

Electronics, Robotics and Engineering at the Australian Science and Mathematics School

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Abstract

The Australian Science and Mathematics School (ASMS) is a state-run purpose-designed senior secondary school aimed at reconceptualizing teaching and learning to develop creative, concerned and committed global citizens. A core purpose of the school is to contribute to a renaissance of the engagement of students in the fields of science and mathematics. The school is located on the campus of Flinders University in Adelaide, South Australia to promote interaction among students, teachers and university staff. The school's interdisciplinary curriculum is designed by the teachers in collaboration with university and industry personnel. Pedagogical approaches aim to move from the conventional teacher-directed approach to one of student-directed learning. Flinders University offers a wide range of general and professional degrees, including computer & electronic systems, biomedical & electronic systems and software engineering degrees.

This paper describes the integration into the teaching program of engineering in general and electronics and robotics in particular, through the strong connections between the ASMS and Flinders University and to local companies in the electronics industry.

Students at the school have the opportunity to engage in modules that complement their core program. University modules, co-taught by secondary and tertiary teachers, have been offered across all areas of science, such as robotics, cryptography and the mechanics of human movement. Industry modules have been run as projects have presented themselves, enabling small groups of students to directly engage with industry as part of their studies. The school also allows students to explore their passions by being given time and support to conduct independent research. The ASMS is one of the schools piloting a new year 12 subject. Extension Studies allows a student to be mentored (for example, by an academic) and directed in a substantially self-chosen area of study that complements or extends their other studies. The Robotics Peer Mentoring (RPM) program has been incorporated into this university module and funded the development of a Year 11 physics course. This is the first of many such learning programs designed to promote and encourage students to consider a career in engineering, especially electronic engineering.

The school's learning program is a show case for other school communities in providing a positive environment in which to encourage the next generation of engineers.

1. Introduction

The paper is organized as follows. This section separately describes the ASMS and Flinders University. The second section describes the interactions and collaborations between the ASMS and Flinders University. The third section gives detail on some exemplars of the collaboration, and the final section concludes with the benefits of the collaboration.

The Australian Science and Mathematics School

In 2000 representatives from Flinders University and the South Australian Department of Education and Children's Services, (DECS) recognised the importance of engaging more senior secondary students studying in the fields of science and mathematics. The establishment and opening of the ASMS in 2003 was the culmination of extensive thinking about designing learning environments that would engage students and allow them to develop deep understanding in the disciplines of science and mathematics. Oliver & Davies stated "The building of this new school provided a unique opportunity to design and implement leading edge developments in senior secondary education from the ground up" ⁶.

Principal, Jim Davies states ³

"The Australian Science and Mathematics School (ASMS) is a bold venture intended to mould a new form of science and mathematics education that speaks to new innovations in science, is responsive to student interests and student directed learning, and achieves a validity and depth endorsed by practicing scientists and educators. It has engendered an integrated learning community of students, teachers, university staff and industry partners that radically alters the learning environment of students and the professional environment of teachers".

The first two years of operation have been a time for the ASMS to define and establish its place as a member of modern educational communities. The following school vision sets the focus for being at the leading edge of developments in senior secondary education ¹

"The Australian Science and Mathematics school will be recognised for its leadership of innovation and reform of learning and teaching in science and mathematics".

The building is of a non-conventional classroom design with open space 'Learning Commons', (LC). Adjacent to every LC is a studio. Studios are regions for technical specialties to be housed. Some are discipline laboratories like Biology and Chemistry. Some are cross curricula in focus like Human Performance and Applied Technology/Electronics. Each student has his or her own home desk with a portable locker in a LC. The LC has a teaching wall where approx. 20 - 25 students can group to participate in a learning activity. The teaching wall is a white board, projector screen and a data projector, which is cabled to attach any appropriate technological tool. This tool will normally be a computer that can be connected to the school network, to the Internet and to Smart Board technologies to assist student learning. Within the LC there is cabling for many computers. Students and teachers are not limited to the cabled ports but can access the school network via the wireless system and the Internet.

Flinders University

Flinders University teaches 15,000 students across a wide range of disciplines. It is "an outward-looking university which seeks out, listens to, takes seriously and meets wherever possible the needs of the multiple external communities that have expectations of universities

generally and of Flinders in particular”, and supports “cross-disciplinary collaborations in education and research”⁴. Its engineering school focuses on electronics, awarding degrees in Computer and Electronic Systems, Biomedical and Electronic Systems and Software Engineering.

Engineering at Flinders has a strong focus on industry and its needs, best demonstrated through its Industrial Affiliates Program. Undergraduate engineers are required to take a 20 week industrial placement, taking the place of one semester of their university studies. As part of the placement they have to write reports and present seminars reflecting on their work and their company, from a management and corporate structure viewpoint as well as a technical engineering one. For many students, this relationship with a company leads on to further interactions, such as an industry-sponsored final year project and then a job upon graduation.

A second major focus of engineering at Flinders is on communication skills. These are taught explicitly and exercised throughout the courses. The success of this work is clearly seen through the Institution of Electrical Engineers final year project presentation prize. This competition has been run individually in all states for many years, and a national competition has now been run since 1998. Despite being one of the smallest engineering schools in Australia, a Flinders undergraduate has won the national prize six times out of seven.

2. Description of ASMS-Flinders interaction

The ASMS operates as a partnership between the South Australian Department of Education and Children’s Services and Flinders University of South Australia. Within Flinders, its champion is the Faculty of Science and Engineering, which earlier restructured in order to focus on the new sciences and a new philosophy of science education. The School of Education plays a major role in interactions with the ASMS, particularly teacher professional development. A Core Group of approximately 8 university science and mathematics academic staff has engaged closely with the ASMS since its conception. The three major areas of interaction are curriculum design, university modules and professional development.

Curriculum design

Curriculum design is underpinned by “the pedagogy of questioning [which] places the question at the center of teaching and learning. It deflects teaching from its focus on a ‘correct answer’ to a focus on ‘a fertile question’.”⁵ Harpaz describes a fertile question as having the following basic characteristics. It must be

- an open question with no discrete answer.
- An undermining question that challenges and casts doubt on traditional assumptions and beliefs.
- A rich question that cannot be “answered without careful and lengthy research”.
- A question that has a connection to the learner and/or to the discipline being investigated.⁵

The ASMS has interpreted the process of answering the fertile question as requiring links to be made across traditional disciplines. The ASMS Teaching and Learning Handbook indicates that, “life is interdisciplinary as is the way in which we think ... [and that] ... Knowledge about the world sits within a range of disciplines”². Learning at the ASMS is about recognising these interdisciplinary connections and seeks to design learning that “allows the learner to generate new meaning to transform” his/her world².

The curriculum at the ASMS has been developed within an interdisciplinary framework with the inclusion of emerging, leading-edge science and mathematics as a key priority. Students in years 10 and 11 are engaged in a two-year pattern of experiences that have as a central platform the “Central Studies”. There are 9 central studies located around leading-edge science and technology, namely Towards Nanotechnology, Biotechnology, The Body in Question, Technological World, Sustainable Futures, Earth and the Cosmos, Variety of Life, Mathematics and Abstract Thinking and Communication Systems.

University Studies are an integral part of the curriculum plan as they foster links between the Central Studies and the latest thinking found in accredited university courses. Curriculum is further enhanced through participation in industry visits, industry projects and through attending conferences like the recent Australia's National Electronics Industry Conference, Technology Futures Conference - 2005, Adelaide, South Australia.

University modules

University modules are electives taken by groups of 10-20 ASMS students for a period of 8-10 weeks. Modules are initiated by university staff and delivered in conjunction with an ASMS teacher. This allows new developments and ideas from the tertiary sector to enter the secondary sector and indirectly provides professional development for the teacher. ASMS students similarly benefit from being able to investigate an area of interest to greater depth than normally available, or an area not normally covered, at a secondary level.

The ASMS also runs other modules similar to university modules that engage the students in non-traditional ways. Industry modules allow secondary students to interact with professional in industry and to learn in a way not possible at any educational institution. The electronics industry in particular is very receptive to the opportunity to instill in students an interest and ability to work in their industry, and several companies have been consistently interested in any projects that have been proposed.

ASMS students are encouraged to develop personal projects and are supported to achieve the learning goals they have negotiated. A student who brings a well considered and achievable project can be supported by allowing them time to pursue their interest.

Professional development

Professionally the ASMS-Flinders relationship has resulted in many benefits to the staff directly involved. It has fostered a mutual appreciation of each others' situations, skills and ideas. The university modules and other similar occasions have allowed the direct development of skills in the secondary teachers involved. In its first year, every ASMS teacher underwent a tertiary-taught session to introduce or improve their soldering techniques and gain an understanding of electrical concepts and OHSW procedures involved in electronic technology. A significant opportunity that has been taken by many secondary and tertiary staff is to jointly attend conferences, such as the Annual Conference of the Australasian Association for Engineering Education or the Annual Conference of the South Australia Maths and Science Teachers Association. This has given secondary teachers a useful insight into engineering education, and university staff have developed a richer understanding of secondary student skills and their willingness to explore. Both educators have had the opportunity to observe and interact with different pedagogical approaches and thus reflect on their understanding of student learning.

3. Exemplars

Communication Systems Central Study

Communication Systems has Physics, Chemistry, Psychology English and Geography as key disciplines. These are intertwined to create an interdisciplinary study on the emergence of new forms of communication. Digital technologies play a major role in the lives of our students and an investigation into their impact on the social and interpersonal connection is warranted.

The fertile question - Are we the controllers or the controlled? is designed to provide openness and irritation as to the purpose of digital technology. Are we the controllers of technology or are we being controlled by it? How should people in the 21st Century relate to the use of such items?

This central study develops content, skills and dispositions in and around basic circuits and electronics, hormone communication in plants and animals, the role of humans senses, remote sensing eg GPS and GIS.

This course will culminate in a personal project where the student will explain an aspect of their understanding of how to answer the fertile question.

Robotics University module

The Robotics University module has been developed to encourage senior secondary students to consider career pathways in the electronics. Students in this module gain knowledge in basic electronics, develop soldering skills, construct a robot and learn how to program it. The chosen hardware is secondary, as the procedures and skills involved is the focus. Currently we uses a variety of hardware (eg Lego Mindstorms, eLabtronics eRacer through the Robotics Peer Mentoring Program described below, etc) according to interest and availability. Students visit the Faculty of Science and Engineering to interact with lecture staff and University equipment, for example using the microcontroller trainer boards used by Flinders' undergraduate engineering students. This provides the ASMS students with a greater appreciation of the current state of technology and the kind of tasks and approaches used in industry.

The robotics module has provided opportunities for the students to learn about soldering, mechanical and electrical construction, engineering design, software development, algorithms, engineering experimentation and redesign. Accurate recording of achievements, learning outcomes and critical self-appraisal has been encouraged through the use of log books.

The Robotics Peer Mentoring Program

The RPM program is providing quality learning experiences in robotics, electronics, science and engineering to secondary students across South Australia. The program trains Flinders University, University of SA, Adelaide University and TAFE electronics students to deliver 20 hours of curriculum to year 10 and 11 students. The key focus is to develop skills to construct and solder components to build a robot and then to develop programming skills through the use of 'Core Chart' to program the robot. This program also has the role of re-skilling, as the peer mentors provide support and guidance to secondary teachers to learn about new technologies.

Industry modules

After completing the 20 hour RPM course in 2004, six students participated in an industry study. In conjunction with Clipsal Integrated Systems (CIS), Uni SA and eLabtronics, the

team of students were given the challenge to build and program an eLabtronics eRacer to interface with the Clipsal C-Bus home automation system in only 13 weeks. The aim of this project was for students to experience working in the electronics industry, and both engineers and senior management at Clipsal provided support for the team. Clipsal emphasized the importance of documentation of our work including flow charts and pseudo code to ensure a good record of the project was kept. To develop the eRacer firmware, the project group was divided into 3 sub-teams to work on different parts of the program. Each team was responsible for a different layer of the firmware which could later be brought together to produce a fully modular program.

The success of this project was clearly evident in the students' ability to communicate to Clipsal management about the capabilities of their project and by how the project was tested using all of the C-Bus switching systems. This highlighted that the design was fully modular and could operate under all conditions. 2005 semester 2 will see an extension of this project into wireless technologies and a second project around the "Robot First" competition in the USA is being explored.

Independent study

The ASMS student-centred focus allows for students to pursue passions. After initial skill development students were encouraged to develop a personal or team project. The role of the teacher and university lecturer was that of support, guidance and in some cases finance. Some of the projects undertaken were:

- developing robots to compete in the state Robo-soccer competitions.
 - describing a model to show how sound could be transmitted via an infrared laser.
 - designing and constructing a working model to simulate the Mars Rover, controllable remotely over the Internet.
 - writing programs to enable communication between a Lego RCX and an eRacer PIC microcontroller.
 - developing software to farm video processing to multiple computers.
- Some of these individual projects have achieved considerable success with four projects being nominated as finalists and one achieving a highly commended recognition at the 2005 EDN Honouring Innovations Award, a competition aimed at university students.

EDN competition

EDN being the design magazine for the electronics industry organised a competition where one category was to provide an opportunity for Australia's next generation of electronics engineers to receive recognition for their academic projects. Wanting to support positive outcomes for student learning all personal project teams were encouraged to enter. The May 2005 edition listed four project teams as achieving finalist nominations. Hugh Considine, a year 11 student, received a highly commended prize for his work on developing a communication link between a microchip PIC microcontroller and a Lego RCX so that distance sensing could be managed as the robot plays soccer.

Electronics through year 11 Physics

The success of the RPM program has resulted in it looking beyond its original aim of mentoring year 10 and 11 students in building and programming a robot. It is also working towards providing clear educational pathways for students to enter a career in electronics. As part of this aim, last year the ASMS team developed a year 11 Physics curriculum centred on understanding the physical principles behind the eRacer robot. When conventional classes study light, this course encourages teachers to investigate how a light emitting diode can

produce different coloured light. When a conventional class studies electro-magnetism this class will study the principle of how the motors of the robot operate.

A more detailed investigation of the course can be found on the ASMS website by conducting a search for RPM Physics or by going to <http://curriculum.asms.flinders.edu.au/rpmphysics>

Extension studies

Extension Studies is a year 12 subject that allows a student to learn in more depth about an area of interest, typically building on another year 12 subject. At the ASMS, students taking the Extension Studies subject are often mentored by someone external to the school, such as a Flinders University academic staff member. In each of the two years the subject has been offered, an ASMS student has undertaken study in an area of electronics. In 2004 a student designed and built a computer-based wireless communication system using CB radios for application in the remote control and monitoring of farms. This year a student is investigating data buses, including building an electronic system using a PIC microprocessor to control peripheral devices using the I2C bus.

4. Conclusions

The ASMS-Flinders interaction has proved to be highly beneficial to all parties: a win-win-win for academics, teachers and students. The professional interaction has led to a common appreciation of the complexities of both secondary and tertiary learning environment. It has also motivated both ASMS and University staff, as the program has shown quite strongly what can be achieved if students are provided with opportunities for self-directed learning. Students have an opportunity to develop knowledge, skills and dispositions about areas such as the electronics industry that are not available in conventional schools. The involvement of university and industry helps students see the relevance of what they are learning and they clearly are engaged in their learning. The personal projects show the community what can be achieved when support and opportunity are given, and students find that they have a clear career path that they want to follow. The university then benefits from having highly motivated students who already have some basic skills to build their university studies upon.

There is also a clear benefit to the electronics industry. The conjunction of the RPM program for year 10 students, the electronics curriculum as the cornerstone of a year 11 course in physics and the year 12 Extension Studies subject now provides students in South Australia with the possibility of including electronics throughout their senior secondary education. This level of engagement is necessary if we are to continue to produce the quantity and quality of electronic engineering graduates required to sustain and further the growth of the industry.

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