tandards **F**ramework **II** (CSF II) dictates the requirements for school years two through ten, and the **V**ictorian **C**ertificate of **E**ducation (VCE) dictates the requirements for years eleven and twelve -- both of which are published by the VCAA. Since CSIRO SEC programs are marketed towards schools, the activities in this Catalogue must comply with the requirements of these documents so that the schools can justify the expense associated with these programs.

Given the scope of this project, it was very easy to lose sight of the project outcomes. In order to ensure a coherent and structured Catalogue, the group established a set of criteria for each activity in the Catalogue. First, the technology behind any activities had to correspond to current research at CSIRO. Second, the learning activities had to parallel current secondary curriculum requirements in Australia. Third, it had to be realistic to expect secondary students to understand the material. Lastly, assessing students' and teachers' attitudes towards emerging technologies was necessary in order to ensure that our selected experiments would meet their interests and expectations.

Internet research and interviews yielded initial ideas and experiments for placement into the Catalogue of Learning Activities. In order to obtain a framework for the progression of these ideas into learning activities, case studies of the current CSIRO SEC programs were conducted and analyzed. They revealed that hands-on programs outperform demonstrative programs. Also notable, programs that featured critical thinking activities outperform those that did not. Comparing the performance of different programs helped to determine how the gathered ideas would be used in a CSIRO SEC program, and therefore, help to create the Catalogue of Learning Activities.

A focus group was conduced to assess the goals of this IQP and those of CSIRO SEC. The focus group included 13 WPI students who were asked to discuss CSIRO SEC's business model and in general, science education. This resulted in numerous recommendations and reinforced many of the hypotheses developed in this IQP. Before the finalization of the Catalogue, the data gathered from this focus group was used to fine-tune its content.

The Catalogue of Learning Activities first offers a basic synopsis of the activity along with where it parallels the CSF II or the VCE. The materials and instructions for each activity are outlined in the Catalogue and accompanied with background information. Each activity in the Catalogue includes a cost analysis which will help CSIRO SEC find the materials required and to understand its investment. The detail provided in the Catalogue will make it easy for CSIRO SEC to use its content to strengthen its existing programs and to develop new programs.

During the research process, many ideas outside the scope of this IQP surfaced. These ideas led to a set of recommendations that include providing supplementary materials to students and teachers, making better use of the CSIRO SEC websites, offering seminars for teachers on science education, and ideas for new marketing strategies. All of these recommendations were developed from our research and could evolve into future WPI IQPs with CSIRO SEC.

Not everyone will be completely satisfied by every activity in the Catalogue. The Edible Optics activity, which demonstrates the basic properties of photonics to students using gelatin, may prove cumbersome for CSIRO Educational Officers when transporting across Victoria in their vehicles; the Aerogel demonstrations, which demonstrate the properties lightest solid in the world, could be rather expensive for CSIRO SEC; and the monolayer demonstration, which uses a layer of ear wax to extinguish a water and ether fire, has safety concerns. However, when the positives are weighed against these negatives, the activities will always prevail. Weighing these pros and cons has been left up to committed professionals at CSIRO SEC. It is the hope of this group that the pedagogical experience of the CSIRO SEC staff will pick up where the technological information in the Catalogue left off.

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Without the assistance and guidance of the following people this IQP would lack such quality and value. We would like to especially thank our liaison, Chris Krishna-Pillay, and our advisors, Laura Menides and Jonathan Barnett for their guidance throughout the course of this project. We would also like to extend our thanks to all those interviewed and surveyed. Their contributions advanced and assisted in the Development of Technological Learning Activities for CSIRO SEC.

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1. Introduction

Imagine a future where 16 and 17 year old students work with material that has baffled scientists and research professionals for the last 40 years. The **S**cience **E**ducation **C**entres (SECs) of Australia's **C**ommonwealth **S**cientific and **I**ndustrial **R**esearch **O**rganization (CSIRO) proposes such a future. CSIRO SEC has sponsored this group of WPI students to help realize its goal of developing learning activities that can expose secondary students to emerging technologies.

Science and technology serve as the lifeblood of the global economy, and for the last hundred years Western society has been the dominant science and technology innovator despite growing concerns regarding the quality of its education. Standardized test scores in math and science suggest that students in nations such as Japan and South Korea are much better prepared than their Westernized peers (CDEST 6.3). This evidence has led to large-scale science education reform efforts around the globe. Coincidentally, Edward Alton Parrish, current President of WPI, has recently published an article in the *Boston Globe* highlighting the need for this reform. Parrish maintains that

> ...until we encourage math and science studies at a very early age, students don't realize what doors they are closing.... We have a responsibility to keep these doors open for them--even if they choose not to walk through (Parrish 1).

With this responsibility comes the need to reform the way people teach. Although Parrish's article is aimed at the curriculum of the United States, the need for this reform is present in Australia as well. CSIRO SEC believes that its programs are at the forefront of this reform. Efforts include the creation of learning programs for school years two through twelve that incorporate emerging technologies such as nanotechnology, photonics and biotechnology.

CSIRO SEC seeks to promote students' interests in science careers through participation in hands-on science activities. The organization believes that any reform of

Australia's curriculum should include emerging technologies and current research practices. CSIRO SEC invested in this IQP to create new programs that will directly expose secondary students to emerging technologies. It is the hope of CSIRO SEC that students will be intrigued by the work being done by researchers in all divisions of CSIRO (CSIRO Homepage 2003).

The goal of this **I**nteractive **Q**ualifying **P**roject (IQP) was to provide CSIRO SEC with a Catalogue of Learning Activities that it could use to strengthen its existing programs and to develop new programs that aim to expose secondary school students to emerging technologies such as nanotechnology and photonics. First, it was important to determine the needs and expectations of students, teachers, and CSIRO SEC. This understanding provided the framework required for the development of the Catalogue of Learning Activities. This Catalogue contains ideas and experiments in the form of learning activities that CSIRO SEC can incorporate into its existing or future programs.

An IQP aims to promote "an awareness of the interactions between science and technology on the one hand, and the physical, institutional, and human environment on the other" (WPI Website 2003). The possibilities presented to CSIRO SEC in the Catalogue of Learning Activities are the embodiment of that statement. This IQP is an exercise in establishing how new technologies can be assimilated into society by exposing them to young students.

2. Background and Literature Review

In the distant future, people will write science and history textbooks that, among other matters, highlight the technological accomplishments of the 1980s up through the early 21^{st} century. The previous decades' accomplishments have resulted in the integration of technology into everyday life and heightened the need for a scientifically literate society. In a traditional educational track, contemporary scientific knowledge does not reach the majority of the population until post-secondary education. The Education Unit of Australia's **C**ommonwealth **S**cientific and **I**ndustrial **R**esearch **O**rganization (CSIRO) recognizes the inadequacies of science education in secondary schools and targets their education efforts at designing curriculum aids that integrate emerging technologies into secondary schools. A detailed description of CSIRO can be seen in Appendix A.

2.1. CSIRO Science Education Centres

The CSIRO **S**cience **E**ducation **C**entres (SECs) are part of CSIRO Education. More information on CSIRO Education is available in Appendix A. CSIRO SEC develops hands-on learning activities, known as education programs, which attempt to inform students through exciting experiments and expositions. Teachers purchase these programs from the CSIRO SEC in order to interest their students in science while covering different aspects of the curriculum. When purchased, a member of the CSIRO SEC staff will travel to the school with all the needed materials for the experiment and teach the class for one to two hours. It is also possible for groups of school students to travel to the SEC facility to use their laboratory space for the program. CSIRO SEC primarily tries to illustrate science and its vital role in the community within these education programs. There are nine CSIRO SECs, one in each capital city and in Townsville, Queensland. Many of CSIRO SEC's education programs are held in a center, but CSIRO SEC Education Officers also travel to schools throughout Australia.

CSIRO SEC education programs are marketed to teachers and administrators as a way of offering advanced laboratory activities on a per use basis. Most of these programs satisfy specific curriculum requirements and offer teachers and schools the option of outsourcing lessons. The curriculum aspects are primarily met or elucidated through the hands-on aspect of each education program. CSIRO SEC invests about $3,000 into the development of an average education program although some have been considerably more expensive. Schools are charged per student with prices ranging from $2.70 to $6.50 per seat (CSIRO Homepage 2003).

2.2. Australian School Curriculum

It was necessary to understand two areas of Australian Curriculum before assessing CSIRO's goals for this project. Evaluating the requirements of Australian secondary school curriculum and recognizing the current state of this curriculum helped to define the individual tasks that were required for successful completion of this project. What are the strengths and weaknesses of the current curriculum? What piques the students' interests? What succeeds and what fails when trying to teach science to students in Australia? The research discussed in the next two sections helped to answer these questions

2.2.1. Curriculum Requirements

The **V**ictorian **C**urriculum and **A**ssessment **A**uthority (VCAA) establishes what students learn in Victorian schools from preparatory year to secondary year 12. The Victorian **C**urriculum **S**tandards **F**ramework **II** (CSF II) is the guideline developed by the VCAA for all primary and secondary education in Victoria, Australia. The CSF "provides sufficient detail for schools and the community to be clear about the major elements of the curriculum and the standards expected of successful learners" (CSFII). Within the CSF, there are eight **K**ey **L**earning **A**reas (KLA), some of which are related to science and technology. Not only does it require a general understanding of science, it also encourages an understanding of high-level concepts. The KLAs aim to give students a "big picture" view of the science world. Some of these goals require students to:

- acquire scientific skills and conceptual knowledge
- acquire and use the skills of scientific investigation, reasoning and analysis to ask questions and seek solutions
- develop scientific attributes such as flexibility, curiosity, critical reflection, respect for evidence and ethical considerations
- recognize and understand the strengths and limitations of science
- be able to interpret and communicate scientific ideas effectively
- appreciate the dynamic role of science in social and technological change (VCAA Homepage 2003)

A topic common to all stages of the science KLAs is the Physical Sciences. The KLA refers to these main topics as strands. There are many learning outcomes expected from the Physical Science strand, including:

- understanding the behaviors of light, such as reflection, refraction, absorption and polarization
- learning the effects of electronic and electrical components in electronic devices
- understanding the relationships between forces, mass, acceleration, and velocity
- evaluating theories on evolution of organisms
- explaining ecosystems
- describing the cellular process
- describing the genetic basis of inheritance (VCAA Homepage 2003)

Any extensions to a student's educational experience beyond what is required must somehow relate to one of these science goals.

Another Key Learning Area deals with technology. In this learning area, students are exposed to how science is used in large-scale systems. Information Technology, Materials, and Systems are the major strands in the technology area. The learning outcomes in these strands include:

- social and environmental implications of certain materials
- design of processes and evaluations of efficiency
- control systems including feedback

- predict the likely uses and effects of emerging technologies if they were to be widely applied
- analyze the suitability of certain materials in different purposes
- analyze how systems are affected by community needs and resources (VCAA Homepage 2003)

Just as in the Physical Science strand, some of these outcomes must be addressed by any embellishments to the Victorian curriculum (VCAA Homepage 2003).

2.2.2. The State of Australia's Science Curriculum

A government study completed in 2000 by the **C**ommonwealth **D**epartment of **E**ducation **S**cience and **T**raining (CDEST) entitled, "The Status and Quality of Teaching and Learning of Science in Australian Schools," characterizes the state of science education in the commonwealth. The report describes secondary science education as, "traditional, discipline-based and dominated by content" (CDEST 6.1). The study also finds discrepancies between the goals of science education and student achievement in Australia. CDEST utilized student focus groups that revealed students feel the content load is too heavy. The focus groups also revealed that students believe many topics are covered too sparingly in an attempt to train them for tests rather than to educate them in science. In fact, only one fifth of lower secondary students surveyed felt that their science curriculum was useful or relevant to them, and nearly forty percent of secondary school students surveyed say they never get excited about what they are studying in science. A similar percentage feels they never have enough time to consider the subject matter (CDEST 6.1-6.2.1).

Primary school students seem to have a different attitude toward science education. Forty-three percent (43%) of students surveyed said that they are always or often interested in science. The percentage of disagree and strongly disagree responses to the question, "I enjoy learning science," is twenty-two percent (22%) for males in primary school and thirty-two percent (32%) for males in secondary schools, nineteen percent (19%) and thirty-seven percent (37%) for females, respectively (CDEST 6.1). The study suggests that this disparity could be the result of different teaching styles between primary and secondary schools. Primary school science education is characterized as "student-[centered] with practical activities and freedom for student investigation resulting in high levels of student satisfaction" (CDEST 6.2.1). The majority of the students in primary and middle primary schools report that lessons are dominated more by discussion than lectures and note taking. With this in mind, teachers reveal that subjective grading methods such as "observation, checklists and anecdotal records" are commonly used in lieu of formal tests. The opposite, that teachers lean more towards objective grading methods rather than subjective ones, is true in secondary schools (CDEST 6.2.1-6.2.2).

The CDEST study suggests that as students grow older their interest in science diminishes. This is reflected by achievement in standardized test scores, specifically the **T**hird **I**nternational **M**athematics and **S**cience **S**tudy (TIMSS). Thirty-seven countries participate in the TIMSS. Australian primary students score higher than all nations except Korea and Japan, and these scores are consistent throughout the Commonwealth. The scores for secondary schools are still high with only Singapore, the Czech Republic, Japan and Korea scoring higher but with much variation. Four jurisdictions scored lower than the top third of participating countries and one particular jurisdiction was within the bottom third of participants. This variation in scores suggests strongly that the level of accomplishment in primary schools is higher than that of secondary schools (CDEST 6.3).

The report offers several recommendations for achieving scientific literacy in students that may or may not be completely appropriate for the situation in the Commonwealth. In the following discussion, each recommendation will be hereafter qualified by Jan Thomas' critique of the study entitled, "Commentary on The Status and Quality of Teaching and Learning of Science in Australian Schools" (Thomas 2). Thomas' main issue with the study is its segregation of mathematics and sciences: "Until young people have a quality science and mathematics education, their scientific literacy must be of questionable quality..." (Thomas 1).

The first recommendation made by the study is awareness. The study finds current science curricula unlikely to achieve scientific literacy, yet the research implies that teachers and researchers support increasing scientific literacy. The CDEST study suggests that although teachers support scientific literacy, they have difficulty understanding the concept of scientific literacy. The first recommendation prescribes a strong effort in marketing the importance of science to teachers, students, prospective teachers, and researchers. It suggests that scientists and researchers work in conjunction with primary and secondary teachers in order to make science curriculum, "more tangible and relevant," to current scientific endeavors (CDEST 7.2.1). This seems at the onset to be quite vague, and Thomas argues that real awareness lies in revealing the effect a strong science and mathematics education has on a student's success in his career of choice. Thomas claims that there is, "a link between mathematics achievement and socioeconomic factors" (Thomas 1). The study also ignores the importance of mathematics in higher-level science. Students may find themselves at a loss when they engage in advanced science courses only to find they lack the necessary mathematics background (Thomas 2).

A second recommendation suggests that Australia work to increase the supply of qualified science teachers by offering university students incentives to embark in the field of education. The universities may further provide incentives for scientists to reeducate themselves as teachers. Maintaining the front-end supply would be achieved by providing incentives to current teachers of the highest quality to remain educators (CDEST 7.2.2). Thomas agrees with the above methods, but worries that the study does not mention the decreasing supply of PhDs in science and mathematics. If the number of college professors in these fields diminishes to non-existent, it will be quite a challenge to educate prospective teachers (Thomas 3).

Thomas finds that the field of mathematics is often ignored when considering issues of science education reform and that the study overlooked a sublime opportunity to improve sciences and mathematics. Students without a firm grasp of mathematics will not have the ability to grasp advanced sciences. In this environment, "scientific literacy" is not feasible (Thomas 5).

2.3. Emerging Technologies

Emerging technologies are scientific fields in their infancy being applied to real world applications. They are born by the synthesis of many traditional fields of science. In the past, computer science was considered an emerging technology; it is now an accredited major. Fields like nanotechnology, photonics and genetic engineering could now be in the same position that computer science was in the 1960s. It was not until the late 1990s that computer science was introduced to secondary curricula. It is interesting to consider how the aforementioned fields could prosper if they were introduced as subject matter to secondary students.

2.3.1. Emerging Technologies at CSIRO

CSIRO Corporate is comprised of four units: Research, Industry, Media, and Education. There are 22 Research Sectors within CSIRO. These sectors are combined in various ways to comprise the 22 industry sections of the organization. The current research being done as CSIRO is vast, covering everything from agriculture to complex systems integration such as mass transit systems. Several groups within CSIRO research topics that are at the core of this IQP. They include:

- Nanotechnology
- The Novel Materials & Processes Group
- Australian Centre for Precision Optics
- Photonics and Micromanufacturing

All of these groups help to keep CSIRO research on the forefront of research on emerging technologies (CSIRO Homepage 2003).

The Nanotechnology research area of CSIRO specializes in "the development of nanosized materials and new processes for application in polymers, pharmaceuticals, cosmetics/sunscreens, paints, coatings, inks and textiles" (CSIRO Nanotechnology Homepage 2003). This research area branches off into inorganic nanostructures, nanoparticle additives for polymers, nanoparticle additives for UV resistance, and using synthetic opals for nanotemplates.

The **N**ovel **M**aterials & **P**rocessing group (NMP) currently does research in designing x-ray instruments, protecting from surface corrosion, and producing nanoparticles. All of this research finds its roots in nanotechnology. The following is a list, taken from the NMP homepage, which details the current applications of its research in industry:

- Microsurface engineering — optically variable devices for currency, biotechnology and fluids mechanics applications
- High performance polymer composites — for the food packaging, aerospace, coatings, textiles and personal care industries
- Ceramics — developing new ceramic and composite products with special properties for special high added value applications.
- Advanced X-ray imaging technologies, for medical imaging, life science and materials characterisation
- Clean construction materials and process technologies for smart precast construction
- Surface engineering of polymers — advanced structural components for bonding and painting in modular construction
- Building—environment interactions — a global model of Australia's microclimatic conditions to model corrosion
- Advanced packaging solutions, including biodegradable resins
- Recycling technologies, chemical benefication and demolition waste
- Sustainable cementitious technology — recycled byproducts for new concretes (CMIT – NMP 2003)

The Australian Centre for Precision Optics is broken up into three sections: Optical Manufacturing, Coatings, and Metrology. Optical Manufacturing deals with creating ultrahigh precision optical lens and, oddly enough, perfect silicon spheres. These perfect silicon spheres have numerous applications in applications with high calibration demands and have a very important use in the Avogadro project – an international initiative aimed at redefining the kilogram in terms of the Avogadro constant. The Coatings section deals with coating optical lens with chemicals to obtain very specific properties. The last section, Metrology, is the science that deals with precise measurement. By working closely with the National Measurement Laboratory and utilizing research from the rest of the Australian Centre for Precision Optics, the Metrology section is on the forefront of precision measurement (ACPO Homepage 2003).

Photonics and **M**icromanufacturing (P&M) is a research area of CSIRO that focuses in the application of photonics in manufacturing small objects and designing products that use thin layers of molecules to perform a task such as corrosion protection. Some of the capabilities include:

- Simulation and analysis of corrosion processes
- Formulation and deposition of inorganic coatings for corrosion protection
- Precision electroforming and electrodeposition of metals
- Optically variable devices for anti-counterfeiting applications
- Development and application of new X-ray imaging systems, including phase contrast X-ray imaging and X-ray ultramicroscopy

These capabilities allow the P&M area of CSIRO to pursue research projects such as X-ray science and instrumentation. This research group develops "X-ray imaging techniques and technologies which form the basis for a range of scientific, industrial and medical instruments" (P&M Homepage 2003). These capabilities also allow P&M to sponsor research groups in Micromanufacturing. The main activity of this team is to design optically variable devices that can be used in anti-counterfeiting schemes on currency and official documents. (P&M Homepage 2003).

2.3.2. Nanotechnology

Each single molecule in nature measures about one nanometer in diameter. "At a billionth of a meter, a nanometer is the essence of small" (Stix 32). Manipulating these nano-sized entities ranks as the most interesting and popular research scheme around the world today. "[T]he word "nanotechnology" has become very popular and is used to describe many types of research where the characteristic dimensions are less than about 1,000 nanometers" (Zyvex homepage 2003). In general, the field of nanotechnology deals with building or creating tiny objects by encompassing the fields of "condensed-matter physics, engineering, molecular biology, and large swaths of chemistry" (Stix 32).

In his 1959 lecture, *There's Plenty of Room at the Bottom*, delivered to the American Physical Society at the California Institute of Technology, Nobel Prize winning physicist Richard Feynman first introduced the concept of maneuvering matter atom by atom. Deemed as "science fiction" then, the possibility of an upcoming micro-technological development seemed impossible to listening researchers and colleagues. "By 1974, the micro-technology revolution, perhaps best represented by the ever-shrinking silicon chip, was in full swing" (Gibney 24). Shortly thereafter, Norio Taniguchi of the Tokyo Science University came up with the term "nanotechnology" to encompass scientific research fields that primarily dealt with molecular manufacturing in a scope less than about 1,000 nanometers. "The next technological revolution might very well be invisible to the naked eye as engineers and scientists probe the enormous possibilities of nanotechnology" (Gibney 23). One should note that the most recent definition of the term nanotechnology includes not only dealings at the nano scale but at the micro scale as well.

Sufficient interest in atomic imaging and nano-fabrication supports efforts in the development of methods or machinery for microscopy advancement. "The invention and development of scanning probe microscopy has taken the ability to image matter to the atomic scale and opened fresh perspectives on everything from semiconductors to biomolecules" (Yazdani 227). Scanning Probe Microscopes produce high-resolution images of samples by sensing changes in the height, depth, or other characteristics in the surface. The Atomic Force Microscope uses a tip on a soft cantilever to feel the sample surface "much as a blind person reads Braille or feels a person's face" (Hansama 14678) to determine surface characteristics of a sample. Also belonging to the SPM family are the **S**canning **T**unneling **M**icroscope (STM) and the **S**canning **E**lectro**C**hemical **M**icroscope (SECM). The SECM measures electrochemical properties of a sample surface under fluid while the STM measures the current of electrons that tunnels through the gap between a conductive tip and a conductive sample.

In actual imaging procedures, STMs "measure the mechanical properties of various materials, and rearrange atoms and bend carbon nano-tubes" (Sincell 1530). The rapid advancements of these microscopy techniques are still in question, however, due to the many intricate problems caused by working with things invisible to the human eye. To point the tip of the STM in the right direction, researchers must scan the surface and locate the target in the resulting three-dimensional image. Then, they must switch from visualization mode to manipulation mode, program the STM tip to move to the right spot, and finally press it against the surface. Meanwhile, thermal vibrations of the surface may have moved the atom away from the tip's preprogrammed target. "It is like trying to play blindfolded billiards during an earthquake" (Sincell 1530).

A reason that nanotechnology is deemed an "emerging technology" resides in the pursuit of modern millimeter sized **m**icro-**e**lectromechanical **s**ystems (MEMS) and in the future nanometer sized **n**ano-**e**lectromechanical **s**ystems (NEMS). "[The] dwindling size of circuits in electronic chips drives much of the interest in nano [technology]," (Stix 35) and has lead to nano-technological growth in other areas of industry. With growing commercial applications for numerous uses such as in blood pressure kits, carbon-monoxide detectors, motion sensors, computer joysticks, and airbags, these tiny silicon-based devices have advanced new applications in sensing and molecular interactions so quickly that researchers are anxious to further advance their knowledge in this area. In regards to the future and the impact of MEMS systems Bishop asks you to "...imagine a world with machines the size of mites tending to all sorts of jobs" (38).

"With the potential global market estimated at up to $14 billion a year, even the most pessimistic believe that MEMS devices will soon have a major impact on our lives" (Mullins 31). The main concerns of the most pessimistic reside in the issues of powering these tiny machines. Regular batteries fail to provide MEMS with enough power due to decreased volume and size of the micro-machines forcing researches to delve into other options. Most promising includes alternatives using siphon energy from the environment, solar power, and nuclear powered batteries. However, many environments do not believe that nuclear power will ever be a realistic power source for MEMS due to the threats they pose on the environment. This issue of nuclear micro-batteries will feed an enormous amount of controversy between the nanotechnologists and environmentalists of the future (Mullins 33).

Despite looming controversy and numerous problems nanotechnology may pose for the future of society, the United States government has implemented The **N**ational **N**anotechnology **I**nitiative (NNI). The NNI is a multifaceted program aimed at increasing funding for nanotechnology research. In addition, nanotechnology research divisions continue to spread from coast to coast at universities and in other countries. Hopeful applications of nanoscale research from these institutes include nanorobots or molecular robots, enhanced semiconductors, computers based on nanotube carbon components, a DNA computer, chemical computers, and numerous biosensor applications (Stix 33).

President Clinton's proposed 83% increase in funding for nanotechnology research created a stir in the science community over this field of study especially important in biology and material sciences. Most important biological units are between one and 100 nanometers including DNA, proteins, viruses and more. Easy manipulation of such tiny entities could lead to great medical breakthroughs (Southwick 1).

Materials researchers hope to acquire the means to build molecular structures atom by atom, which could lead to new metals, plastics, and medicines that could drive many new technologies. Molecule sized devices could perform invasive surgery on a patient from the inside out without the trauma of traditional surgery (Southwick 1). The building blocks of understanding these concepts relate to knowledge of cells with motor ability.

Nanotechnology researchers hope to build from an understanding of biology in order to promote many aspects of their research (Monaghan 4). Nanotechnology has the potential to revolutionize medical implants from heart valves and blood vessels to hips and lenses. Existing studies in bio-nanotechnology will enable doctors to coat replacement organs and tissues with a molecular-engineered surface. This coating would prevent the immune system from rejecting the organ (Monaghan 2).

Researchers at Hewlett-Packard and the University of California at Los Angeles have created a strain of rotaxene to act like an electronic transistor. Chemical transistors could be far smaller and less expensive than their silicon counterparts (Southwick 2). Silicon transistors and therefore processors are built using photolithography, and as we reach the limits of this process, we begin to require more and more the potential of nanotechnology (Monaghan 5).

Matter has been found to behave curiously different at the nano-scale. This behavior could lead to major, unforeseen discoveries. One example is an environmental engineer's efforts to create a better catalytic converter for automobiles and other burners of fossil fuels.

When catalytic converters are coated with a very thin finish, only several atoms thick, of gold they are much better at controlling pollution. Even slightly larger particles of gold have no effect (Monaghan 3).

Some theorize that nanotechnology stands today where computer science stood in the 1950s. The above anecdotes, though ambitious, could become a reality in the next ten or twenty years, but to the private sector, a ten or twenty-year payoff is not worth the gamble. It was with this in mind that the Clinton administration offered such a large increase in spending on this emerging technology (Southwick 3).

2.3.3. Photonics

Photons are the smallest division of light; they are to light as electrons are to electricity. The word "photonics" was coined by the engineers at Bell Labs to describe "the combination of light technologies and electronics in telecommunications" (Menzel 1). Since then, the term has grown to encompass anything that involves the application of laser light.

But what is a laser? The word laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation (Menzel 325). A laser focuses photons more than a simple flashlight. By exciting atoms in a controlled medium, a laser can emit a beam of light where all the photons have the same frequency and velocity. There are now dozens of different types of lasers. They use different elements in their core, have different energies, and cover a range of prices. They have spread into all aspects of technology from medicine to material processing (Menzel 6).

A majority of people in Australia have benefited from an application of photonics known as X-ray lithography. However, most of these people probably have no idea what x-ray lithography is. Creating a microprocessor is not as simple as connecting a few transistors. Microprocessors are so small that there are entire techniques dedicated to their fabrication. X-rays are used to etch pathways in a substrate; these pathways are then used as wells for doped metals that create the transistors and trace line. X-rays are also used for high precision magnification. Some things are so small that light cannot be used to see them. No amount of magnification will matter once the objects trying to be viewed are smaller than the wavelength of light. X-rays can be used to see things at the size of 2-4nm. In fact, using X-rays makes it possible for scientists to observe the molecular reactions inside living cells (Menzel 7).

Laser medicine is a rapidly growing field in photonics. Precision lasers are now used in eye surgery to repair deformed retinas and lenses. In addition, skin abnormalities, clogged arteries, and kidney stones can all be treated with fine tuned precision lasers. These procedures are minimally invasive and very accurate (Menzel 7). They use a small fiber optic cable to carry the laser light through the body. These tools have been refined over the past decade and now are offering some of the most reliable surgery available.

Fiber Optic technology is the application of light waves to long fibers of glass. Information is sent down these glass fibers by pulses of different color light. Applications of fiber optics include, but are not limited to, communications, compact disk players, long-distance underwater and land telephone cables, cable television transmission, sensors for monitoring or detecting change in the environment surrounding the fiber, and illumination. "[T]he potential for expansion is truly enormous" (Beynon 11); fiber optic technology is growing at an amazing rate.

Laser machining is a technique that shows a lot of promise in the future decades. Laser cut holes will be more precise and create better airflow in devices like turbines and airplanes. Laser cutting will revolutionize the way we mass-produce things like cars and appliances. On a smaller scale, low power lasers could be used to clean surfaces or add texture to surfaces (Menzel 7).

The US government in 1995 realized that there is a great shortage of men and women skilled in the field of photonics. This concern drove the creation of the Department of Education funded **N**ational **P**hotonics **S**kills **S**tandard **P**roject (NPSSP). The NPSSP proposes high school and college level photonics curricula and the needed background in math, physics and biosciences to complete such curricula. The photonics industry warns that the shortage of skilled individuals in the field of photonics puts the United States in a "preparedness shortfall". Representative Steve Gunderson suggests that, "The information superhighway is a photonics superhighway," further emphasizing the importance of the field ("U.S. on imaging education: it better get better." 8).

2.4. Teaching Advanced Science

Teaching the alphabet to a student in primary year one is not like teaching Newtonian mechanics to a secondary school student. First, the students are at a different level of maturity with a different set of skills. Second, the material goes from being memorization, as in the case of teaching the alphabet, to critical thinking and scientific application, in the Newtonian mechanics case. Teaching advanced science is a science in itself. There are many different methods of how to relay high-level information to students. Interviewing science educators from the United States and reading American educational journals provided our team with a wide base of information on these areas. The next sections highlight these teaching methods used in teaching advanced technologies, along with some example learning activities.

2.4.1. Methods of Teaching

Professor Nancy Burnham, a Professor at **W**orcester **P**olytechnic **I**nstitute (WPI), is one of the school's foremost professionals in nanotechnology and currently runs WPI's **A**tomic **F**orce **M**icroscopy (AFM) lab. She is a professor of practice in her third year of teaching at WPI. She has written two articles for *Highlights*, a magazine aimed at children six to ten years old. Although she has not taught high school children, her work with *Highlights* gives her valuable insight into designing educational material.

In a recent interview, Professor Burnham answered some questions regarding nanotechnology education in secondary schools. She emphasized the fact that there are two different areas in nanotechnology. First, one can think of nanotechnology as the miniaturization of things. Microprocessors and modern computer engineering are the epitome of this facet of nanotechnology. Transistors and electron trace pathways on these microprocessors are quickly approaching a point where the features are less than 0.1 micrometer in length. However, those tiny electronic components operate based on the same principles as transistors on the macro level. The second part of nanotechnology explains the behavior of small things and helps apply them to real world applications. Down at the nano level, probability and quantum mechanics come into play and the laws of Newtonian mechanics and electromagnetic theory are tossed aside. While the near future of computing rests in miniaturization, the distant future rests in the hands of quantum mechanics and the science of the small (Burnham).

Professor Burnham was also asked about the feasibility of teaching nanotechnology to high school students. She agreed that a program of this nature should be short and to the point. There is no need for an elaborate explanation of the science, only that the students are engaged and interested. Professor Burnham suggested that such a lesson would only skim the surface of the very interesting parts of nanotechnology and quantum mechanics such as quantum tunneling and quantum telepathy.

Judith Lawson is a teacher of AP Calculus and AP Physics at Holy Name Central Catholic High School in Worcester, MA USA. She has been teaching high school students for 30 years. In a recent interview, Mrs. Lawson was asked her opinion on exposing high school students to emerging technologies. She initially stated that she would tend to shy away from presenting cutting-edge material to students. She feels that the majority of students would not be able to handle any in-depth lessons in the fields of photonics, genetic engineering, quantum mechanics, or nanotechnology. Reasons for not attempting to teach these topics to students range from the possibility of general student apathy on the subject, to the fact that some students many not be able to understand the material. After a short discussion on the nature of the project, she changed her tune in support of the idea but with the warning that students must be prepared ahead of time. Sending the students a handout before the presentation, for example, will help to ensure that they have a basic understanding of the material (Lawson).

Designing realistic instructional material to support our curriculum can be a daunting task. There are several techniques given in Volume 41, Number 1 of *Educational Technology* that can be applied to teaching advanced topics in secondary school. This is a special issue dealing with teaching physics to secondary school students. In explaining the motivation behind this special issue, the guest editor, Ward Cates, writes about the difficulties of finding success stories that designers of instructional media can build upon. Cates asked four teaching professionals to independently develop a lesson that would teach physics to teenagers.

While sticking mostly to Newtonian mechanics, the articles submitted do a very good job of describing how to develop curriculums that are "cool" to students and that teachers "can use" (Rieber). Rieber specifically talks about certain assumptions that must be made in order to make a reasonable lesson plan, or design, for students. Rieber refers to such lessons plans as designs in his writing. These assumptions are:

1. This design is meant to be instructional in nature. That is, there are specific learning outcomes that must be achieved in a timely fashion
2. This lesson is to be used in a formal educational environment, such as a middle or high school classroom, with all of the typical constraints that such an environment entails, such as limited time and the associated pressure to accomplish the school's or district's curriculum.

3. The learning environment includes a professional teacher to work with the students.
4. The design is to be based on existing technologies. We resisted the temptation to delve into "science fiction: and invent technologies currently not possible, like "hover boards" from science fiction movies.
5. Schools that use our product have an adequate technology infrastructure. While we were mindful of assumption #2, we did not want to unnecessarily constrain ourselves to only a one-computer classroom (Rieber 15).

Using these five assumptions, Reiber goes on to create a realistic method for teaching math and science to students.

In Reiber's article, there is much mention of the possibility of using computers for simulation purposes. One simulation allows the user to choose the slope of surface, and the mass of a car. On "Go," the car is released from the top of the plane and the speed and acceleration are plotted. This very simple simulation tool is effective with students (Reiber 16). Tools like this could be utilized in teaching photonics. For example, in emphasizing the wave/particle duality of photons, a simulator could allow the user to change the size of a diffraction gradient. The result would show the user what the scattering pattern would be on a wall from a certain distance. Other examples include the effects of lensing. Inputs could be the concavity of a certain mirror or lens and the distance from of the lens or mirror from the source. The output would be a simulation of a picture under such a lens or mirror.

The editors of this issue of *Educational Technology*, Cates and Bishop, finished the special issue with an editorial to correlate their findings. One thing that Cates realizes is that the methods all seem to share four properties. First, all the methods are problem-oriented; they have real world problems as opposed to theoretical ones. Second, all of the designs have an experimental element that allows students to change variables and see how those variables change the response of the system. All the designs also stress testing hypothesis or ideas. Some ideas might not be brought out into the open until after an experiment already confirms it. All the designs provide a structure for all activities. There is a not an opportunity for students to become lost or off-track in their quest for understanding the material. Lastly, all the methods involve high order thinking. These lessons are not designed to tests a student's ability to memorize facts. Instead, they encourage, and in some cases require, students to think about relationships and theories (Cates 60).

In designing a quick and easy method for teaching science to secondary school students, it is important to get to the point quickly. There are some people who believe that the current system of *review what you know, learn some more things, review what you learned* is inefficient. In a short article published in *Curriculum Review*, Cher Tufly notes that teachers should trust students to remember what they learned. Instead of an involved review process, Tufly calls for a shorter summary of the material required for a class. She says that the current system is inefficient in the way that it focuses heavily on review. If the students were taught correctly in the first place, they should not need an elaborate review (Tufly 1). This should be taken into consideration while designing a curriculum or a program dealing with emerging technologies. Since the nature of the programs offered by CSIRO Education are to get kids interested in science, there will not be a need for any evaluation at the conclusion of the program. In addition, due to the nature of the program being developed, there will not be time to review any elementary math or physics with the students.

One newer technique that came out of research is a Family Technology Night. Susan Pendergast talks about how such an event can be pulled off even in schools that do not have fully integrated technology classrooms. These end up being high-tech science fairs. Students spend about 4 or 5 months planning projects and presentations. When the event is finally held, all the presentations are kept to around 15 minutes. The parents never stop moving and get to see multiple aspects of technology being used in the school (Pendergast 1).

The benefits of such a program are far reaching. The parents become more involved in the education of their child. They know what to expect from their children and feel like they can help more in the child's education. Parents get to see what the teachers are doing. They get to interact on a level above that of a Parent-Teacher Conference. The parents can ask technical questions of teachers so that they are better equipped to answer questions from their children when the time comes. This also opens the door for teachers to make phone calls and visits to the homes of their students (Pendergast).

As Pendergast says, "Always plan for technical glitches." She recommends having a technical specialist on hand. If that is not possible, it is imperative that the event planners can get in touch with a specialist at a moment's notice. Another point of general advice that Pendergast makes is that an open house feeling is always preferred. All the doors should be open, and there should be no schedule for parents to follow as they tour the room. It should feel like a fully open event. Even in schools where technology is not predominant, it is still possible for such an event to succeed. There is no reason why the teachers cannot prepare slides and handouts for parents. Even with a few computers, lesson plans can be tailored to run presentations or show the parents a demonstration (Pendergast).

Schneider states that the prevailing opinion of science education is that inquiry based processes do not expose students to as much content as lectured teaching. Schneider's study tries to find empirical data to prove the opposite. This study was conducted on 142 students in years 10 and 11. These students were exposed to well-crafted project based science in lieu of their regular curriculum. These students then completed the 12th grade National Assessment of Educational Process science test scoring higher than 44% of their 12th grade peers (Schneider 1). Schneider identifies five key points in developing proper project based science curricula:

- Engage students in investigating a real-life question or problem that drives activities and organizes concepts and principles
- Result in students developing a series of artifacts, or products, that address the question or problem
- Enable students to engage in investigations

- Involve students, teachers, and members of society in a community of inquiry as they collaborate about the problem
- Promote students' use of cognitive tools (2)

In an ideal environment with interested participants, Schneider's study suggests that project based science provides students with a deeper understanding of science content and processes (3).

The importance of technology will be ever increasing. One example of technology's hand in the betterment of society is the food production industry. Robert Malthus, almost 200 years ago, warned of a global food shortage as humankind overpopulated the earth and stripped it of its limited resources. It is due mainly to technology that certain, heavily populated regions of the world are able to sustain human life. In the last century, 80% of increased grain production was due to increased yield of existing plots and only 20% due to new land usage (Besley 1-3).

Recognizing the numerous positive impacts technology has on so many aspects of life, it is important for Australia to work toward technological independence, which means sufficient domestic educators and a rejuvenated high-tech industry. Australia faces a great shortage of mathematicians and scientists. In an article titled "Australia minus maths equals big problem," Geoff Maslen finds that at the current rate of loss, Australia will have no mathematicians left in any of its universities by 2012. Without a conscious effort in opposition to current trends, Australia's secondary school curricula will be stripped of physics, chemistry and advanced mathematics. Australian government officials have proposed a multifaceted reform of technology education that, "[begins with] a total review and rejuvenation of the way we teach mathematics and sciences in schools" (Maslen 1).

2.4.2. Examples of Teaching Activities

Teaching advanced science is not a simple task, and education theory can be useful only to a certain extent. Specific examples such as the following apply education theory while engaging students in order to enhance their problem solving skills. While this is a somewhat truncated list, the possibilities discussed provide a view of how vast the opportunities are for students and teachers seeking interactive learning. These opportunities also provided a stepping-stone for the gathering of ideas and experiments for the out come of this IQP: the Catalogue of Learning Activities.

2.4.2.1. Hands-on Activities

Patrick Bunton outlines the details of a fun physics experiment in the October 1997 issue of *The Physics Teacher*. The activity uses gelatin to demonstrate the different properties of light. Due to the irregularity of the structure of certain gelatins, light is scattered when a beam propagates through the material. "Most introductory physics courses deal with properties of light such as reflection, refraction, and total internal reflection and then progress to the practical use of these properties in the form of lenses, prisms, and fiber optics" (Bunton 421). Using gelatin allows students to make numerous shapes and then test the outcome of passing light through them. They can learn the different properties of a lens, a prism, and a light guide while also observing properties like internal reflection. Photonics concepts may also be introduced using this engaging hands-on experiment.

Shifting focus from the science of light to the technology of lasers leads to a plethora of other interesting activities. James O'Connell outlines nine "basic experiments that demonstrate the wave nature of light and the optical properties of water" (O'Connell 445) using a laser pointer in the October 1999 issue of *The Physics Teacher*. He explains that this method is an inexpensive way to perform introductory optical experiments with minimal eye-safety requirements for students performing the experiments.

As photonics becomes a more widely used technology, the price of the equipment is coming down. Currently, a Helium-Neon (He-Ne) based laser costs only $800 (USD) and outputs 0.005W. A laser like this could be purchased for demonstration purposes. There are several other types of lasers, such as the diode laser, that cost more but have a much higher power to price ratio. These lasers could be used in demonstrations in which soft objects are cut or melted. The price for a diode laser is around $10,000 (USD) and it costs, on average, an additional $200 to operate over its 10,000-hour lifetime (Menzel 9).

2.4.2.2. Demonstration

The National Science Foundation Division of Undergraduate Education developed a visual demonstration that entices students to explore nanotechnology in a project titled **I**nteractive **N**anovisualization in **S**cience and **E**ngineering **D**esign (IN-VSEE). This project promotes "[t]he integration of nano-science and technology concepts into upper-division high school and lower-division college curricula" (IN-VSEE homepage 2003). The National Science Foundation goes on to explain that the project

> will require innovative educational approaches that will help students understand the structures and properties of matter on a scale below 100 nanometers, i.e., the nanoscale. The centerpiece of this project is the revolutionary scanning probe microscope (SPM), which has evolved rapidly into a relatively simple, yet powerful, technique capable of imaging and manipulating materials at resolutions down to the atomic scale. The proposed emphasis on SPM will allow students and teachers nationwide to operate and learn about nanotechnology using this Nobel-prize-winning technique. The key objective of IN-VSEE is to bring the exciting world of nanotechnology into the classroom to help inspire today's students to become tomorrow's scientists and engineers (IN-VSEE homepage 2003).

The IN-VSEE offers several experiments through their website that promote discovery and active learning using "cutting edge research tools as learning tools" (Ong 1115). One of the ultimate goals of the project is to "create a new level of excitement about careers in science and engineering" (IN-VSEE homepage 2003). The project includes a photo gallery of pictures both made for the project, and photos that have been taken because of the project. Members of the IN-VSEE are given remote access to a Scanning Probe Microscope at the University of Arizona. With the SPM, members are able to image objects at the atomic scale. Also included with a membership is access to extra educational programs that accompany all experiments and processes. Teachers and students become participants by contacting the IN-VSEE through e-mail. "[I]t is generally accepted that active visualization-based learning can heighten understanding and retention" (Ong 1114). Visual demonstrations also tend to catch the eye of even the most un-attentive student.

3. Methodology

The primary goal of our IQP was to provide CSIRO SEC with a Catalogue of Learning Activities that relate to emerging technologies. These activities can be used to strengthen existing CSIRO educational programs and create new programs. In order to accomplish this goal, we first had to answer several research questions. This chapter outlines the methods we used to answer those questions.

3.1. Demonstrating Project Relevance

Why does CSIRO want to develop learning activities that highlight the use of emerging technologies in the real world? How will these activities benefit secondary school students in Australia? Before we could safely explore different avenues for this IQP, it was important to know the answers to these questions.

This IQP directly relates to science education, so we looked to a comprehensive study on the state of Australian science education completed by the **C**ommonwealth **D**epartment of **E**ducation **S**cience and **T**raining (CDEST). This study attempts to quantify the erosion of Western science education and proposes a plan to improve Australia's scientific literacy.

With an understanding of the importance of this IQP to Australian science education, we still needed to demonstrate its usefulness to CSIRO SEC. The programs developed by CSIRO SEC are marketed toward schools, and many schools will not purchase a program if they cannot relate it in some way to the curriculum. In order to be of any use to CSIRO SEC, the results of this IQP must relate in some way to Victoria's curriculum. Throughout this IQP, we referenced the **V**ictorian **C**urriculum and **A**ssessment **A**uthority (VCAA), which regulates the requirements, goals, and outcomes of the Australian curriculum. The **C**urriculum and **S**tandards **F**ramework II (CSFII), maintained by the VCAA, outlines these requirements, goals, and outcomes for the state of Victoria. We were led to the VCAA homepage by our CSIRO SEC liaison, Chris Krishna-Pillay.

3.2. Researching Emerging Technologies

Before we developed the concrete learning activities for our Catalogue, we found it important to become educated in the sciences behind the emerging technologies under consideration. Up to date textbooks and encyclopedias proved to be excellent sources of data on the basic sciences relating to nanotechnology, photonics, and other emerging technologies. Electronic journal indexes, such as *Lexis-Nexis Academic Universe*, *Education Index*, and *Emerald Library*, allowed us to efficiently research further into the preliminary data collected about emerging technologies in general and in education. New questions arose as our research continued. These questions led us to interview several WPI faculty members.

Each of our interviewees provided suggestions on how to relate their field of study to secondary students. Some even presented us with possible experiments and activities that they have used to generate student interest. WPI professors Nancy Burnham and Robert Thompson are engaged in nanotechnology research on campus. They were able to offer us interesting concepts for activities that are now in the Catalogue of Learning Activities. Interviews with professors Theodore Crusberg and Richard S. Quimby relating to genetic engineering and photonics, respectively, were equally as useful.

3.3. Understanding Science Education

Equipped with knowledge about emerging technologies, our research became focused on how to relate the subject matter to secondary students. There are many schools of thought in how to relay high-level information to students, and through our research, we realized that teaching advanced science is a science in itself. Through conducting interviews and reading education journals, we became familiar with multiple teaching methods deemed successful.

We also familiarized ourselves with established learning activities, similar to those we created, in order to investigate successful teaching methods applied.

WPI Professor Nancy Burnham gave her opinion of the feasibility of teaching nanotechnology to secondary students while also providing suggestions on how to successfully teach nanotechnology ideas to young students. Judith Lawson, a teacher of AP Calculus and AP Physics at Holy Name Central Catholic High School in Worcester, MA USA, expanded on these opinions of feasibility and ideas for success.

We also used an electronic journal index called *Education Index* to obtain qualitative and quantitative data on the effectiveness of many popular teaching methods. Many of these journeys provided information such as methods to design realistic instructional material that supports a secondary school curriculum. Some outlined ideas of how to develop curriculums that are "cool" to students and that teachers "can use".

As our information on teaching methods began to accumulate from the interviews and education journals, we realized that researching education theory could only be useful to a certain extent. We proceeded to researching examples of multiple teaching methods being applied in demonstrations, learning activities, and hands-on programs. We researched and analyzed these existing learning activities and education programs in order to develop a set of tools for use in the outcomes of our IQP: the Catalogue of Learning Activities.

As with most research activities, our IQP had a somewhat broad precedent. There were many programs sponsored by CSIRO SEC in the past, and there currently exists many similar programs domestically. Reading about these CSIRO SEC programs provided us with valuable preliminary knowledge that helped to develop the Catalogue for our final product.

3.4. Selecting Ideas for Learning Activities

Selecting appropriate ideas for learning activities depended on the development of a solid set of topic criteria. We took into consideration input from teachers, students, CSIRO staff, and other sources to define what it is that makes an effective learning activity. Once the topic criteria were defined, our focus shifted to gathering ideas and experiments for the design of the Catalogue of Learning Activities. Each activity includes a synopsis, a description of how it parallels the CSF II, background information, and suggestions on how CSIRO SEC can incorporate the activities into existing educational programs or into the creation of new programs. Where applicable, the activities were also accompanied by an economic analysis and worksheets for students and teachers.

3.4.1. Determining Criteria for Learning Activities

In order to select appropriate learning activities, we developed a set of criteria. First, the technology behind the experiments must correspond to current research at CSIRO. CSIRO has a very large and detailed web site that we found to be an informative resource for acquiring information about the organization.

Second, the experiments had to parallel current secondary curriculum requirements in Australia and be explainable in terms of the core aspects of the curriculum. We requested documentation outlining specific curriculum requirements from our liaison. He informed us of the **V**ictorian **S**tate **C**urriculum **S**tandards **F**ramework **II** (CSF II), which is available online.

Third, the learning activities must be realistic in terms of expecting secondary school students to be able to understand the basic concepts behind each emerging technology. Research and interviews with WPI faculty members helped determine how realistic our ideas of exposing selected emerging technologies to secondary students were. A large portion of our research highlighted opinions for and against exposing secondary students to higher-level technologies and research endeavors. The interviews conducted with the WPI faculty were loosely structured around the questionnaire shown in Figure 3.1.

Educator Interview Script for use in United States

- Explain to the interviewees the goals of the IQP.
- Ask them what they think of the IQP.
- Ask them for any general advice based on our goals.
- What age groups have they dealt with before?
- How long have they been teachers?
- How long have they been in their field of interest?
- What is the most important application in their field?
- What are some interesting aspects of their field?
- Do they think it is realistic to teach this material to secondary students?
- What do they think is the best way to market this to secondary students?
- Do they see this being used as a week long or day long activity or does it need to be part of the curriculum?

Figure 3.1- Educator Interview Script

Lastly, assessing students' and teachers' attitudes toward our ideas was necessary in order to ensure that our selected experiments would pique students' interests in emerging science research. We created a pilot survey based on the areas of interest for the different emerging technologies expressed in our interviews. The content of the Catalogue of Learning Activities must ultimately pique students' interests not only in the topics presented to them but also in science in general. We designed a survey consisting of three cutting-edge ideas for nanotechnology, photonics, and genetic engineering. We did not use the words nanotechnology, photonics, or genetic engineering since they have become "buzz words" in the last few years and could sway a student's responses. The survey (Figure 3.2) asked the students to state whether they were interested in each idea and to add an explanation of why they reacted that way.

Pilot Survey
Please specify if you are interested in the following anecdotes followed with a brief explanation of your decision. (Yes or No. Why?)

1.) Researches believe they will be able to "grow" human organs.

2.) Light can be used to cut through steel.

3.) Molecular robots will be used in the future to perform invasive surgeries.

4.) Genetic engineers may have the ability to prevent such things such as obesity, poor eyesight, and baldness.

5.) High intensity white light can be used to kill bacteria and fight against-bio-terrorism.

6.) DNA molecules have the potential to serve as computer "memory"

7.) Researchers believe that the plastics (such as those used in automobile manufacture) may be able to "self heal" if dented or damaged.

8.) In the future the ageing process could be reversed.

9.) Doctors may soon embrace the possibility of performing laser open-heart surgery.

Figure 3.2-Student Pilot Survey

The pilot survey did not produce useful results. The students were confused by the instructions and in many cases wrote simply "true" or "false," which were useless responses. Even students who understood what they were being asked rarely offered useful responses to the open-ended questions.

Based on the outcomes of our pilot survey we developed a final survey (See Figure 3.3). The pilot survey had asked too much from students and had lacked clear instructions. These mistakes were corrected in the final survey, which asked eight closed-ended questions and had instructions that were more useful. The final survey also asked the students to list their three favorite topics from those listed. This data was used to check the validity of each student's answer sheet. If a respondent's top ranked items conflicted with the way he filled out the first part of the survey, his or her response was discarded.

Final Student Survey

WPI/CSIRO Student Survey

Program:

Date:

These eight ideas are at the cutting-edge of modern science.

Please rate the following by how interesting you find them.

Ideas	Not Interesting	Somewhat Interesting	Very Interesting	Extremely Interesting
A. Scientists will be able to "grow" human organs	1	2	3	4
B. Light can be used to cut through steel	1	2	3	4
C. Tiny robots will be used in the future to do surgery	1	2	3	4
D. Very intense light can be used to kill bacteria and fight against biological weapons	1	2	3	4
E. DNA will be used for computer memory	1	2	3	4
F. Plastics used in automobiles may be able to "self repair" if damaged	1	2	3	4
G. Scientists will be able to make people live longer by manipulating DNA	1	2	3	4
H. Artificial Intelligence will allow cars to drive themselves	1	2	3	4

Please write the letters corresponding to the three most interesting ideas below:

First Choice	
Second Choice	
Third Choice	

Figure 3.3- Final Student Survey

Using an Educator Survey (Figure 3.3) helped us determine what teachers are looking for from CSIRO SEC. Traveling to schools allowed us to distribute the survey to teachers at each program site. We accomplished this by making approximately 130 copies and sending them out to every booked program over the course of a week. Teachers were given the option of filling the survey out on the spot or mailing it back to us in an attached envelope.

WPI/CSIRO IQP '03
Educator Survey
Name: ______________________
School: ______________________
Program: ______________________
Date: __________

1) Why did you choose this CSIRO program?

2) How were your students prepared for this program? Was any preparation helpful in your judgment?

3) How would you improve this program?

4) What is the most important thing you look for when choosing programs?

5) How often will you refer back to this program in your classroom?

6) How does this program fit into your current or future teaching unit?

7) What other programs or topics do you wish CSIRO Education provided?

Figure 3.3- Educator Survey

Traveling with CSIRO Education Officers allowed us to interact with the teachers before, during, and after the course of a program. We were also able to give them an idea of the bulk of our project in order to gain any insight that they may have for our own program development. These methods helped us clarify our project's goals, its marketability, and our topic selection.

The analysis of educators' attitudes towards CSIRO Education, its current programs, their needs and expectations in regards to future CSIRO SEC programs, and their feelings in general, were finalized by studying the educator feedback sheets.

3.4.2. Gathering Ideas for Learning Activities

In addition to the early gathering of teaching methods applied in the form of established experiments and learning activities, we needed to build upon these initial ideas and develop more ideas. Through extensive internet research using www.google.com, www.nanospot.org, and www.education-world.com, and through interviews with staff members of CSIRO, we were able to create a toolbox of ideas to draw from during the development of the Catalogue of Learning Activities.

3.5. Developing the Catalogue of Learning Activities

In order to obtain a framework for the Catalogue design we conducted case studies on some of the education programs offered by CSIRO SEC. First, we observed the programs by traveling out to Victorian schools to examine the following programs:

- Forensics Frenzy
- Electronics
- Cool Chemical Science
- Materials Chemistry: Unit 1
- VCE Chemistry: Science Procedures and Processes
- VCE Physics: Materials and Structures

Next, we looked at the programs from a pedagogical viewpoint. We looked for trends in the way the material was presented by the Education Officers of the CSIRO SEC. Was it all hands on? Was there always a demonstration? Did the activities revolve around a critical thinking activity? Comparing these aspects by weighing their different strengths and weaknesses helped us to determine how our own ideas and experiments would be used in a program, and therefore, helped us in creating our Catalogue of Learning Activities.

The documentation pertaining to the educational programs offered by the CSIRO SEC also proved very useful. We read educator feedback sheets to gain insight on what teachers in the past have wanted in a program. We looked at the annual report of CSIRO for information on the cost of certain educational programs. We were able to compare successful programs was with those that was not successful. These methods helped us develop the cost, risk, and marketability assessment, which accompanies the learning activities in our Catalogue.

We also interviewed CSIRO SEC Education Officers to see what they required in an educational program. Does it need to be able to fit in a car? Does is need to be on wheels? Can they transport the needed chemicals safely? The answers to such questions were taken into consideration when developing our final Catalogue of Learning Activities.

3.6. Finalizing Project Goals

In order to give further significance to the outcomes of this IQP, a focus group discussion was enacted with the professors and students participating in WPI's Melbourne project center. The discussion began with a presentation detailing the goals of this IQP and those of CSIRO SEC, and once it was determined that the participants understood the goals they were presented with a set of preliminary outcomes. The presentation given during the focus group is available in Appendix F.

With an understanding of the IQP's outcomes and content, the focus group participants were led into a discussion about science education, CSIRO SEC's business model, emerging technologies in schools, and generating youth interest in science education.

4. Results and Analysis

The goal of this project was to provide CSIRO SEC with a Catalogue of Learning Activities that will excite students about emerging technologies. CSIRO SEC may use these activities to improve existing educational programs or to create new programs. Building a list of ideas and experiments is the easy part; ensuring that the summary of the activities, background information, and basic ideas will intrigue students is much more difficult. This chapter presents the results of the student surveys, the educator surveys, the case studies, and interviews. The analysis of these results are also presented and led to the creation of the Catalogue of Learning Activities.

4.1. Student Survey Results

Distributing surveys, as outlined in section 3.7, resulted in 133 valid responses. The students surveyed ranged from academic year seven through year ten. The data is representative of private and public school students engaged in science courses. The results of the student surveys helped to identify areas of interest for students. Figure 4.1, at the end of this section, represents all the data collected by the surveys.

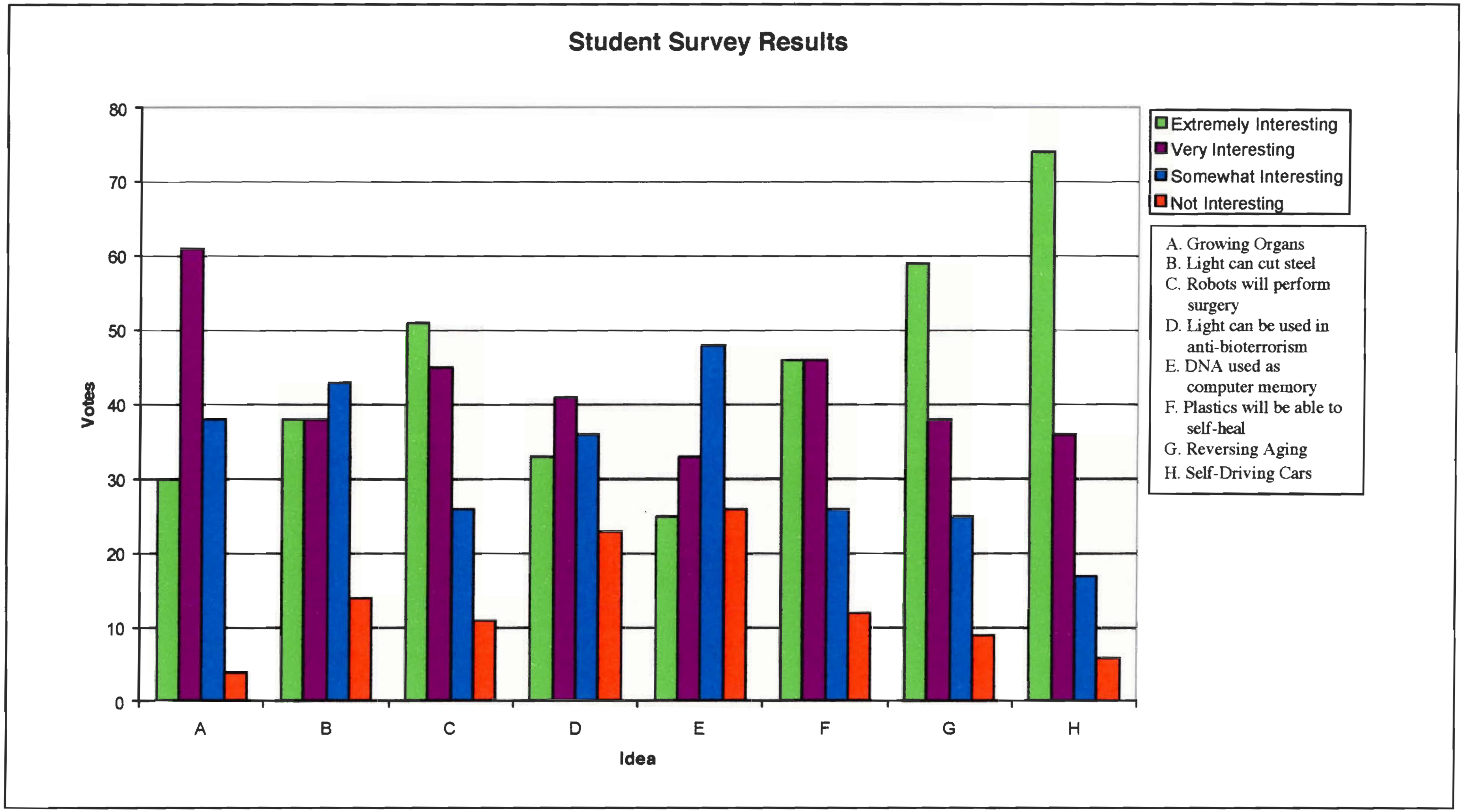


Figure 4.1- Student Survey Results

Successful CSIRO SEC programs require a high level of initial student interest. For this reason, Figure 4.2 represents only the number of "Extremely Interesting" responses for each item in the survey. Only four items exceeded the mean of 40, and they are, in descending order: H, "Artificial Intelligence will allow cars to drive themselves"; G, "Scientists will be able to make people live longer by manipulating DNA"; C, "Tiny robots will be used in the future to do surgery"; and F, "Plastics used in automobiles may be able to 'self repair' if damaged." Also to note is the low number of "Not Interesting responses to items H, G, C. An overall analysis also shows that the combined "Extremely Interesting" and "Very Interesting" responses represent over 70% of the total responses in each of H, G, C and F, far exceeding the "Somewhat Interesting" and "Not Interesting" responses.

Idea	Responses
A	24
B	35
C	45
D	29
E	22
F	42
G	52
H	69
Mean	39.75

Figure 4.2- Extremely Interesting Responses

4.2. Student Survey Analysis

The data collected from the student survey further refines the topic selection process. The quantitative interpretation of the survey is that each item represents a topic in consideration for the project, and the highest rated topics are the best candidates for the final product. In this scenario, the top four topics are H, representing computer engineering; G, representing biotechnology; C, representing nanotechnology and biotechnology; and F, representing nanotechnology.

A more qualitative analysis of the survey results would be to identify a trend in student interest. Each of items H, G, C and F are geared at people and enhancing their daily lives while lower scoring items such as "Lasers can cut through steel" have little effect on the average person. The key to generating student interest in science may be to link topics to real world situations and ideas.

4.3. Educator Input Results

The educator survey, shown in Figure 3.3, asked seven questions aimed at finding out why certain CSIRO SEC programs are successful or unsuccessful. This section presents the results of that survey. Due to the qualitative nature of the educator survey, these results will be a summary of what teachers said with no responses being ignored.

4.3.1. Why did they choose this CSIRO program?

When asking teachers why he or she chose a particular CSIRO program, the most common answers referred to CSIRO's current reputation. Four teachers pointed out that the traveling programs offered the opportunity for students to do experiments they otherwise could not do at school. Another common reason for teachers choosing CSIRO programs was that the programs generally fit into the curriculum being covered in class.

4.3.2. How were their students prepared for this program?

Educators indicated that they used the CSIRO SEC programs to stimulate students at the start of teaching a curriculum area. One teacher said that she would refer back to the "Gene Technology" program at different points in her DNA technology lessons to keep the student interested. The majority of teachers surveyed said that their students had no preparation before a program was presented to them. One teacher said that she used the "Cool Chemical Science" program to introduce certain aspects of the chemistry unit she would cover over the next few weeks.

4.3.3. How would they improve this program?

The survey asked educators in an open-ended format to offer suggestions for improvements to the program they purchased. Responses included less lecturing, more student participation and discussion, charts displaying "real world" connections, modifying the program to allow students to move at their own pace, and making the programs longer. Two teachers left this question blank and three teachers said that there was no need for improvement.

4.3.4. What is the most important thing in choosing a program?

One teacher said that a program had to appeal to young learners while paralleling the curriculum. Many teachers said the need for a program to contain a stimulating, hands-on approach. One teacher wrote that she looks for programs that will broaden her students' experiences with technology. Two teachers said cost was the most important factor.

4.3.5. How often will they refer back to this program?

As expected, many educators wrote that they would refer back to this program over the coming unit. Some educators, however, took it one step further and said that parts of these programs are very useful in other areas. One teacher said that she would use the Gene

Tech program as a springboard for an ethical discussion about the role played by science in health care.

4.3.6. How will this program fit into their current or future unit?

All of the educators reported that these programs fit very well with their current teaching units. Even when the program was not at the center of the current unit, teachers said that critical thinking skills and building interest in science was always a part of teaching. None of the educators said that these programs did not fit into the CSF.

4.3.7. What other programs do they wish CSIRO Education provided?

One teacher wrote that she hoped to see a more advanced electronics program developed for CSIRO SECs. She went on to explain that students would benefit from actually soldering components to build simple electronic devices. Another teacher expressed his desire for an earth science program and a fossils program. The chemistry of materials for higher-level secondary students was a suggestion given by another teacher. A response that stands out compared to the ones previously mentioned dealt with the desire for CSIRO SECs offering a program that introduced a topic and then having one to conclude the topic. Two wrote that they were happy with the programs offered. Four left the space blank.

4.4. Educator Survey Analysis

CSIRO SEC weighs the opinions of educators more heavily than student opinions because the educators are the ones who are usually responsible for booking a program from CSIRO SEC. The results from the educator survey covered every possible part of a program including cost, content, relation to material, and possible improvements.

From the results, it is easy to see that educators want a program to exhibit some key characteristics:

- **Can travel to schools:** Must be portable so that the programs can be offered at the schools as well as at a CSIRO SEC facility
- **Appeals to students:** Students must be interested in what they are doing
- **Parallels the curriculum:** Topics covered must be in the CSF
- **Incorporates hands-on activities:** Students must be engaged during the activity.
- **Is Affordable:** Program must follow the current pattern of pricing at CSIRO SEC

4.5. Case Study Results

Over the last 20 years, the Highett CSIRO Science Education Centre (SEC) has run hands-on science programs for over 750,000 students. Among these are multiple educational programs that consist of a science class or a science and technology presentation. These programs are offered to all levels of students and with many different location possibilities. The educational programs are available with a small fee or charge per student.

4.5.1. Forensics Frenzy

Forensic Frenzy is a hands-on workshop for secondary students in which they "assume the role of forensic scientists to solve a crime" (CSIRO Education Homepage 2003). The Education Officer introduces the scenario for the crime and then shows the students the numerous evidence driven experiments placed around the room. The topics covered include chromatography techniques, facial identification, fingerprints, soil analysis, dental X-rays, bloodstains, ballistics, and DNA analysis.

The session usually runs for about 1.5 hours and is designed for groups of up to 30 students for there are 15 activities and the students work in groups of 2-3. Each group of students is not specifically expected to complete all of 15 experiments, but the class as a whole covers all activities. The students record the data in their student workbook and later, as a class, they use the evidence to solve the crime. It is expected that they will report their findings to the class and write a report. This assignment is outlined in detail in the teacher notes, which also include a summary of the workshop and the correct answers to all activities.

With 331 sessions booked, *Forensic Frenzy* was undoubtedly CSIRO SEC's most successful program for the year 2002. The program reached 7,778 students and 653 educators over the course of 12 months. The gross income was well over $42,000 for CSIRO Education, Victoria in one year. Most Education Officers and CSIRO SEC staff communicated the belief that the program will continue to be successful in the future.

Forensic Frenzy can be held in Highett at the CSIRO SEC, or the program can be brought to metropolitan and country schools as a "labs on legs" deal. "Labs of Legs" means that the materials for the program are packed up in a vehicle and brought to an actual school classroom. There are some cost differences for the three different locations the program is offered, which are noted in Appendix C.

Requirements for a "labs on legs" booking include access to the presentation room one hour prior to the first session in order for the education officer to set up for the program. The lab room or classroom must be large with at least 12 tables or equivalent bench area. By large, the CSIRO SEC requires that the room fit at least 30 students comfortably. The room must contain a sink and at least three power points.

Most programs of CSIRO SEC fulfill the scientific Key Learning Area requirements of the CSF II set by the VCEE. In fact, an Education Program in consideration for purchase must usually parallel the current curriculum being taught in the classroom. Oddly enough, Forensics Frenzy does not cover any specific area of the CSF II but remains the most popular. Most staff members of the CSIRO SEC in Highett believe that in this circumstance student interest outweighs the usual direct need for curriculum-based programs.

4.5.2. Electronics

The *Electronics* program is a hands-on workshop for year nine and ten students in which they introduced to concepts involving energy and its uses. Students are introduced to concepts such as series and parallel circuits, and they use components such as resistors, capacitors, transistors, diodes and integrated circuits (IC's). After being introduced to these components through building several simple circuits, students then build several more complex circuits (CSIRO Education Homepage 2003).

The *Electronics* hands-on session usually runs for about 1.5 hours and is designed for groups of up to 30 students that are divided into groups of two or three. They complete the circuit building activities using the "Electroflash" electronics kit, which are distributed to each groups of students. The students each receive a student work booklet that contains questions for them to answer during the course of the program. The teachers also receive a booklet that includes a summary of the workshop and the correct answers to all activities.

With only 36 sessions booked in 2002, *Electronics* was the least successful program of all the CSIRO SEC programs for the year. The program reached 669 students and 72 educators over the course of 12 months. The gross income was around $3,700 for CSIRO Education, Victoria in one year.

Electronics can be held in Highett at the CSIRO SEC, or the program can be brought to metropolitan and country schools as a "labs on legs" deal. There are some cost differences for the three different locations the program is offered, which are noted in Appendix C.

Requirements for a "labs on legs" booking include access to the presentation room one hour prior to the first session in order for the education officer to set up for the program. The CSIRO SEC also requires that the room fit at least 30 students comfortably and have at least two power points.

The *Electronics* hands-on session is specifically "designed to address the learning outcomes of the CSF strand Physical science section 6.2 - Energy and its uses" (CSIRO Education Homepage 2003). Specifically, the *Electronics* Education Program teaches students to "describe the effect of electronic and electrical components in the operation of electronic and electromagnetic devices" (CSFII).

4.5.3. Cool Chemical Science

Cool Chemical Science is a hands-on program that immerses lower level secondary students to the world of chemistry. In ten hands-on activities and demonstrations, students examine chemical and physical changes and chemical reactions. They also learn to relate materials and chemicals to their common uses in everyday life.

The session usually runs for about 70 minutes and is designed for groups of two to three students. Each group of students is not specifically expected to complete all of ten experiments, but the class as a whole covers all activities. The students record the data in their student workbook and then later use the material in class or in a written assignment. Sample assignment ideas are outlined in detail in the teacher notes, which also include a summary of the program and material to accompany all ten activities.

CCS can be held in Highett at the CSIRO SEC or the program can be brought to metropolitan and country schools as a "labs on legs" deal. There are some cost differences for the three different locations the program is offered, which are noted in Appendix C.

Requirements for a "labs on legs" booking include access to the presentation room one hour prior to the first session in order for the education officer to set up for the program. The lab room or classroom must be large with at least 14 tables or equivalent bench area. By large, the CSIRO SEC requires that the room fit at least 30 students comfortably. The room must contain a nearby sink and at least two power points.

The *CCS* program is "designed to suit Levels 4 and 5 of the Chemical Science strand of the CSF" (CSIRO Education Homepage 2003). In respect to Level 4, the learning outcomes of this KLA expect students to have the ability to "distinguish between physical and chemical change" (CSFII). Level 5 specifies that students "use a simple particle model to explain the structure and properties of solids, liquids and gases" (CSFII). It goes on to say students should learn to "relate the safe use and disposal of common substances to their physical and chemical properties" (CSFII). All of the experiments included in the *CCS* program cover at least one, if not all, of these specifications.

4.5.4. Materials Chemistry: Unit 1 VCE Chemistry

Materials Chemistry is a brand new hands-on program that immerses upper level secondary students to the world of polymer chemistry and manufactured materials. Through the testing of polyurethane, evaluating polymer elasticity, the modeling of polymer chains, investigating biodegradable polymers, and observing the applications of nanotechnology, the students become aware of recent applications of materials chemistry.

The session usually runs for about 1.5 hours and is designed for groups of up to 30 students for there are 12 activities and the students work in groups of 2-3. Each group of students is not specifically expected to complete all of 12 experiments, but the class as a whole covers all activities. The students record the data in their student workbook and then later use the material in class or in a written assignment. Sample assignment ideas are outlined in detail in the teacher notes, which also include a summary of the program and material to accompany all 12 activities.

Materials Chemistry can be held in Highett at the CSIRO SEC or the program can be brought to metropolitan and country schools as a "labs on legs" deal. There are some cost differences for the three different locations the program is offered, which are noted in Appendix C.

Requirements for a "labs on legs" booking include access to the presentation room one hour prior to the first session in order for the education officer to set up for the program. The lab room or classroom must be large with at least 14 tables or equivalent bench area. By large, the CSIRO SEC requires that the room fit at least 30 students comfortably. The room must contain a nearby sink and at least two power points.

The *Materials Chemistry* program is taken from Unit 1 VCE Chemistry. In this Education Program, students "explore the production of new materials, their properties and the ways their special properties have contributed to scientific and technological development" (CSF II). Each activity in the *Materials Chemistry* program also emphasizes the students' ability to "describe the production and uses of substances with unusual and specialized properties" (CSFII). The assignment suggestions provided in the teacher notes promote activities that will allow the students to "present their findings in a logically structured and well reasoned report" (CSFII), which is another aspect of the Unit 1 VSE Chemistry.

4.5.5. Science Procedures and Processes

Science Procedures and Processes is a hands-on program that teaches lower level secondary students the scientific method. Students are engaged in experiments that help them identify relationships between living things and how they survive. They also learn how to relate properties of common substances to their uses, and they investigate devices that transfer or transform energy. The students then analyze, tabulate, and discuss the results. They learn how to verify or disprove a hypothesis while increasing their understanding of the scientific process.

The session usually runs for about 1.5 hours and is designed for groups of two to three students. Each group of students is not specifically expected to complete all of ten experiments, but the class as a whole covers all activities. The students record the data in their student workbook and then later use the material in class or in a written assignment. Sample assignment ideas are outlined in detail in the teacher notes, which also include a summary of the program and material to accompany all ten activities.

Science Procedures and Processes can be held in Highett at the CSIRO SEC or the program can be brought to metropolitan and country schools as a "labs on legs" deal. There are some cost differences for the three different locations the program is offered, which are noted in Appendix C.

Requirements for a "labs on legs" booking include access to the presentation room one hour prior to the first session in order for the education officer to set up for the program. The lab room or classroom must be large with at least 12 tables or equivalent bench area. By large, the CSIRO SEC requires that the room fit at least 30 students comfortably. The room must contain a sink and at least three power points.

Science Procedures and Processes covers the general aspects of the level six science requirements for lower level secondary students. The CSF II states "knowledge of the processes and procedures of science is integral to the understanding and practice of science" (VCAA Homepage 2003). Science Procedures and Processes accomplishes this by recognizing the hypothesis, the scientific method, and its applications.

4.5.6. VCE Physics: Materials and Structures

VCE Physics: Materials and Structures is a hands-on program that teaches upper-level secondary students the ideas central to the study of mechanical properties of materials and structures. Students perform a number of experiments from undertaking axial tests to observing the elastic and plastic behavior of different materials. Students also examine the effects of heat treatment on steal and study the effects of temperature on toughness.

The session usually runs for about two hours and is designed for groups of two to three students. Each group of students is not specifically expected to complete all of the experiments, but the class as a whole covers all activities. The students record the data in their student workbook and then later use the material in class or in a written assignment. Sample assignment ideas are outlined in detail in the teacher notes, which also include a summary of the program and material to accompany all ten activities. For the *VCE Physics: Materials and Structures* program, the teachers receive all written materials beforehand.

VCE Physics: Materials and Structures can be held only in Highett at the CSIRO SEC. This is due to the materials needed for the session being too heavy to carry and commute. The cost of the program is outlined in Appendix C.

VCE Physics: Materials and Structures "illustrate[s] the central ideas of Unit 4 of the VCE Physics Study Design and enable a depth of analysis unavailable in most school laboratories" (CSIRO Education Homepage 2003). This unit covers the diverse areas of motion, gravity, structures, materials, light, and matter. The program also meets the requirements of Unit 4 if the teachers have the students write a formal report of investigation.

4.6. Case Study Analysis

The case studies performed on the CSIRO SEC Education Programs helped us to understand what teachers wanted by the popularity of various programs. By studying different aspect of the most popular programs, and then comparing these qualities to those of the least popular programs, we were able to decide what teachers look for when booking Education Programs from CSIRO SEC.

The first thing noticed when comparing the most successful program to the least successful program was the fact that the two are advertised in a drastically different manner. The program description posted on the Internet for *Forensic Frenzy* is captivating and interesting to read. The program description posted on the Internet for *Electronics* is written from a curriculum standpoint and is not so fascinating. This discovery implies that educators who book programs through the Internet may be more attracted to a more captivating program description that is captivating but not entirely curriculum based.

It would be incorrect to state that teachers are not interested in Education Programs that are curriculum based. *Forensics Frenzy* is in fact the only Education Program the CSIRO SEC offers that does not parallel some part of the Curriculum Standards Framework II. Most of the program descriptions imply that numerous areas of the curriculum will be covered or emphasized through different aspects of the programs. Many of the Education Programs do not however make the curriculum component the focus of the program description.

It is interesting to note that *Forensic Frenzy* is offered to year seven through year ten secondary students, while *Electronics* is offered only to years nine and ten. From the number of bookings over the course of 2002, it is apparent that teachers find it easier to book multiple programs on the same day if more than two classes can be exposed to the Education Program.

Each learning activity included in our Catalogue followed the handout model of all educational programs studied. Not only did each activity have a captivating description, but also they all included a section showing the relationship to the curriculum outlined in the CSF II or the VCE. In addition, we included background information for the Education Officers and teachers.

The most successful and cost beneficial educational programs are offered both in Highett at the CSIRO SEC and as "labs on legs". The programs that are offered only at the Highett site do not gross as much money as the "labs on legs" programs. Experiments that are as affordable and portable as possible were chosen so that they can be part of a "labs on legs" program.

4.7. Interview Results

The interviews were loosely structured and more geared towards an informal discussion in order to gather large quantities of input from both areas.

4.7.1. CSIRO SEC Education Officers

Employees of CSIRO SEC are classified as full-time Education Officers. Many of the Education Officers say that since they do not evaluate students, they are just presenting information to the students, not educating. That is why this section will avoid use of the word "teaching" when referring to CSIRO Educators Officers.

The Education Officers are responsible for traveling to schools along with the occasional onsite presentation. They must take the equipment to the school, set it up, do the presentation, pass out worksheets, and pack up when it is over. Some Education Officers even take on the role of program designer. Right now, two of CSIRO SEC's educators are designing a Natural Disasters program and a Mathematics program in their spare time.

An Education Officer designing the new Natural Disasters Program mentioned that her favorite program to teach is the Cool Chemical Science because she can tell many jokes and the kids think she is "cool". In contrast, her least favorite is the Lego Simple Machine program because students do not seem to get involved. The CCS program is aimed at years five through eight and the Lego Simple Machine program is aimed at students in years two through four.

This particular Education Officer is currently in the process of designing a new program, which is aimed at teaching students why certain natural disasters such as earthquakes, tornadoes, and hurricanes occur. When discussing the methods behind designing her program, the Education Officer would first look at the CSF II requirements for a given subject and age group. Then she would find experiments that address those requirements. Each activity would be refined and put into a final form that included teacher notes, student worksheets, and a presenter's script. We were also informed that a very involved script is not necessary or even possible in most cases. When providing a script for presenters, it is more efficient to provide the key points and where the material fits into the CSF; then, let the presenters use their teaching skills to run the class.

Another casual presenter for CSIRO SEC is a retired primary teacher who specializes in making hands on physics models using "old junk," and who is a wealth of knowledge. He also coordinates and runs Family Science Nights at the CSIRO SEC building. He gave us ideas on possible experiments for nanotechnology and photonics, which are incorporated into our Catalogue of Learning Activities.

All of the educators at CSIRO have advanced degrees in some field of science or technology. Some have a Masters of Education, others have doctorates in various field. While some educators are experts in the field they present, it is not a requirement as long as they have a rudimentary understanding of what is being presented.

4.7.2. CSIRO Researchers

One other valuable outcome of the interviews was a wealth of ideas for learning activities. These ideas range from very practical homegrown tests, to highly technological and expensive experiments. Interviewing one of the directors of CSIRO's Manufacturing and Infrastructure Technology sector provided some of the best nanotechnology experiments that we considered for development into learning activities for the Catalogue. They include:

- Synthetic Opals- Building opals from compressing 240nm polymer spheres
- Gold solutions- Changing the color of gold by altering the size of the gold particles in a mixture
- Zinc Oxide- Applications that use nanoparticles of zinc oxide to absorb UV rays

- Natural Effects of Nanotechnology- There are many natural effects of nanotechnology like butterfly wings, which do not have pigment, but rather a diffraction gradient. This gradient is an organic use of nanotechnology.

4.8. Interview Analysis

While student and educator requirements are important in designing a program, the requirements of the CSIRO Staff are also significant. Understanding the CSIRO SEC staff needs are essential to a program's success. Without the Education Officers being able to do their job efficiently, there is no way that the program can get the message across to students.

Since the CSIRO staff usually travel alone to schools, the program must be portable. Portability is defined as ease of setup and cleanup, along with weight and size; in most cases, it needs to be able to fit into the backseat of someone's car.

A program cannot be too technically complicated. As stated in section 4.4.1, the CSIRO educators do not need to be experts in the field they are presenting. This means that the material must be rudimentary, both for the students, teachers, and presenters. If presenting the material requires any technical detail, a background sheet would need to be provided to the presenter so that that they would be prepared to answer any questions from the students.

One interesting point brought up by a CSIRO SEC presenter is that sometimes it is very easy to give the students too much information. Therefore, a person who is well versed in electronics will need to be careful when teaching the Electronics program so that they do not flood the students with details that are meaningless or too complicated.

4.9. Focus Group Results and Analysis

The purpose of the focus group conducted at CSIRO SEC was to gain a better understanding of students' attitudes towards this project. During the focus group, a group of 13 WPI students in their 3rd year at a technical university were encouraged to talk about five major issues:

- The CSIRO SEC business model
- Emerging technologies in science education
- Technology in the classroom
- When and why they became interested in science
- What made them choose their particular area of study

The focus group started with a 20-minute presentation detailing the CSIRO business model and the essence of this IQP. The focus group conversation lasted for about 30 minutes.

When asked about the CSIRO SEC business model, students said that they liked the way that students could sit in their classrooms and have the technology go to them. Students also liked the CSIRO SEC business model because they said that it is usually not possible for schools to purchase all the materials needed for experiments in emerging technologies. Multiple students stated that in their own experience, it was always exciting to have a professional come speak to the class. In addition, none of the students said that having professionals travel to schools was a bad idea. It was generally accepted that traveling to schools to present secondary students with information about emerging technologies was a good idea. This all backs up the CSIRO SEC business model as a successful way to get students interested in science.

Students were asked what they thought of emerging technologies in science education. One student said that in today's society, an education in the basic sciences, such as chemistry, physics, and biology, is not very useful. For people who want to pursue careers in science, this student said that it is necessary to know how science applies to their lives. This asked the students to discuss the debate over teaching students basic science in-depth and letting them learn about emerging technologies later in life, or teaching them about emerging technologies in the beginning and leaving it up to them to fill in the blanks. Many of the students felt that the basic sciences need to be taught in schools. However, they also stated that rigorous proofs are not a necessity, and that it would be perfectly acceptable to brush over the basic sciences and learn about newer fields of science and technology. Another student actually reinforced the idea of giving the students and teachers some handouts that described these applications, along with the technologies' impact on society. For example, when talking about the Aerogel demonstration, one students said that the teachers or Education Officers should explain not only how Aerogel works, but also explain that it will help society by reducing the amount of aluminum used in industry; this will then reduce the amount of aluminum in landfills.

The third topic of conversation was whether technology in the classroom is a distraction for secondary school students. Almost unanimously, the students said that technology is not a distraction in the classroom. Many students said that technology could be used to make a topic "memorable." One student remembers an experiment where they made peanut brittle in a chemistry lab. These experiments go beyond equations on a chalkboard and provide students with an experience that will not forget as easily as a list the list of equations and laws.

Next, the students were asked to talk about why they became interested in science. Specifically, they were asked if they could remember why they became interested in science. Most students said that the decision to become a scientist is usually not the results of a single event, but rather the culmination of good teachers and exciting experiments. One student said that her sister that did an experiment in chemistry and, because of it, decided to become a chemical engineering. However, after two weeks without any reinforcement, she had already changed her mind. It takes exciting activities combined with a teacher who is willing to relate material back to those activities at every opportunity. Students said that it would be beneficial if CSIRO SEC offered teachers more information on the subjects that were being introduced in their programs.

The last topic of conversation asked the students to comment on why they chose their area of study, and whether they thought these CSIRO SEC programs could be modified to help students choose a specialized area of study at an early age. Not many of the students had strong opinion on this matter. Some said that it really was not the point of secondary school to get students interested in one major over the other, but just to get students interested in science in general and then let the universities help students to choose an area of study.

This focus group resulted mainly in possible recommendations for CSIRO SEC. However, beyond these recommendations, the focus group also reinforced all the research, surveys, and interviews previously accomplished for this Interactive Qualifying Project. The focus group is one more way of showing that this IQP is relevant to the future of CSIRO SEC.

4.10. Summary Analysis

The research in this IQP seeks to answer one primary question: how can emerging technologies be best presented to students? The criteria listed in section 3.4.1 were important in selecting experiments, but the challenge was to develop complete learning activities from those experiments. This section will summarize all the research in this IQP and in doing so answer the major research question.

Before taking steps to develop any concrete learning activities, it was important to understand their target audience. Student and teacher interests can often be conflicting. Students want to study material that is outwardly exciting and in some way related to their personal lives; this is further demonstrated in section 4.1. Teachers' interests are more pragmatic as seen in section 4.2. Teachers need a learning activity that directly links to the curriculum, and in most cases, cost is a major concern. These conflicts lead to an interesting dilemma. A developer must consider both of these interests in concert, not overemphasizing one at the expense of another. Our analysis revealed that maintaining a consistent level of criticism is important in developing balanced, useful activities.

With an understanding of the needs and expectations of the target audience, it became appropriate to design a structure for the learning activities in the Catalogue. Since the Catalogue of Learning Activities will be used by CSIRO SEC, studying its existing programs when designing new activities is a clear strategy. CSIRO SEC's most popular programs tend to have an emphasis on hands-on activities and to use a central critical thinking challenge in order to tie together the ideas of a program. Some of the basic functional boundaries for CSIRO SEC activities are detailed in section 4.3. These are somewhat rigid, as any new learning activity must fit into CSIRO SEC's business model.

With the structure defined, raw experiments found as described in section 3.4.2 were either fitted to the structure or discarded if inappropriate. In order to strengthen the Catalogue of Learning Activities, a focus group assessment was conduced on the initial activities as described in section 3.7. The analysis of this assessment, section 4.5, led to a final Catalogue of Learning Activities, which was reflective of strong background research and apt development.

5. Outcome: Catalogue of Learning Activities

The final goal of this IQP was to offer CSIRO SEC a Catalogue of Learning Activities that will be used to strengthen existing programs and to develop new CSIRO SEC programs. Accompanying each activity is a synopsis, a section relating the activity to the CSF II or VCE, and the activity details. Background research and original research completed in Australia made this chapter a robust, educationally viable set of learning activities. All of the activities in this Catalogue have their focus in emerging technologies. The majority of the activities have their basis in photonics or nanotechnology, but no activity was left out simply because it did not fall into one of those categories. Many of these ideas were found on the internet and, as such, represent work from various organizations. Before using these ideas in an experiment, it would be prudent for CSIRO to research the fair use policies of these organizations.

5.1. "What's up with Jane, Doc?" – An Immunology Laboratory Exercise

This activity was originally developed by Cornell University's **N**ano**B**io**T**echnology **C**enter (NBTC), a research center funded by the United States' National Science Foundation. A background of the center can be found at http://www.nbtc.cornell.edu/education/. As part of an immunology curriculum developed by high school teachers, this experiment introduces students to a wide range of biotechnology concepts. This is one of the experiments that does not fall into nanotechnology or photonics, but immunology is nonetheless a cutting-edge technology which should interest students in science careers.

5.1.1. CSFII/VCE Compliance

In an assessment guide listed on the VCAA website, one of the outcomes of the VCE states that, at the end of Biology Unit 3, students should be able to explain "functions that are essential to the survival of unicellular and multicellular organisms" (Assessment Guide 2003). By discussing allergies, this activity explains to students the nuances of the human immune system, a function of the human body that is essential to its survival. This activity shows students how a requirement of the VCE can be extended to something that affects them in their everyday lives.

5.1.2. Activity Details

This activity follows the scientific method as it guides students toward Jane's prognosis. The kit includes detailed worksheets available at: http://www.nbtc.cornell.edu/education/Immunity_and_you.html. Students are given some background information about the immune system and how allergies can be developed. The activity begins with a brief summary of Jane's medical history. Given this history, a hypothesis is made: Jane has an allergy (NBTC 2003).

The first set of data to analyze is a standard checkup including blood work. Students are helped to evaluate this data, and in doing so learn about some basic medical techniques.

The first set of medical data is inconclusive and suggests that Jane does have an allergy. This leads students to further investigate their initial hypothesis (NBTC 2003).

An ELISA test is used to detect the presence of IgE antibodies, which are common to patients with allergies. Students will conduct something very similar to an ELISA test which uses safe, non-human serums. The procedure and materials for this test are included in the kit. The results of the ELISA test will be positive and this leads the students to investigate which allergy Jane has (NBTC 2003).

A Western Blot test is used to identify a specific allergy. Students will test for allergic reactions to pollen, dust mites, cats, birds and dogs. Again, the procedure and materials needed for this activity are included in the kit (NBTC 2003).

At the end of this experiment, students will have been introduced to the scientific method, as well as to basic medical techniques including blood work analysis, the ELISA test and the Western Blot test (NBTC 2003).

5.1.3. Cost Analysis

Kits for this lab can be purchased from West Hill Biological Resources, Incorporated, a company based in New York, United States. The kits, Catalogue number NBTC-101, are available for $US5.95 plus the international shipping cost. Using a conservative exchange rate of $AU0.61 = $US1.00, this would translate into a cost of $AU9.75 per kit. These kits would be the only cost for the program (WestHillBio Homepage 2003).

5.2. Aerogel- A Demonstration of the World's Lightest Solid

Aerogel was first made in the 1930s, but it was dangerous and difficult to make. In the 1980s, the United States' National Aeronautics Space Administration (NASA) revisited the material and refined the process. Information on Aerogel can be found at http://www.jpl.nasa.gov/technology/features/aerogel.html. While Aerogel would not be suitable for a hands-on activity, it has many amazing properties that would allow for an intriguing demonstration (JPL 2003).

5.2.1. CSFII/VCE Compliance

VCE Chemistry states that students must be introduced to new materials. Aerogel is one of the most cutting-edge materials under development. Not only does Aerogel fit into the curriculum under this "new material" clause, but its uses in insulation, spacecraft, and even automotive safety could allow teachers to bridge gaps between different areas of the curriculum (VCE 2003).

Source: http://www.airglass.se/

Figure 5.1- Flower Protected from Flame by Aerogel

5.2.2. Activity Details

Aerogel is the lightest solid in the world. It can be comprised of up to 99% air. This unique property of Aerogel is from billions of molecule size holes through its structure. Aerogels are created by super-critically drying a silica gelatin. When super-critically drying occurs, the chemical structure of the silicon does not have time to break down before the water is gone. This leaves behind a cloudy, semi-transparent solid with some amazing properties. Aerogel is one of the best insulators in the world. One pane of Aerogel would have the insulation power of 33 panes of regular glass. As shown in

Figure **5.1- Flower Protected from Flame by Aerogel**, Aerogel is such a great insulator, only a few millimeters of it can protect a flower from a flame. Another interesting property of Aerogel is its strength. One pound of Aerogel would be the size of the average man, but could support the weight of a Honda Civic (JPL 2003).

5.2.3. Cost Analysis

Aerogel is made at several places throughout the world. AirGlass, a company based in Sweden will sell pieces of Aerogel for $US110. Figure 5.1- AirGlass Specs shows what CSIRO SEC could purchase for what would be around $AU175.

Airglass Sample Package of Aerogel	
No of pcs	4
Thickness of pcs	~1,5 cm
Total area of pcs	~200 cm^2
Total volume of pcs	~300 cm^3
Total mass of pcs	~45 g
Total mass of package	~200 g
Density of pcs	~0,15 gcm^{-3}
Refractive index of pcs	~1,030
Price of Package	**125 euro or $110**

Source: http://www.airglass.se/

Figure 5.1- AirGlass Specs

This would be more than enough AirGlass for CSIRO SEC to do any demonstrations they want (AirGlass 2003).

5.3. Monolayer Demonstration

This activity will demonstrate the self-assembly of a monolayer. Monolayers are a field of nanotechnology that have applications in anti-corrosion and creating materials with exact properties. Since a layer of matter only one molecule thick is difficult to observe, the existence of the monolayer will be demonstrated as it extinguishes a fire on the surface of a water and ether solution. Though ether burns at a low temperature, this activity is somewhat dangerous and should be used only as a demonstration. A video of this activity can be found here: http://www.nanosonic.com/schoolkits/Monolayer%20Demonstration.htm.

5.3.1. CSFII/VCE Compliance

The new VCE for chemistry demands that students be introduced to cutting-edge materials. One of the main products of nanotechnology research is the development of new materials. Monolayers are used to create materials with very specific electrical resistance, heat conductivity and surface friction. This demonstration allows students to see a concrete example of a monolayer, something that may otherwise be difficult to grasp (Nanosonic 2003).

5.3.2. Activity Details

Materials:

- 1 liter ether
- 3 liters water
- human ear wax
- ventilated room
- wide containter

Procedure:

1. Mix the water and ether solution in the metal container
2. Using a long-stem lighter, ignite the solution
3. Once the solution has reached a full burn, try to get some ear wax on either finger
4. Place earwax covered fingers into the solution at either end
5. Fingers should remain in the solution until the flame is extinguished by the monolayer

5.3.3. Cost Analysis

The only costs for this demonstration will be for ether. Petroleum ether sells commercially in bulk for $AU6.02 per liter at Crescent Chemical Sales, http://www.creschem.com/solvents.mv.

5.4. Building a Scanning Probe Microscope

Students can build or disassemble a **S**canning **P**robe **M**icroscope (SPM) using LEGO bricks. Specifically students learn about the two different aspects of the SPM over the course of its construction. This activity is completely hands on and it provides a revealing view of the instrument and the principles behind it. The following material is outlined from the ideas and descriptions presented in the book titled *Exploring the Nanoworld with LEGO Bricks,* by Dean Campbell, and is available online at:

http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

5.4.1. CSFII/VCE Compliance

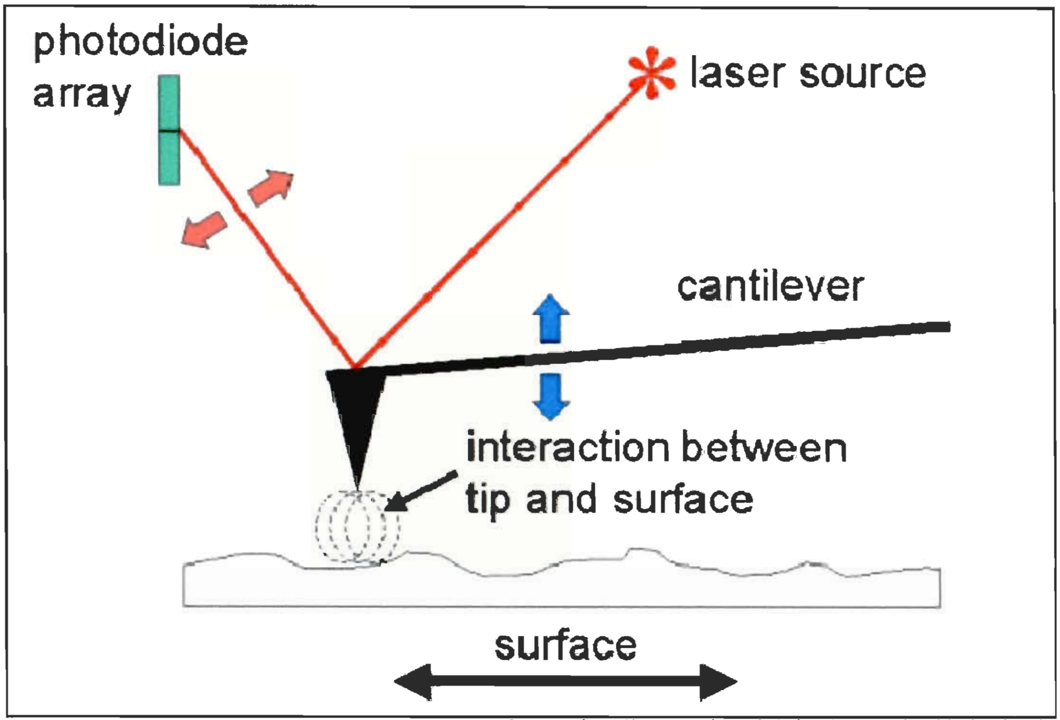
This activity engages students in a hands-on situation, which enables their teacher to lead them into a discussion of theories and models. In regards to VCE Physics Unit 1, students must be able to demonstrate the interactions of light and matter. This activity does this, and goes on to connect these topics to the emerging technology of nanotechnology (VCE 2003).

5.4.2. Activity Details

Background:

Scanning Probe Microscopy is a method for mapping surface forces of materials at the nano-level. Mapping these forces provides a window for researchers to view the numerous interesting and complex phenomena that occur at the nano-level. SPM includes the methods of Atomic Force Microscopy (AFM), Magnetic Morce Microscopy (MFM), and Lateral Force Microscopy (LFM). Most force microscopy techniques are variations of the same basic principle, illustrated in

Figure **5.2**. All of the figures in this section are taken from the *Exploring the Nanoworld with LEGO Bricks* book available online at http://mrsec.wisc.edu/edetc/LEGO/bookindex.html



Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.2- SPM Diagram

Forces exist between the surface and a cantilever tip, which cause the tip to deflect up and down. This deflection shifts the position of a laser beam that reflects off the top of the cantilever onto a photodiode array. The movement of the beam between the photodiodes is used to calculate the cantilever deflection. Additional information may be found at: http://ice.chem.wisc.edu/materials/stm.html.

The booklet titled *Exploring the Nanoworld with LEGO Bricks* and its associated website, http://mrsec.wisc.edu/edetc/LEGO/index.html, continuously update as new technologies emerge. Currently CSIRO SEC may visit the website and view instructions and background information for LEGO activities dealing with the following:

- Build a LEGO model of a Charged Coupled Device
- Build a LEGO model of a working Photometer
- Build a LEGO model of a polymer structure in order to demonstrate biodegradable polymer
- Build a LEGO model of a multi-layer magnetic structure

The purpose of the book is to demonstrate that various physical and chemical principles that relate to nanotechnology can be demonstrated with LEGO activities.

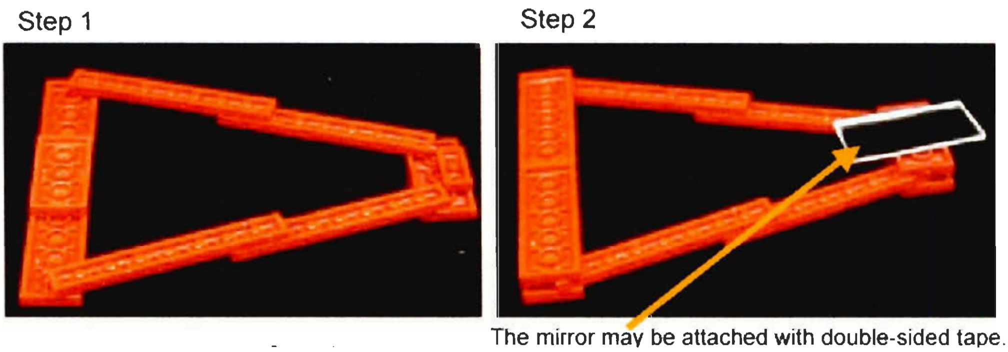
Materials:

- 5, 5 peg long, 1 peg wide, flat LEGO bricks
- 3, 3 peg long, 1 peg wide, flat LEGO bricks
- 4, 8 peg long, 1 peg wide, flat LEGO bricks
- 1, 1 peg long, 1 peg wide, flat LEGO brick
- approximately 20, 4 peg long, 2 peg wide, tall LEGO bricks
- a small mirror
- double sided tape
- triangular plastic probe
- laser pointer or small flashlight
- tape or rubber band fasteners
- nine round LEGO magnets

AFM Building Procedure:

AFMs are instruments that allow three-dimensional imaging of surfaces with nanometer resolution. They are also used to determine chemical and mechanical properties of surfaces. For the duration of this section, all the pictures were taken from the LEGO website at: http://mrsec.wisc.edu/edetc/LEGO/index.html

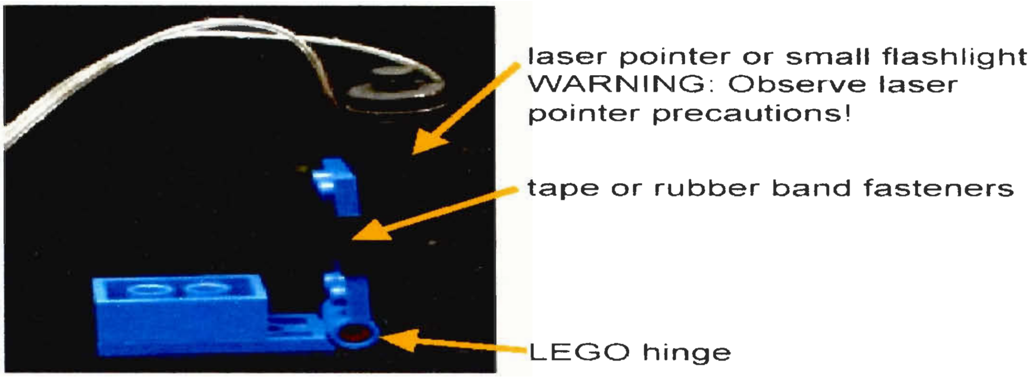
1.) First students must construct the cantilever out of LEGO bricks, a small mirror, a triangular plastic probe, and double sided tape.



Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.3- LEGO probe for SPM

2.) The light source mount consists of a laser pointer or small flashlight, tape or rubber band fasteners, and a LEGO hinge.

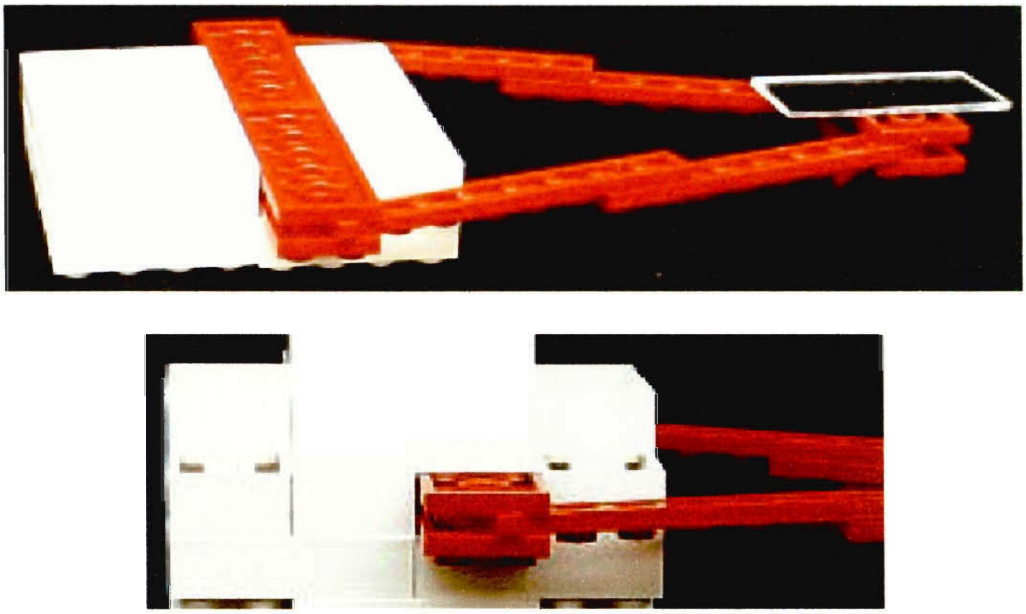


Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.4- LEGO Laser Mount

3.)

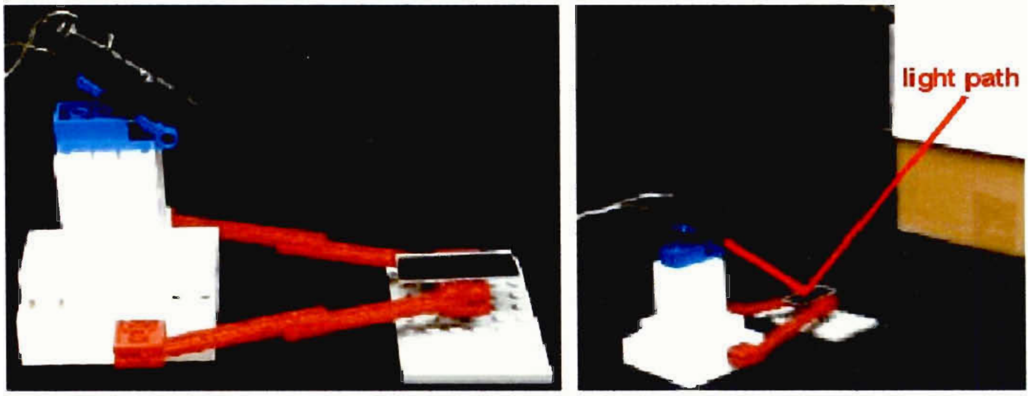
Figure **5.5** shows the construction of the platform.



Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.5- LEGO Base Mount

4.) Figure 5.6 shows the completed scanning probe microscope



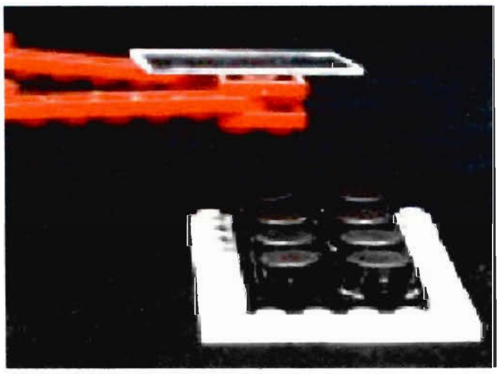
Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.6- LEGO Complete SPM

MFM Building Procedure:

Modification of the AFM model by addition of eight magnets converts the model from an AFM to an MFM. The magnet at the end of the cantilever interacts with the magnets on the LEGO surface to deflect the cantilever.

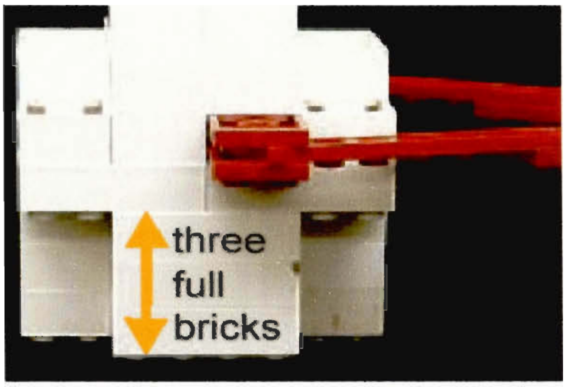
1.) Students arrange the eight magnets with an alternating pole pattern. Replace the triangular probe with a ninth magnet.



Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.7- LEGO MFM Tip Design

2.) Due to the strong interactions between the probe magnet and the magnetic surface, the cantilever platform must be raised by three LEGO bricks.



Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.8- LEGO MFM Base Picture

3.) Completed Model

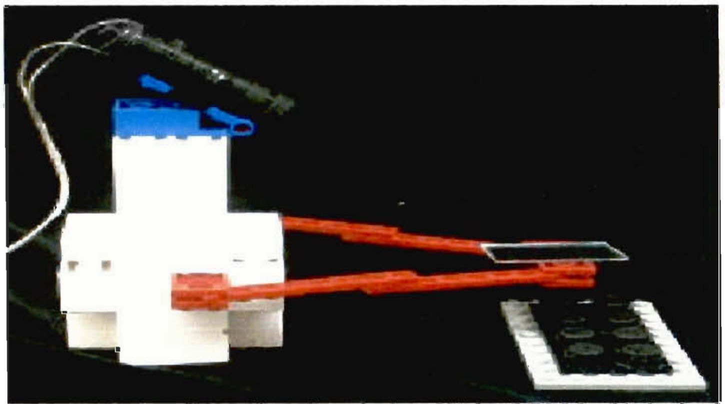

Source: http://mrsec.wisc.edu/edetc/LEGO/bookindex.html

Figure 5.9- LEGO Completed MFM

5.4.3. Cost Analysis

Since CSIRO SEC has a rather large collection of Legos, it is probable that the only costs associated with this activity will be a laser pointer which can be purchased for $19.95 from Dick Smith Electronics: http://www.dse.com.au

5.5. Edible Optics

This activity introduces students to optics, the study of light through mediums. It is important to have an understanding of optics to understand photonics. Students will make concave and convex lenses with concentrated gelatin. They will also determine the index of refraction of the gelatin using Snell's law. Students can easily construct any shape of lens, prism, or light guide they wish and then immediately test the outcome. This activity is possible by making optics out of common gelatin.

5.5.1. CSFII/VCE Compliance

Not only does this activity explain the topics outlined in the 6 learning outcomes of the CSFII, but it also explains outcome one of Unit 1 VCE Physics. This activity could also be used as a basis for ideas revolving around the topic of photonics, primarily optical communication.

5.5.2. Activity Details

Materials:

- Pre-prepared petri-dishes of colored gelatin (two for each student)
- Pre-prepared petri-dishes of clear gelatin (two for each student)
- X-Acto knifes
- Spherometer
- Cooler (to transport or store chilled gelatin petri-dishes)

Procedure:

Cut triangular and circular lenses out of the gelatin. Use a small flashlight or laser pointer to demonstrate refraction, and trace the rays inside the cut optics. Students may estimate the index of refraction of the gel using nothing more than a laser or a protractor; however using a spherometer will be more accurate. Total internal refraction may be demonstrated with a right angle prism. Students may also create a wave-guide by cutting a strip of gel and bending it into the shape of an "S". If the small flashlight or laser is held at one end of the "S" shape, the beam will seem to propagate down the material in multiple internal refractions. More information on these techniques may be found at the following websites:

- http://www.opticsforkids.org/resources/GO_3.pdf
- http://207.150.194.17/0901focalpoint/0901fp_sandiego.html
- http://www.opticsforkids.org/article/articles_by_topic.cfm
- http://www.sciencekit.com/Products/Display.cfm?categoryid=322361

5.5.3. Cost Analysis

CSIRO SEC may have the ability to purchase the "Edible Optics™ Study" kit from Science Kit and Boreal Laboratories. The Edible Optics Study kit uses the method of thickness to determine refractive index of gelatin. The kit includes four petri-dishes, four watch glasses, one plastic tube, three packages of gelatin, one spherometer, and a manual. The kit is priced at $AU74.91 ($US44.95) and is available at: http://www.sciencekit.com/Products/Display.cfm?categoryid=323004.

Should CSIRO choose not to buy the kits, the prices for the needed materials would be nominal since their current stock holds many of the needed materials

5.6. The Groovy CD Experiment by Michael Gilmore

When a beam of light reflects from the "groovy" surface of a CD, a diffraction pattern is produced. This experiment shows how lasers can be used to read the data off a Compact Disc, and therefore is an experiment in photonics. Students can apply simple mathematical skills to investigate diffraction patterns and laser light with material as familiar to their everyday lives as a compact disk (Gilmore 2003).

5.6.1. CSF II/ VCE Compliance

The Science Level Six Curriculum Focus for Physical Science states that students must use materials of "direct relevance to their lives to investigate and experience a wide range of physical phenomena related to light, electricity and motion" (CSF II). The students at this secondary level must also "take accurate measurements and apply quantitative calculations to their observations and data" (CSF II). Since this activity investigates diffraction patterns and laser light of a compact disk using mathematical concepts, it parallels the curriculum focus.

5.6.2. Activity Details

The grooves in a compact disc are very close together. One side of a disc can hold more music than two sides of a vinyl record. When looking at the grooved side of the CD, a student will see a rainbow spectrum. This is due to the reflection of white light that has been diffracted off of the grooved side.

To measure the distance between the grooves one must inspect the diffraction patterns from a laser with a known wavelength. The equation for this distance **d** is:

$d = n\, L \sin A$ where

1.) n is order of the bright spot in the pattern
2.) L is the wavelength of the light reflecting from the CD
3.) A is the angle of orientation of the bright spot

$A = \tan^{-1} (y/x)$

This angle is determined by measuring the distance *x* from the CD to the "screen" (in this case, the mounted meter stick) and the distance *y* of the first or second order bright spot from the central (zero order) bright spot. Knowing the wavelength of a laser light-for the helium-neon laser and measuring the distances x and y, the distance between the grooves on a compact disc can be determined.

Materials:

- Compact disc
- Laser pointer (with known wavelength)
- Mounting Device
- Two meter Sticks

Procedure

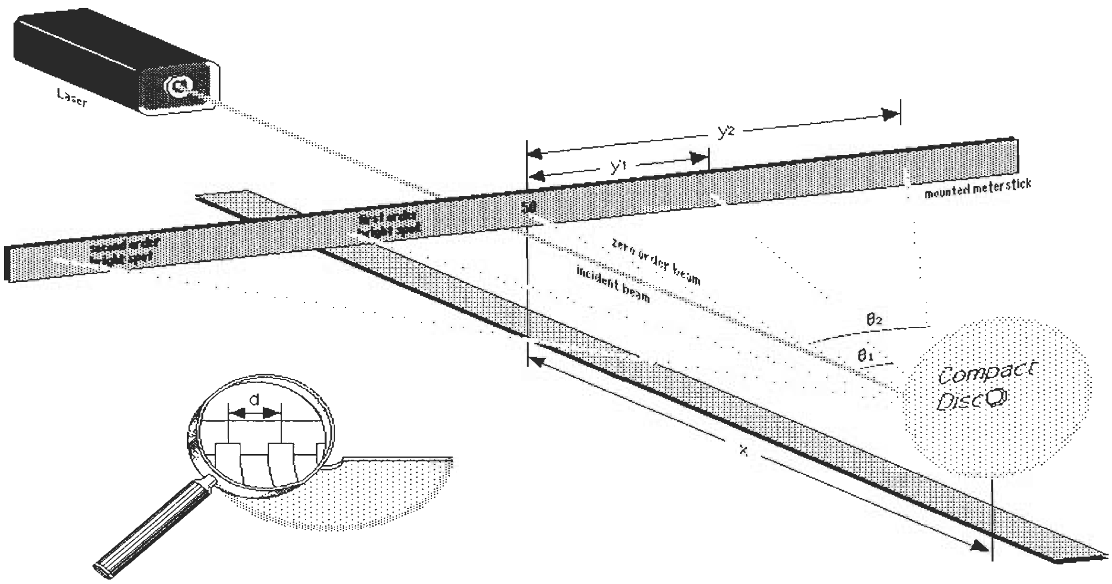
1.) First mount at least 6 cm into the air.

2.) Next place the laser at least two meters away from the CD and point it toward the CD.

Do not turn the laser on until everything is set up and ready.

3.) Set up a meter stick to measure the diffraction pattern. A diagram of the arrangement is shown below in

4.) Figure **5.10- Groovy CD Experiment**(taken from http://chem.lapeer.org/PhysicsDocs/GroovyCD.html):



Source: http://chem.lapeer.org/PhysicsDocs/GroovyCD.html

Figure 5.10- Groovy CD Experiment

4.) Turn on the laser and measure the distance from the appropriate distances.

By using the data from the background of the lab, the wavelength of the helium-neon laser (usually 632.8nm), and by measuring the distances x and y, the distance between the grooves on a compact disc can be determined.

a.) Make the x and y measurements for at least two orders and carry out the calculations for the angles.
b.) Determine the distance between the grooves on a compact disc. Show all work.
c.) The actual distance is 1.6 microns. What is the percent error for each order?

5.6.3. Cost Analysis

The cost of this activity for CSIRO SEC would be a $AU19.95 laser and a $AU1.00 burned, recordable compact disc both available at Dick Smith Electronics: http://www.dse.com.au. CSIRO SEC would also need an inexpensive meter stick and ruler.

5.7. DNA Optical Transform

This activity allows students to model X-ray diffraction using a laser and two-dimensional patters to simulate Rosalind Franklin's landmark discovery that led to the discovery of double-helix structure of DNA (Institute for Chemical Education Homepage 2003).

The technique used by Franklin is called X-ray crystallography. This technique maps out the precise location of atoms in a crystalline structure. Franklin was one of the first chemists to use this technique on biological molecules, and her research led to the eventual discovery of the double-helix nature of DNA by James Watson and Francis Crick (Ardell 2003).

5.7.1. CSF II/ VCE Compliance

This activity addresses outcome 3.2 of the Unit 1 Physics VCE. The outcome specifies that students must be able to describe and explain applications of lasers and X-rays. It also satisfies unit 4, outcome 1 of the VCE, which demands that students complete, "a practical activity to investigate the structure and role of DNA" (VCE 2003).

5.7.2. Activity Details

The activity is available in kit form from the Institute of Chemical Education. The kit includes directions, patterns on 35mm slides, and an overhead transparency. Additional 35-mm slides with different patters are available. The kit also requires a laser pointer, not included (Institute for Chemical Education Homepage 2003).

The 35mm slides act as the diffraction medium and produce two dimensional patterns on a screen. The kit guides students as they analyze the patterns. This is a safe way to learn about X-ray crystallography (Institute for Chemical Education Homepage 2003).

5.7.3. Cost Analysis

The kit includes everything needed for the activity with the exception of a laser pointer. The kit is priced at $US50. A common laser pointer can be obtained from Dick Smith Electronics for $AU19.95: http://www.dse.com.au (Institute for Chemical Education Homepage 2003).

5.8. Nanocrystalline Solar Cell

Solar power will become more and more important as the world taps its fossil fuel reserves. This kit harnesses solar energy with dyes from berries. The solar cell created generates enough electricity to power a small motor (Institute for Chemical Education Homepage 2003).

5.8.1. CSF II / VCE Compliance

The new VCE for physics will specifically require students be introduced to photonics which, as described earlier in the IQP, includes the use of light to generate electricity. This activity also introduces students to photosynthesis, which is required by the VCE for biology (VCE 2003).

5.8.2. Activity Details

The activity begins with background information on photosynthesis, environmental science, and the chemistry of the solar cell. Students will then create a solar cell and test its output with a small electric motor (Institute for Chemical Education Homepage 2003).

Each kit includes adequate materials to create five solar cells. Most of the materials can be used repeatedly, which supports recycling and using renewable energy sources (Institute for Chemical Education Homepage 2003).

5.8.3. Cost Analysis

This activity is available in kit form from the Institute for Chemical Education. The cost of the kit is $US80 (Institute for Chemical Education Homepage 2003). This does not include the cost of a small electric motor which would be approximately $US3.99 from Radio Shack (Radio Shack Homepage 2003).

5.9. Exploring the Nanoworld

This kit allows students to learn how nano-researchers "see" at the nano-level. It also illustrates how nano-manufacturing works and how this may lead to new technologies. The molecule by molecule manufacturing of materials could lead to great advances in medicine, computer technology and many other fields as previously discussed in the IQP (Institute for Chemical Education Homepage 2003).

5.9.1. CSF II / VCE Compliance

The new VCE for chemistry demands that students be introduced to cutting-edge materials. One of the main products of nanotechnology research is the development of new materials. Nano-manufacturing methods are used to create materials with very specific properties. This demonstration allows students to experience this process first hand (VCE 2003).

5.9.2. Activity Details

This activity is available in kit form from Institute for Chemical Education. The kit includes:

- a color booklet
- light emitting diode and circuit
- magnifying glass
- diffraction slide
- magnet
- memory metal
- fiber optic (Institute for Chemical Education Homepage 2003)

Students will use the materials in the kit to simulate the advanced scientific techniques required to model atoms and molecules. Students will also simulate the assembly of atoms into very specific molecules, customizing their properties using methods similar to those used by nanotechnology researchers to develop materials with set properties (Institute for Chemical Education Homepage 2003).

5.9.3. Cost Analysis

Everything required to complete this activity is included in the kit available from the Institute for Chemical Education. The kit costs $US48.

5.10. Amorphous Metal Demonstrations Kit

Amorphous metals are "glassy" metals. That is, they do not have a crystalline structure like most metals and therefore have high strength to weight ratio and excellent elastic energy storage. This activity will demonstrate the latter. These properties lend themselves in some small part to the behavior of molecules at the nano-level and, therefore this activity deals with nanotechnology (Amorphous 2003).

The Institute for Chemical Education offers hands-on activities to educate introduce students to cutting edge technologies relating to chemistry. This is one such activity. Students will be introduced to amorphous metals through a hands-on experiment demonstrating the high elastic energy storage of amorphous metals (Institute for Chemical Education Homepage 2003).

5.10.1 CSF II / VCE Compliance

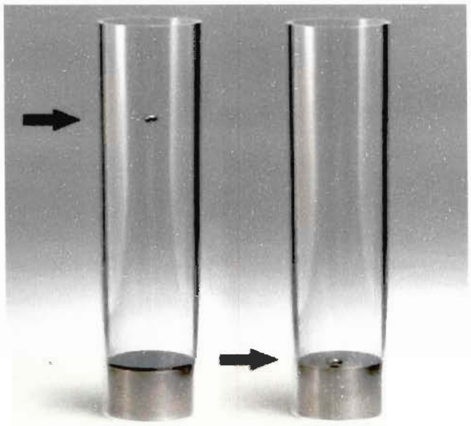
The new VCE for chemistry demands that students be introduced to cutting-edge materials such as amorphous metals. These metals are very strong and resilient with advanced applications in golf and bulletproof vests. As researchers develop methods to create larger and thicker units of this type of material, amorphous metals could help to strengthen many things people use everyday (VCE 2003).

5.10.2 Activity Details

This demonstration is simple to perform, and requires only the items in a kit distributed by the Institute for Chemical Education. The kits include:

- Two stainless steel bases
    - One with an amorphous alloy on top
- Two acrylic tubes
- Two stainless steel ball bearings
- A booklet with figures and descriptions of the science behind the demo

Figure 5.11 shows the demonstration. Notice the bearing on the left has bounced nearly to where it was dropped. The bearing on the right lies flat. This is because of the elastic properties of amorphous metals (Institute for Chemical Education Homepage 2003).



Source: ICE Homepage

Figure 5.11- Amorphous Metals Demo

5.10.3 Cost Analysis

This kit is priced at $US100, but it does not have any consumable pieces, so for this price, the demonstration can be performed countless times (Institute for Chemical Education Homepage 2003).

5.11. Electrostatic Self-Assembly

This activity will introduce students to electrostatic self-assembly, a cutting-edge nanotechnological process that is used to create materials with very specific electrical, optical, magnetic, thermal or mechanical properties. Students will use this process to create a material with near perfect molecular order, and they will be able to compare the properties of the substance they created to a predicted value (Nanosonic 2003).

5.11.1. CSF II/ VCE Compliance

The new VCE for chemistry demands that students be introduced to cutting-edge materials. One of the main products of nanotechnology research is the development of new materials. Electrostatic self-assembly is used to create materials with very specific properties. This demonstration allows students to experience this process first hand (VCE 2003).

5.11.2. Activity Details

The electrostatic self-assembly activity is produced in kit form by NanoSonic, Inc, a division of Virginia Tech Intellectual Properties, Inc. Electrostatic self-assembly has four steps:

- Create a charged substrate (as a base for the self-assembled material)
- Place the substrate into an anionic (positive) solution
    - This assembles the first nanocluster monolayer
- Rinse substrate
    - Removes loosely bonded particles
- Place the substrate with its positively charged monolayer into a cationic solution
    - Assembles the first polyelectrolyte monolayer
- Rinse substrate
    - Removes loosely bonded particles

This process is repeated until the desired number of layers has been applied. Each specific number of layers has predictable properties. These are tested by the students with the materials included with the kit. A flyer for the electrostatic self-assembly classroom kits is available here: http://www.nanosonic.com/schoolkits/schoolkitsFS.html
(Nanosonic Home Page 2003).

5.11.3. Cost Analysis

Nanosonic, Inc sells electrostatic self-assembly classroom kits for $US100 per 24 kits. This includes all the materials needed to begin offering an electrostatic self-assembly activity. After purchasing the base materials the only recurring cost are the consumables such as safety gloves and chemicals can be purchased in sets of 24 for $US70. This makes the average price per student working in groups of two less than $US1.50 before shipping. See Appendix E to view e-mail correspondence with a Nanosonic salesperson.

5.12. Fiber Optic Communication

Fiber optic communication is the most widespread application of using lasers to transmit information. In electronic wires, data is sent using analog waves. Sometimes these analog waves are abstracted by a digital scheme, but it is nonetheless the same. In fiber optics, pulses of light send data. The underlying scheme is the same, but since fiber optics is on track to be the data transit technology of the future students should start learning about the basic properties now. There are several fiber optic kits available for commercial purchase that would help students learn the basics behind lasers, analog and digital data transmission while learning about the ways fiber optics work in electronic circuits.

5.12.1. CSF II / VCE Compliance

This activity will fill into the VCE Physics curriculum which requires that students learn about "direct relevance to their lives to investigate and experience a wide range of physical phenomena related to light, electricity and motion" (CSF II). Since this activity uses lasers to teach students about photonics and telecommunications, it is a perfect candidate for a learning activity. (CSF II 2003)

5.12.2. Activity Details

The kit available from EfsonScience comes with a matched fiber optic LED and photodetector, 1m of fiber, printed wiring boards, polishing film and various other required electronic components. It also includes a 28-page comprehensive booklet describing in detail procedures for all the experiments that are possible with the kit (EfsonScience 2003).

The kit from Electronix Express contains dual-purpose analog and digital transmitter and receiver modules, input connections for external analog and CMOS-compatible signals, an on-board microphone for an audio analog signal source and a built-in 15 Hz oscillator. Furthermore, according to their website, their fiber optic communication kits are one of the only few that do not need an external oscilloscope. All while requiring only two 9-volt batteries (Electronix Express 2003).

Admittedly, there are not many details without buying the kit, but anything using lasers for fiber optic communication is bound to be interested to students and teachers. These kits are well designed, come with complete documentation, and have well built hardware. It will not be difficult for the staff at CSIRO SEC to integrate one of these kits into a current or future program.

5.12.3. Cost Analysis

Kits are available for purchase from EfstonScience. The product number for this kit is 484N027, and they can be ordered for $US29.95 at:

http://www.e-sci.com/genSci/RENDER/7/1034/1079/9990.html

The Electronix Express kits are product number N3200IF545. They can be ordered at http://www.elexp.com/opt_f545.htm for $US49.95.

5.13. Biosensor Module

In this biotechnology exercise, students will be engaged in six guided activities and one design project. Each of these will introduce them to a different type of biosensor. This program is distributed by Materials World Modules, a National Science Foundation inquiry-based science and technology educational program (MWM 2003).

5.13.1. CSF II / VCE Compliance

The VCE for biology demands that students understand, "...terms, concepts and relationships related to the maintenance of a stable internal environment in organisms" (VCE 2003). Biosensors are important to the stability of an organism, as they tell it how to react to changes in its internal or external environment.

5.13.2. Activity Details

The activity is composed of six guided activities and a design activity. The six activities are as follows:

- **Investigating Biological Molecules and Bioluminescence**
  - Introduces students to biological materials and their uses even outside an organism
- **Investigating Enzymes and Indicator Molecules**
  - Enzymes and indicator molecules are commonly used in biosensors. Students are introduced to these materials in this activity
- **Making a Peroxide Biosensor**
  - Create a sensor to detect the presence of peroxide
- **Testing a Cholesterol Biosensor**
  - Create a cholesterol biosensor on paper and then conduct cholesterol tests on unknown samples
- **Evaluating a Home-Use Cholesterol Biosensor**
  - After designing a cholesterol biosensor on paper, students are asked to consider the challenges of creating a cholesterol tester for home use
- **Researching Biosensors**
  - Students write a formal report about a biosensor of their choice (MWM Homepage 2003)

The guided activities lead up to a design activity where students create a glucose biosensor (MWM Homepage 2003).

The kit includes all needed supplies and is available in full and refill formats. The supply list is in Appendix H.

5.13.3. Cost Analysis

This activity comes in kit form, and the initial price is $US150. The refill costs $US80. More information is available at:

http://www.materialsworldmodules.org (MWM Homepage 2003).

6. Conclusions

The goal of this IQP was to provide CSIRO SEC with a Catalogue of Learning Activities that it can use to strengthen its existing programs and to develop new programs that could be used to help pique interest in science among secondary students. This IQP was an exercise in establishing how interest in science can be heightened in society by exposing students to emerging technologies at a young age. However, to describe the outcomes of this project as a simple Catalogue undermines a great deal of the work that went into creating it.

Before arriving in Australia, weeks were spent researching the science behind photonics and nanotechnology, CSIRO as a company, and educational theory; not to mention how to write a project proposal and work as a group. The bulk of Chapter 2 came from this research, and although it might not have been referenced elsewhere in the IQP, it provided a solid base for the group to work from while developing the Catalogue.

Once in Australia, a good amount of time and effort went into understanding the needs and expectations that the students and teachers have for these learning activities. Teachers want inexpensive, hand-on activities that have a basis in the curriculum. Students want exciting, hand-on activities that can be related to things in their everyday world. This is why activities like Edible Optics, the LEGO Scanning Probe Microscope, and the Immunology Lab are included in the Catalogue.

Since most of the time spent in Australia was at CSIRO, the group was able to learn a great deal about CSIRO's business model and the requirements of the Education Officers. CSIRO SEC gets most of its funding by selling educational material to homes and schools. Therefore, the CSIRO SEC desires programs that are relatively inexpensive to maintain, while a minimal start up cost in also preferred. The needs of the CSIRO SEC Educational Officers were also taken into account when designing the Catalogue. Activities cannot be heavy or immobile. The activities cannot be extremely complicated because it becomes cumbersome to perform then in a classroom. Also, since Education Officers are not required to be experts in the field they present, the material must be easily learned by the Education Officers themselves. For example, an activity using quantum mechanics may be so complicated that an Education Officer would have a difficult time gaining a strong enough background to survive the endless questions from secondary school students. Almost all of the activities in the Catalogue are simple examples of complex technological ideas.

Not everyone will be totally satisfied by every activity in this Catalogue. The Edible Optics may prove cumbersome for CSIRO Educational Officers when transporting across Victoria in their vehicles; the Aerogel demonstrations could be rather expensive for CSIRO SEC; and the Monolayer demonstration is not the safest presentation available. However, when the positives are weighed against these negatives, the activities will always come out on top. Weighing these pros and cons has been left up to the people at CSIRO SEC. It is the hope of this group that the pedagogical experience of the CSIRO SEC staff will pick up where the technological information in the Catalogue left off.

7. Recommendations

After spending 15 weeks on this IQP, the team had gathered many ideas for recommendations. These ideas came from background research, interviews, surveys, focus groups, and the analysis of those results. Most of these ideas lie outside the realm of the objectives for this particular IQP, but it would be unfortunate for CSIRO Education to remain unaware of the avenues for improvement within their reach.

7.1. Emerging Technologies Programs

From our focus group, it became apparent that in today's society, an education that strictly covers the basic sciences, such as chemistry, physics, and biology, is not very useful. Inspiring students to pursue careers in science often requires exposing students to how those basic sciences apply to their lives. Educators that make the connection between basic science and emerging technologies reveal to students the numerous opportunities that exist in a science career. For this reason, CSIRO Education should take the time to invest in the creation of educational programs that make this connection. For example, offering programs titled *Exploring the Nanoworld* or *Photonics and Your CD Player* would strengthen the repertoire of programs already offered by CSIRO Education. It is the hope that CSIRO Education will use the Catalogue of Learning Activities created during this IQP as a jumping off point for the creation of new cutting-edge educational programs.

7.2. Seminars for Teachers

The decision to become a scientist is usually not the result of a single exciting event such as a classroom visit by CSIRO. The inspiration sparks from a culmination of great teachers accompanied by exciting experiences. CSIRO Education could benefit greatly by not only educating the students of Victoria, but by also educating the educators of Victoria. Creating seminars for educators that focus on connecting basic sciences to their multifaceted impact in society would assist in the CSIRO Education goal of inspiring students to partake careers in science.

7.3. Supplementary Material for the Teachers

Often students will have an experience where they become intrigued in such a way that they wish to become a scientist. However, if time goes by without any reinforcement, it is likely that such students will lose interest quickly. It takes exciting activities combined with a teacher who is willing to relate material back to those activities at every opportunity.

CSIRO Education should increase the amount of material given to teachers who purchase programs from CSIRO Science Education Centres. For example, this material could include background information about the program and examples of how the concepts presented to the students relate to emerging technologies or to current research. CSIRO Education could guide teachers to relate back to the programs in their classroom by providing sample homework ideas, in-class assignments, and sample tests. Also, CSIRO Education could alert teachers to websites that relate to the concepts in each program. These methods would help prevent students from forgetting about the material presented to them in a program.

7.4. Supplementary Material for the Students

During the research for the creation of the Catalogue of Learning Activities the team discovered numerous web-based opportunities for emerging technology education. The Internet offers nano-visualization sites as well as java-applets for many emerging technologies. CSIRO Education should alert students to these availabilities so that students can take in upon themselves to learn more about the subjects presented to them in the programs.

There are two ways that CSIRO Education could provide this material to students. First, it could be added to the handouts that students already receive from CSIRO SEC when participating in a program. Second, the material could be offered on the CSIRO Education webpage.

7.5. E-Commerce

Currently, all CSIRO SEC programs are booked through the phone or by fax. The SEC could gain from a robust e-commerce investment. All of its programs are listed on-line, and if an interested party had the ability to make an on-line purchase while his or her interest was piqued, there is a possibility that sales may increase.

The efficiency of e-commerce is difficult to ignore. Perspective buyers can make purchases at any time, day or night. Integrating web enquiries with CSIRO SEC's existing database system would provide customers with real-time availability information at any time. Staff would also be free to complete more important tasks than answering a phone or booking an order.

Considering the fact that CSIRO SEC already has a web site and a database system in place, extending its facilities to offer real-time availability information and on-line bookings is an attractive option with only limited startup costs.

7.6. Future IQPs for WPI and CSIRO SEC

These ideas could all be the subject of multiple IQPs in the future of the CSIRO-WPI collaboration. The goal of this current project was not specifically to design new programs for CSIRO SEC. This project was centered on finding technical knowledge that can be used by CSIRO SEC. A future IQP could research the pedagogical aspect of these emerging technology programs. A future IQP could also research the possibility of CSIRO SEC running seminars for teachers. In the focus groups, it because clear that a single event in a classroom is simply not enough. The third and fourth recommendations deal with extra material for students and teachers. These materials could designed by a future IQP. No matter what recommendations are made, however, it still takes teachers who are interested in teaching science and willing to spend the time learning how to teach science to students.

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Glossary of Terms

Advanced Science: Science that requires higher-level learning expertise.

Catalogue of Learning Activities: The goal of this IQP.

CDEST: Commonwealth Department of Education Science and Training.

CSF II: Curriculum Standards Framework II.

CSIRO: Australia's Commonwealth Scientific and Industrial Research Organization

CSIRO SEC: CSIRO Science Education Centre

Education Programs: Hands-on Science classes and Science & Technology shows provided by the CSIRO SEC.

Education Officers: An employee of the CSIRO SEC that conducts the Education Programs both at the CSIRO SEC and at schools. They also may create new Education Programs.

Educators: One trained in teaching; a teacher.

Emerging Technologies: Technology fields in their infancy.

INVSEE: Interactive Nanovisualization in Science and Engineering Design.

KLA: Key Learning Area (a part of the CSF II).

Learning Programs: See Education Programs.

Nanotechnology: An emerging technology; a branch of engineering that exploits the properties of matter at the nanometer level.

Photonics: The technology of generating and harnessing light and other forms of radiant energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to communications and information processing (Photonics.com 2003)

Presenters: See Education Officer.

Primary School Students: Year One through Year Six.

Secondary School Students: Year Seven through Year Twelve.

Sector: One of the 22 specialized research areas within CSIRO.

Teachers: One trained to educate.

Technology: The practical application of science to commerce or industry.

Technology Education: Knowledge through practice of the synthesis of ideas and skills through solving identified technological problems.

VCAA: Victorian Curriculum Assessment Authority.

VCE: Victorian Curriculum Extension.

Appendix A: CSIRO Background

CSIRO was founded during World War I as the Advisory Council of Science and Industry. The Australian government soon saw a need to advance this organization and renamed it the Council for Scientific and Industrial Research in order "to carry out scientific research in connection with or in promotion of primary and secondary industries in Australia" (CSIRO homepage 2003). This name stood for the next twenty years until the Science and Industry Research Act of 1949 was passed. The council was then reconstituted as the Commonwealth Scientific and Industrial Research Organization.

Australia's CSIRO is among the world's leading and most diverse scientific research organizations. The organization conducts research not only in the commonwealth, but also throughout the world. CSIRO researches many aspects of science from general biology to genetic engineering and from general physics to fiber-optic telecommunications. CSIRO's vision is to "deliver great science and innovative solutions for industry, society and the environment" (CSIRO homepage 2003).

CSIRO's board of directors ensures efficient operation of the organization by providing guidelines to the Chief Executive, Dr. Geoff Garrett. The organization's Executive Committee assists Garrett. Due to the varying topics of research the organization covers, its structure consists of 22 industrial sectors concentrating in agribusiness, environmental studies, information technology, manufacturing, and education to name a few. Divisions made up of one or more sectors carry out specific research goals and encourage a multidisciplinary approach to completing research goals. In order to ensure that each sector remains effective, Sector Advisory Committees exist to govern each sector's overall activity and report to the CSIRO Board of Directors and Executive Committee.

The Education Unit of CSIRO aims to stimulate students' interests in science through learning programs marketed to school systems throughout Australia. These programs are geared toward students and their relationship with science and society. Below are some CSIRO Education initiatives.

- **The Double Helix Science Club**: The science club provides children ages seven and up with two magazines: *The Helix* and *Scientriffic*. The club offers events and activity sessions in all states of Australia, including opportunities for young students to participate in national experiments with professional researchers. It also offers to teachers and school administration educational science resources for purchase.
- **Creativity in Science and Technology (CREST)**: The CREST Award program recognizes students who do exemplary work in science. Students "choose, organize and undertake" (CSIRO Homepage 2003) their own experiments. The program generates contacts between professionals and students so that students can obtain an innovative view of the role of science and engineering in the community. Awards are distributed by CSIRO based on project creativity, perseverance, and application.
- **BHP Billiton Science Awards**: These program rewards students who have completed research projects that demonstrate innovative approaches and thorough scientific procedures. Over 100 cash awards and trips are given out to outstanding students for four areas of scientific achievement. There are also prizes of $500 and $5,000 for outstanding teachers at schools affiliated with CSIRO.

Appendix B: CSIRO Education Annual Report

This is the statistical summary from the CSIRO Education Victoria Annual Report. It is used in this IQP to compare several CSIRO SEC programs.

CSIRO Education, Victoria

2002 Annual Report

Statistical Summary

Programs for Schools	2002			2001		
Program (in Centre)	**Sessions**	**Students**	**Adults**	**Sessions**	**Students**	**Adults**
Air and Weather	1	25	2	1	14	2
Cool Chemical Science	0	0	0	1	11	2
Cool Chemistry	5	120	18	0	0	0
Electricity and Magnetism	14	471	38	11	257	22
Electronics	6	130	12	0	0	0
Energy and Its Uses	14	430	30	1	23	2
Flat Cats and Mind Games	8	217	17	7	152	14
Force and Movement	12	396	39	8	179	16
Forensic Frenzy	22	435	45	18	363	36
Gene Technology	5	111	8	9	201	18
Genetic Engineering	96	1744	194	110	1858	226
Lego Robotics	0	0	0	1	22	2
Lego Technic	4	83	8	1	19	2
Light and Sound	11	386	22	4	82	8
Materials and Structures	95	1446	193	105	1680	225
Reaction and Change	14	370	28	NA	NA	NA
Science in Action	13	360	26	0	0	0
Solids, Liquids and Gases	3	57	6	NA	NA	NA
Sub-total (in Centre)	**323**	**6781**	**686**	**277**	**4861**	**575**
	2002			**2001**		
Program (out of Centre)	**Sessions**	**Students**	**Adults**	**Sessions**	**Students**	**Adults**
Air and Weather	122	5552	268	124	5704	250
Biological Science	NA	NA	NA	6	152	12
Cool Chemical Science	145	3505	284	133	3258	330
Electricity and Magnetism	162	7018	434	144	6366	288

Electronics	30	539	60	5	71	10
Energy and Its Uses	161	7566	358	80	3489	224
Exploring Science	NA	NA	NA	6	164	12
Flat Cats and Mind Games	98	4033	361	55	2448	214
Force and Movement	153	6741	346	239	10474	615
Forensic Frenzy	309	7343	608	178	4225	423
Gene Technology	154	3416	343	139	2888	326
Genetic Engineering	8	190	18	8	181	30
Lego Dacta	12	259	23	NA	NA	NA
Lego Robotics	41	1029	82	40	949	82
Lego Technic	48	1109	82	23	583	46
Light and Sound	80	3734	185	117	5353	237
Reaction and Change	168	4110	329	224	5510	450
Science in Action	61	2917	133	28	1361	76
Science Procedures and Processes	28	675	56	19	459	38
Special Science Shows	4	137	22	39	815	434
Solids, Liquids and Gases	154	3507	326	NA	NA	NA
Starlab	127	3372	310	NA	NA	NA
Sub-total (out of Centre)	**2065**	**66752**	**4628**	**1607**	**54450**	**4097**
Total (in and out of Centre)	**2388**	**73533**	**5314**	**1884**	**59311**	**4672**
Percentage of government schools	60.0%			64.3%		
Percentage of Catholic schools	27.9%			25.4%		
Percentage of other schools	12.1%			10.3%		
Percentage of metropolitan schools	81.0%			77.0%		
Percentage of non-metropolitan schools	19.0%			23.0%		
Percentage of primary students	73.2%			81.9%		
Percentage of secondary students	26.8%			19.1%		

Double Helix Science Club	2002			2001		
Chapter	**No. of Events**	**Students**	**Adults**	**No. of Events**	**Students**	**Adults**
Melbourne	38	686		48	814	
Bendigo	52	920		9	860	
Sub-totals	90	**1606**		**57**	**1674**	
Number of Chapters during year		**1**			1	
Scientriffic Members		1604			N/A	
Helix Members		2113			2234	
Number of Members (at Dec)		3717			2234	

Student Research Scheme	2002	2001

Number of students who completed projects	54	42
Number of female students who completed projects	47	27
Total number of projects completed	54	41
Number of engineering projects	10	4
Number of CSIRO projects	23	14
Number of institutions (count each CSIRO Division and Uni campus separately)	19	11
Number of supervising scientists	81	37
Number of people attending functions	158	159
Total number of people involved	**293**	**238**

CREST	2002	2001
Number of Primary CREST Centres	173	171
Number of Green Awards	4576	3480
Number of Orange Awards	694	92
Number of Blue Awards	8	2
Sub-total Primary Awards	**5278**	**3574**
Number of secondary CREST Centres	**112**	107
Number of Bronze Awards	743	514
Number of Silver Awards	5	0
Number of Gold Awards	0	0
Sub-total Secondary Awards	**748**	**514**
Total number of CREST Awards	**6026**	**4088**

BHP Science Awards	2002	2001
Number of student entries	46	13
Number of student entrants	60	NA
Number of teacher entries	18	84
Number of teacher entrants	20	NA
Total number of entrants	118	NA

Teacher Professional Development	2002		2001	
Program (in Centre)	**Sessions**	**Teachers**	**Sessions**	**Teachers**
Springboard into Science	0	0	1	29
Teacher Prof Development	1	4	0	0
Sub-total (in Centre)	**1**	**4**	**1**	**29**
	2002		**2001**	
Program (out of Centre)	**Sessions**	**Teachers**	**Sessions**	**Teachers**
CREST Workshops	36	447	54	636
Almost Free Physics	3	36	0	0
Science From Scrap	2	28	4	84

Springboard into Science	4	66	7	145
Student Teacher Sessions	2	165	5	452
Teacher Prof Development	25	437	20	579
Lab Technicians	6	118	6	137
Electricity and Magnetism Workshop	2	48	3	48
Gene Technology Workshop	3	31	NA	NA
Sub-total (out of Centre)	**83**	**1376**	**99**	**2081**
Total (in and out of Centre)	**84**	**1380**	**100**	**2110**

Other Programs and Visitors						
	2002			**2001**		
Program (in Centre)	**Sessions**	**Students**	**Adults**	**Sessions**	**Students**	**Adults**
Holiday Science Activities	75	1532	844	69	1362	919
Sub-total (in Centre)	**75**	**1532**	**844**	**69**	**1362**	**919**
	2002			**2001**		
Program (out of Centre)	**Sessions**	**Students**	**Adults**	**Sessions**	**Students**	**Adults**
Holiday Science Activities	57	1459	317	36	976	474
Family Science Program	19	838	590	17	752	682
Public Science Shows	1	16	122	6	175	250
CREST for Students	1	40	0	1	7	0
Public Science Events				7	1817	307
Sub-total (out of Centre)	**78**	**2353**	**1029**	**67**	**3727**	**1713**
Total (in and out of Centre)	**153**	**3885**	**1873**	**136**	**5089**	**2632**
			2002		**2001**	
Total participants in all Programs			**94028**		**79911**	

(CSIRO Education Victoria 8-11)

Appendix C: Existing CSIRO SEC Program Cost

CSIRO SEC offers many programs with varying prices. This appendix lists the prices for all programs studied in section 4.4 and 4.5.

Forensic Frenzy

At the CSIRO SEC			
Duration	**Cost per Student**	**Minimum Cost per session**	**Maximum No. of Students per Session**
1.5 hours	$4.50	$110	30

Lab on Legs					
	Duration	**Cost per Student**	**Minimum Cost per Session**	**Maximum No. of Students per Session**	**Minimum Cost per Day**
Metro	1.5 hours	$5.50	$125	30	$300
Country	1.5 hours	$6.70	$155	30	$420

Electronics

At the CSIROSEC			
Duration	**Cost per Student**	**Minimum Cost per session**	**Maximum No. of Students per Session**
1.5 hours	$4.50	$110	30

Lab on Legs					
	Duration	**Cost per Student**	**Minimum Cost per Session**	**Maximum No. of Students per Session**	**Minimum Cost per Day**
Metro	1.5 hours	$5.50	$125	30	$300
Country	*1.5 hours*	*$6.70*	*$155*	*30*	*$420*

Cool Chemical Science

At the CSIROSEC			
Duration	**Cost per Student**	**Minimum Cost per session**	**Maximum No. of Students per Session**
70 mins	$3.50	$84	30

Lab on Legs					
	Duration	**Cost per Student**	**Minimum Cost per Session**	**Maximum No. of Students per Session**	**Minimum Cost per Day**
Metro	70 mins	$4.00	$100	30	$300
Country	70 mins	$5.20	$140	30	$420

Materials Chemistry: Unit 1 VCE Chemistry

At the CSIROSEC			
Duration	**Cost per Student**	**Minimum Cost per session**	**Maximum No. of Students per Session**
90 mins	$4.50	$110	30

Lab on Legs					
	Duration	**Cost per Student**	**Minimum Cost per Session**	**Maximum No. of Students per Session**	**Minimum Cost per Day**
Metro	90 mins	$6.00	$150	30	$300
Country	90 mins	$7.20	$180	30	$420

Science Procedures and Processes

At the CSIROSEC			
Duration	**Cost per Student**	**Minimum Cost per session**	**Maximum No. of Students per Session**
90 mins	$4.50	$110	30

Lab on Legs					
	Duration	**Cost per Student**	**Minimum Cost per Session**	**Maximum No. of Students per Session**	**Minimum Cost per Day**
Metro	90 mins	$5.50	$125	30	$300
Country	90 mins	$6.70	$155	30	$420

VCE Physics: Materials and Structures

At the CSIROSEC			
Duration	**Cost per Student**	**Minimum Cost per session**	**Maximum No. of Students per Session**
2 hours	$6.50	$120	24

(CSIRO SEC Homepage 2003).

Appendix D: Email from Nanosonic Inc.

Nanosonic, Inc. does not list its prices on its webpage, so it was necessary to obtain the price of its electrostatic self-assembly kit via e-mail. The following is the e-mail with the prices. Names have been withheld.

Date: Thu, 27 Mar 2003 15:12:38 -0500 All headers
From: "xxxxxxxxxx" <xxxxxx@nanosonic.com>
To: "Benjamin Polidore" <polidore@WPI.EDU>
Subject: Re: Nanotechnology Classroom Kits

Benjamin,

I apologize for the delay in responding to your request.

We sell the two variations of the education kit. The "base" kit which provides the materials for a 24 student classroom, sells for $100. The "refill" kit which replensishes the consumable materials, but does not replensih nonconsumable experiments and materials, sells for $70. Finally, I can offer a "slide" replenishement kit which provides only additional functionalized slides for the student assembled nanostructured film experiment. This slide kit can allow multiple classes to share some of the same chemicals, snap tight containers are provided to facilitate short term storage.

The consummable materials are prepared chemicals, functionalized slides, and safety gloves. Making a few assumptions, such as 28 classrooms of which none are taught simultaneously and that 4 class rooms are using the kit in the same 2 - 3 week time frame, I would propose the purchase of 2 base kits, 6 expansion kits and 21 slide kits. This results in an approximate annual budget as low as $1200, to as high as $2800.. Obviously, once you have reviewed the kit and decided to incorporate it into your education program, we would need to discuss the distribution of kits in light of actual planned utilization to determine .

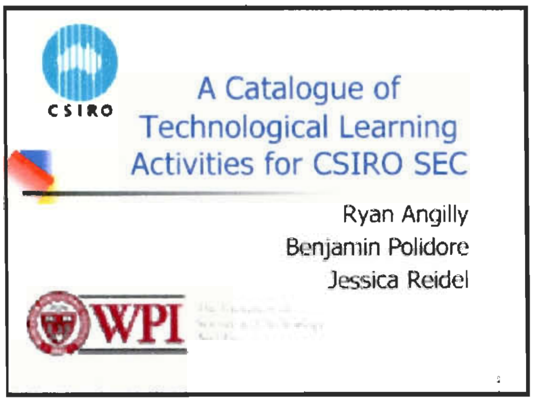
We do not assemble single usage evaluation kits. For evaluation, you would only need to consume 1 students group worth of materials from a single base kit, leaving enough material for 5 student groups that can be used at a later time.

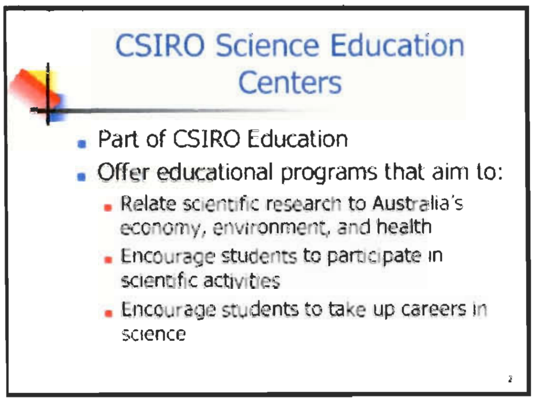
Regards,

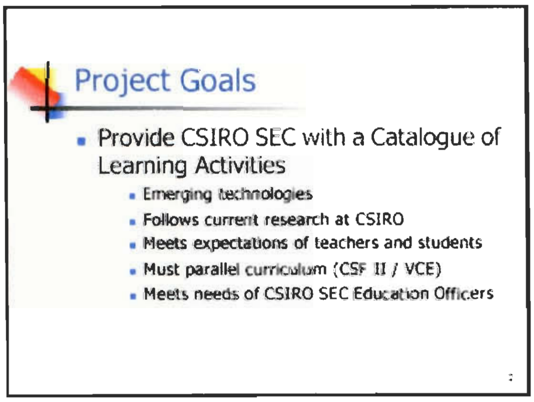
xxxxxxxxxxxxx

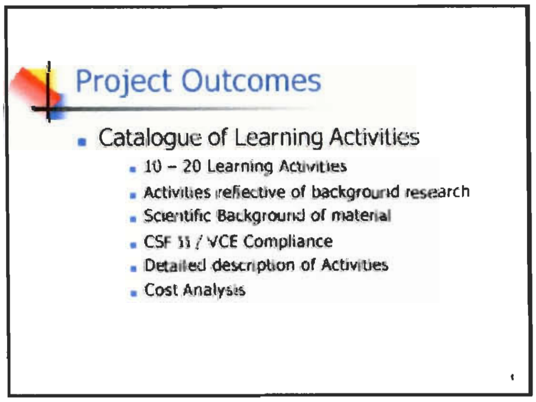
Appendix E: Outline for Focus Group Presentation

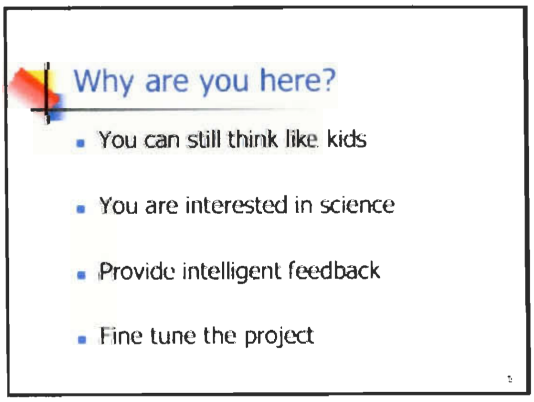
This is the presentation used during the WPI student and faculty focus group conducted on 22 April 2003.

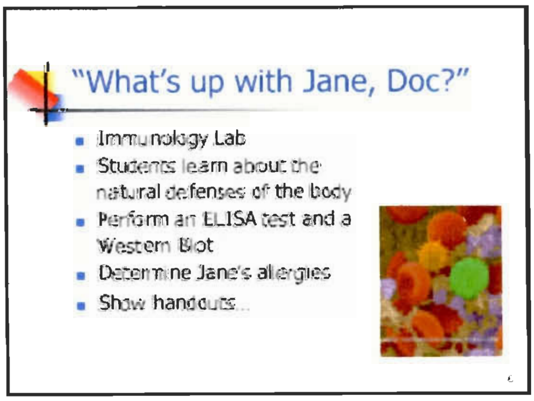












Monolayer Demonstration

- Demonstrates self-assembly of a monolayer as it extinguishes a fire on the surface of a water and ether solution
- VCE for chemistry demands that students be introduced to cutting-edge materials
- Video . . .

7

Aerogel Demonstration

8

Extremely Efficient Insulator

Material	Thermal Conductivity (W/mK)	Density (kg/m^3)
Aerogel	0.017	3
Air	0.025	1.29
Fiber Glass Insulation	0.03	50
Aluminum	237	2700

9

Very high surface area

This 5 mL aerogel has more surface area than the area of the football field at Camp Randall Stadium!

10

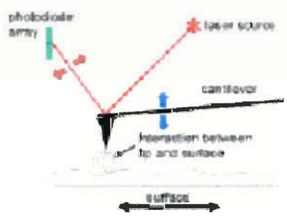
Very Strong

A pound of Aerogel would be the size of a man but could hold the weight of a Honda Civic.

11

Building a Scanning Probe Microscope

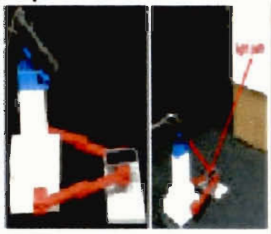
The theory behind a scanning probe microscope



Demonstration...

12

Building a Scanning Probe Microscope

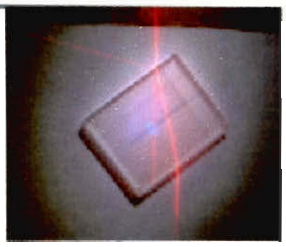


- Uses LEGO bricks to build AFM and MFM of a SPM
- Engages students in a hands-on situation
- Enables discussion of theories and models. (VCE Physics Unit 1)

Edible Optics

- Students use gelatin to:
  - Make concave and convex lenses
  - Determine index of refraction using a spherometer
  - construct any shape of lens, prism, or light guide
- Explains the topics outlined in the 6.1 learning outcomes of the CSFII and outcome one of Unit 1 VCE Physics

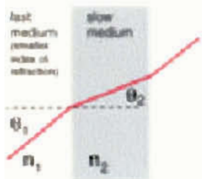
Determining the Index of Refraction



Snell's Law

Snell's Law

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$



Summary

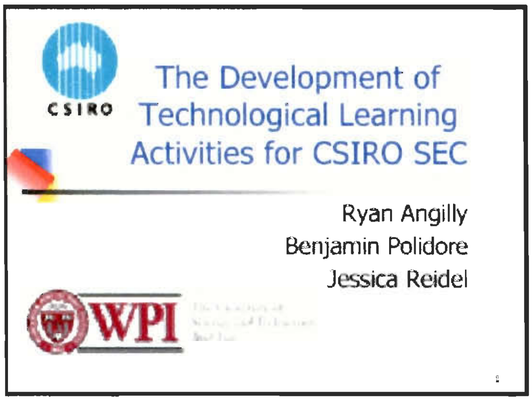
- Just an excerpt from entire Catalogue of Learning Activities
- Evolved from hands-on craziness to discussion
- Your following input may help different aspects of the catalogue and recommendations

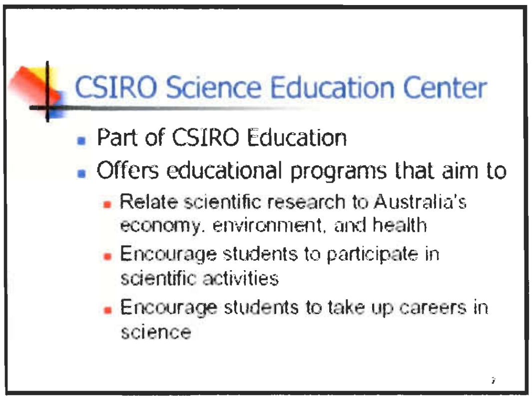
Discussion Topics

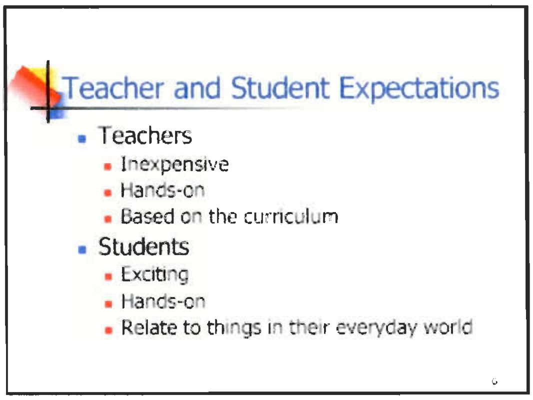
- CSIRO SEC business model
- Emerging technologies in science education
- Technology in the classroom
- Retrace your interest in science
- Ideas that pique interests in technologies that are not popular

Appendix F: Outline for Final Presentation

This is the final presentation given to WPI students and staff, professionals from each Melbourne project center and various other guests on 29 April 2003.



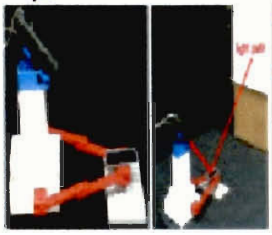




The Catalogue of Learning Activities

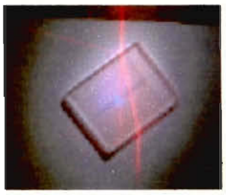
- Synopsis
- CSF II / VCE Compliance
- Activity Details
  - Scientific Background of Material
  - Materials and Cost Analysis
  - Procedures
- Additional Information for CSIRO SEC

Building a Scanning Probe Microscope



- Uses LEGO bricks to build a SPM
- Engages students in a hands-on activity
- Enables discussion of theories and models. (VCE Physics Unit 1)

Edible Optics



- Students use gelatin to learn about optics
- Explains the topics outlined in the 6.1 learning outcomes of the CSFII and outcome one of Unit 1 VCE Physics

Aerogel Demonstration

- One of the World's lightest solids, best insulators, and strongest materials
- Exposes students to cutting-edge materials as outlined in the VCL

Recommendations for CSIRO SEC

- Make better use of the WWW
- Offer seminars for teachers on science education
- Develop supplementary materials for each program, possibly web-based
- Offer assessment strategies for teachers

Conclusions

- Proved the project necessary
- Created a Catalogue of Technological Learning Activities
- Developed recommendations for CSIRO SEC
- CSIRO will use this IQP to develop a more cutting edge repertoire


Acknowledgements
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WPI Students

Appendix G: Parts for MWM Biosensor Module

Materials World Modules lists all the materials required for this learning activity on its web page. This is the list as of April 2003.

Module Activity	Quantity	Unit	Item Description
1	1	roll	Masking tape
1, 2, 3, 4, Design	24	ea.	Plastic syringes, 3 mL
1	100	mL	0.1M phosphate buffer, pH 7.4
1, 2, 3, 4, Design	100	ea.	Graduated droppers, 0.1-0.3 mL
2, 3	1	ea.	3% hydrogen peroxide, 4 oz.
2	8	ea.	Permanent markers
2	75	mL	0.05M Tris buffer, pH 8.0
2	100	mL	0.1M phosphate-citrate buffer, pH 5.0
2	100	mg	Luminol
2	100	mg	Sodium luminol
3, 4	60	mL	Triton X-100
3	250	mL	0.05M Tris buffer, pH 8.0
3	8	ea.	Whatman 541 filter paper circles
3	1	box	Disposable gloves
3, D	100	ea.	Test tube caps
4	3	g	Cholesterol
4	20	mL	0.05M phosphate buffer, pH 7.4
4	150	mL	0.1M phosphate-citrate buffer, pH 5.0
Design	12	mL	5% glucose solution
1, 2, 3, 4, Design	*1*	*pack*	*Kraft envelope of FROZEN chemicals (sealed with RED tape). Please FREEZE immediately. Contains the following:*
1	48	ea.	Desiccated whole fireflies
1	4	mL	10 mg/mL ATP solution
2	4	mL	0.1% 4CN solution
2	6	mL	90 U/mL peroxidase enzyme solution
3	100	mL	2 mg/mL 4CN solution
3A	2	mL	70 U/mL peroxidase enzyme solution
3B	8	mL	70 U/mL peroxidase enzyme solution
3C	5	mL	70 U/mL peroxidase enzyme solution
4A	6	mL	3 U/mL cholesterol oxidase enzyme solution
4A	6	mL	100 U/mL peroxidase enzyme solution
4B	8	mL	3 U/mL cholesterol oxidase enzyme solution
4B	8	mL	100 U/mL peroxidase enzyme solution
Design	12	mL	60 U/mL peroxidase enzyme solution
Design	12	mL	60 U/mL glucose oxidase solution
2, 4	*1*	*pack*	*Kraft envelope of REFRIGERATED chemicals (sealed with YELLOW tape). Please REFRIGERATE immediately. Contains the following:*
2	4	mL	1 mg/mL TMB solution
4A	120	mL	0.1 mg/mL TMB solution
4B	160	mL	0.1 mg/mL TMB solution

(MWM 2003)

Appendix H: Parts for MWM Smart Sensors Module

Materials World Modules lists all the materials required for this learning activity on its web page. This is the list as of April 2003.

Module Activity	Quantity	Unit	Item Description
1	2	ea.	Motion detectors
3, 4, 5, Design	16	ea.	Plain PVDF films
3	8	ea.	Audio connecting leads
3	8	ea.	Mini amplifier-speaker units
3, 4, 5, Design	8	ea.	Laminated PVDF films
3	8	ea.	Balloons
3	8	ea.	9-oz. clear plastic cups
3, 4, 5, Design	1	roll	Double-stick tape
3	1	ea.	Audio speaker element, 3x6" PVDF film
3	1	ea.	Audio cable
4, 5, Design	16	ea.	Jumper leads with alligator clips
4, 5, Design	8	ea.	PVC plastic cards
5	8	ea.	3/8"-diameter ball bearings
5	8	ea.	1/2"-diameter ball bearings
5	8	ea.	3/4"-diameter ball bearings
5, Design	8	ea.	5x6x1" foam rubber
Design	8	ea.	Rulers with channels

(MWM 2003)

Appendix J: Preliminary Research Gantt Chart

This Gantt chart details the IQP group's activity during the preparatory period in Worcester, MA from 9 January until 27 February, 2003.

Activity	1/9 – 1/16		1/16 – 1/23		1/23 – 1/30		1/30 – 2/6		2/6 – 2/13		2/13 – 2/20		2/20 – 2/27	
Spokesperson	Ryan	Ryan	Jessica	Jessica	Benjamin	Benjamin	Ryan	Ryan	Jessica	Jessica	Benjamin	Benjamin	Ryan	Ryan
Email liaison	Group		Group			Group			Group		Group			Group
Problem Statement	Group	Group												
TILT Modules	Group	Group												
Education Research		Ryan	Ryan	Ryan	Ryan									
Technology Research		Jessica	Jessica	Jessica	Jessica									
Curriculum Research		Benjamin	Benjamin	Benjamin	Benjamin									
Creating Questionnaire		Group												
Internal Interviews			Group	Group							Ryan			
Lit. Review Outline			Group											
Literature Review			Group	Group	Group	Group		Jessica	Ryan	Benjamin	Group			
Methodology Outline					Jessica						Group			
Methodology					Group	Group	Group					Group	Group	Group
Introduction					Group	Group	Group			Group				
External Interviews							Ryan		Jessica	Ryan			Ryan	
Creating Survey								Group	Group					
Presentation									Group	Group	Group	Group	Group	Group
Final Proposal										Group	Group	Group	Group	Group

Key	
Group	(orange)
Ryan	(green)
Benjamin	(purple)
Jessica	(blue)

Appendix K: Gantt Chart for Activity in Australia

This Gantt chart details the activity of the IQP group during the IQP period in Melbourne Australia from 11 March until 29 April, 2003.

Activity	3/11 – 3/18		3/18 – 3/25		3/25 – 4/1		4/1 – 4/8		4/8 – 4/15		4/15 – 4/22		4/22 – 4/29	
Clarify Methdology	■	■	■	■	■	■	■	■						
Setup Internal Interviews	■													
Carry out Interviews		■	■											
Write Educator Survey	■	■												
Write Student Survey	■	■												
Implement Student and Educator Surveys			■	■	■									
Setup External Interviews					■	■								
Setup Focus Group									■	■	■			
Carry out External Interviews							■	■						
Carry out Focus Group												■	■	
Case Studies					■	■	■							
Revise Introduction								■		■		■		
Revise Background and Literature Review	■	■	■	■			■							
Results and Analysis Section									■	■	■			
Catalogue of Learning Acitivities						■	■	■	■	■	■	■	■	■
Conclusion Section												■	■	
Recommendations														■
Abstract												■	■	■
Executive Summary												■	■	■
Presentation										■	■	■	■	■
Final Report			■	■	■	■	■	■	■	■	■	■	■	■