Cross-curricular Electronics in High Schools

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Abstract

This paper describes an electronics programme for high schools that was developed and tested at The University of Western Australia. Project ideas were developed in a central pool and disseminated free of charge to high school teachers. Individual teachers, who may not have the time or knowledge to create advanced projects, could use these resources in their classrooms with the support of a university. Projects developed in one school could also be shared across all schools in the programme. One of the strengths of this programme was its direct connection to teachers, bypassing the traditional hierarchy in high schools and giving individual teachers an opportunity to boost their visibility within their school.

The projects included an electronic puppet, an anemometer for measuring wind, a turtle that draws pictures, a robot that plays board games, an air track for physics experiments and a set of scales for weighing fruit electronically and counting the calories. Construction of any of these projects required co-operation across the curricula between the science, mathematics, and technology (design and materials) departments.

In four years the programme grew to include more than 120 schools in Australia. Thousands of students benefited from year 7 to year 11. The most popular projects were the puppet and turtle, with some schools making these by the hundreds. The benefits of the programme are hard to measure objectively but it certainly increased awareness and encouraged young people to consider engineering. The feedback from schools is that this programme filled a void in electronics and in cross-curricular activities.

Introduction

Practical education in electronics is vital to the development of young people today, yet this subject tends to escape the curriculum net. Electronics falls between the pure sciences on one hand and the technology courses on the other. Electronics projects require both the theory of electric circuits and the practical knowledge of materials and components.

Many schools have excellent science departments and technology departments operating independently. The teaching resources in each area do not span across to the other area. By establishing projects in electronics, this programme created a seamless link between these departments. Each department contributes. This teamwork approach models the real world, where successful engineers work in project teams that cover all aspects of a project, from theory to design and implementation.

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Evolution of the Programme

The programme began in response to a simple request for help from a school teacher. The teacher wanted his Design and Technology class to build an anemometer, an instrument for measuring wind speed and direction. He had the knowledge and facilities to build any design of mechanical anemometer in metal and plastic but he had no way of taking a reading electronically nor interfacing the instrument to a computer. He recognised that he could not undertake the electronic portion and he saw the opportunity to stretch his department's capabilities.

The initial response of UWA was to assist this school with its anemometer project. Time and resources were allocated at no charge. The Electronics Workshop at the Department of Electrical and Electronic Engineering, which normally provides a service to the academic staff, designed and built an electronic anemometer interface for the school. The work was performed by the workshop staff, as none of the academic staff members who were approached were interested in assisting with the project.

The author became aware of this project a few weeks after the Electronics Workshop had built the prototype anemometer circuit. What became apparent was that this project was not an isolated request from one school. The majority of schools could benefit from this work, so the author set about formalising the anemometer project and formulating a more general programme of electronics projects that could be made available to all schools.

The programme was given the name GENESIS and had the initial goals of:

- responding to requests from schools for assistance in electronics technology,
- empowering schools to build technologies that have a use within the school, (thus encouraging personal growth and self-sufficiency of the school) and
- changing the perception that UWA was unapproachable and not interested in schools.

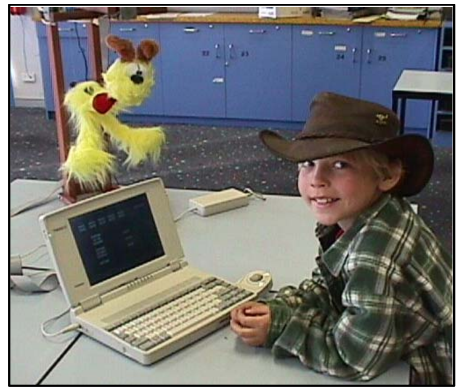
The third point was specific to UWA. The majority of school teachers do not train at UWA but rather one of the other four universities in Western Australia. Without adequate engagement and knowledge of UWA, they tend to promote the other universities. Human nature is to side with the familiar.

A meeting with high school teachers led to a decision to establish two projects initially – the anemometer and an electronic puppet. The motivation for the electronic puppet was to support schools that did not have adequate manufacturing facilities for making the anemometer. The puppet frame can be built from wood with a hand saw, drill and screwdriver.

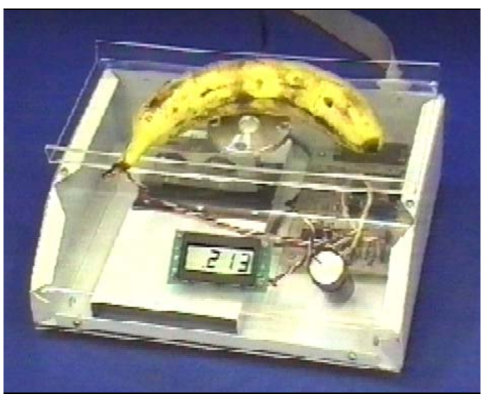
To share the projects amongst schools, teaching resources were prepared for the projects and placed on a web site. Any school teacher could download the class material after the school registered for the programme. The registration process was for administration purposes only - there was no charge for registration, and all the teaching resources were free. The logic in providing these free of charge to all schools was that it costs only a little more than the support given to just one school, yet the benefit is far greater.

Within two years, the range of projects had increased with the addition of an electronic turtle, a robot for playing board games, an electronic scale and a frictionless air track with high precision carriage detection for Physics experiments.

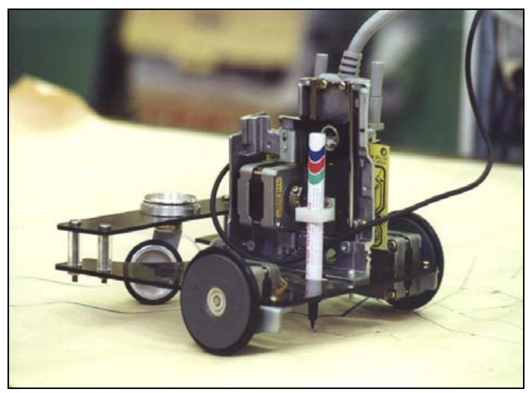
(a) Digital Anemometer – measures wind direction and wind speed



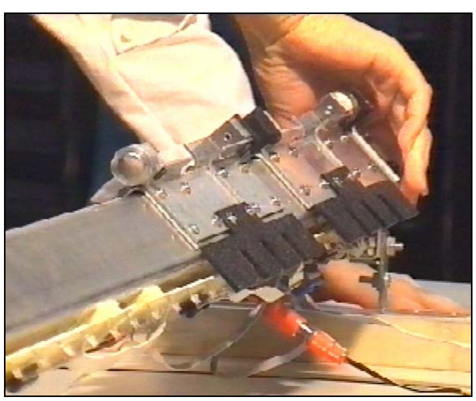
(b) Electronic Puppet



(c) Electronic Scale – weights and converts to calories with computer interface



(d) Electronic Turtle - draws pictures and fractal curves



(e) Air Track - for Physics experiments

(f) Geranos Robot – plays board games

Figure 1. The first six projects in the electronics programme.

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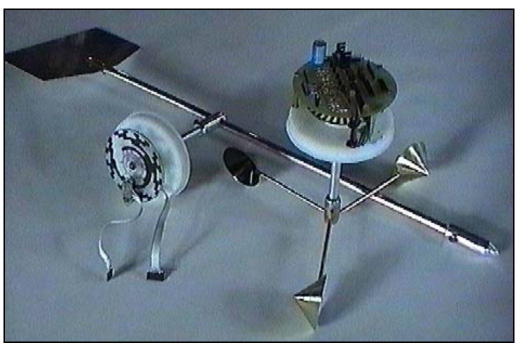
Technical Content

For a project to be supported in this programme, it had to have novelty value or not be commonly available to schools. There is no point in developing resources that compete with products or kits that are available commercially. In addition, each project had to be:

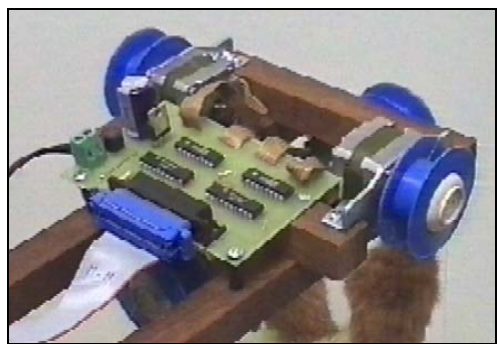
- scientifically and technically sound,
- capable of being built by schools,
- educationally relevant across several curriculum areas, and
- expandable to include further design and creative ideas.

If a project failed to meet any one of these criteria, it would not be considered for the programme.

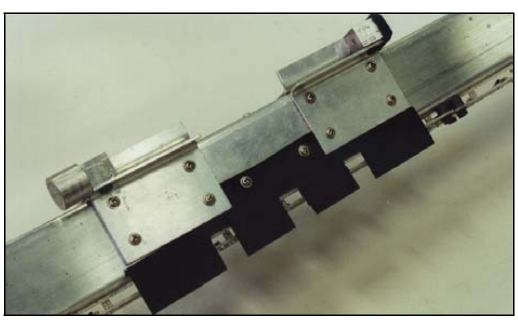
Each project introduces specific technical theory and design innovation. The anemometer wind direction sensor was based on a 6-bit Gray code, dividing the circle into 64 segments of 5.6º with adjacent segments differing by only one binary digit. The electronic puppet used stepper motors recycled from old 5.25-inch disc drives and a circuit that converts 8 lines from a PC parallel port into 16 lines for driving four steppers. The air track used a patterned comb to expose the light sensors, achieving a resolution of 5 mm despite the sensors being 40 mm apart. The electronic scale used a bridge of four strain gauges to measure vertical displacement of the tray.



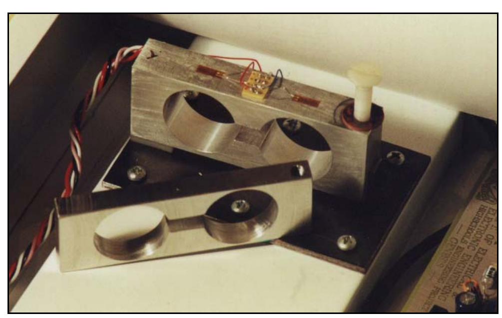
(a) Wind direction sensor uses 6-bit Gray code wheel pattern, giving 64 segments for wind.



(b) Puppet circuit runs four stepper motors by expanding 8 PC parallel signals into 16.



(c) Air track comb enables 5 mm resolution despite the sensors being 40 mm apart.



(d) Strain gauge bridge measures vertical displacement of the scale pan.

Figure 2. Project aspects that combine scientific theory with innovative design.

Programme Structure

Correspondence with each school was maintained via a single coordinator at the school, who was responsible for liaising between the various departments within the school. Similarly a single academic at UWA, the author, provided the coordination on the university side. The benefit of this simple structure was that it bypassed the traditional hierarchy within a school, avoiding delays in administration.

A team of five undergraduate university students volunteered to help run the programme. This team set up displays at science shows and visited schools throughout Australia. Whilst students were not paid for their time, the travel costs were reimbursed from a government grant.

The programme was aimed at teachers rather than students. Most high school teachers do not have the time to create such advanced technological projects, and may also lack the specialised knowledge for aspects of each project. Teaching the teachers was therefore a priority. Teacher training sessions were run for each of the projects, scheduled tightly for one hour at a time, with an optional second hour for those teachers who had time. The teacher training sessions were held on the university campus and, as with all parts of the programme, were offered free of charge.

Resources were provided to schools free of charge. Schools sourced their construction materials from their regular suppliers of metals, plastics and electronic components. The only parts supplied through the university were printed circuit boards, if schools could not manufacture their own. The circuits were provided free of charge for small numbers, thanks to a government grant, or at cost for larger numbers. A large number was considered more than 100 per year.

The resources were distributed primarily through a dedicated web site. Schools were issued with a master password when they registered, and this enabled their coordinator to set up individual teacher passwords, which in turn could set up individual student passwords if required. Teachers had access to all the resources, whilst students had access only to selected resources.

Teaching resources included mechanical drawings, theory of operation, mathematical theory, construction tips, printed circuit board designs and computer software. The students built each project from start to finish, and learned additional theory along the way, according to the resources selected by the class teacher.

One of the benefits of the students building the projects is that they feel ownership of the equipment they are building. Consider, for example, the air track. The air track is a linear frictionless track for Physics experiments in momentum, gravity and acceleration. Carriages float along the track on a cushion of air blown from a vacuum cleaner hose. Although many schools have an air track, they typically do not measure (or cannot measure accurately) the locations of the carriages. The track offered in this programme enables rapid and precise monitoring of multiple carriages, giving opportunities for complex Physics experiments. As a result of students building the track, they take a more active interest in the subsequent Physics experiments. These tracks have been used for measuring gravity to two significant figures, for experiments in momentum and kinetic energy, and for demonstration of acceleration from propellers and sails.

Operating on a shoestring budget, the programme was run predominantly by the goodwill of a small team of university staff and student volunteers. The programme offered university kudos, teaching material, and ongoing practical support. With this structure in place, teachers were able to take up the projects with confidence.

Results

This programme resulted in a very large number of projects being built by students in the 126 schools that registered. Class groups have ranged from age 12 (in primary school) through to 17 (upper high school).

(a) PEAC (Primary extension and challenge) students building puppet frames.

(b) Primary school student cutting a base for an electronic turtle.

(c) High school students building an electromagnetic robot for playing board games.

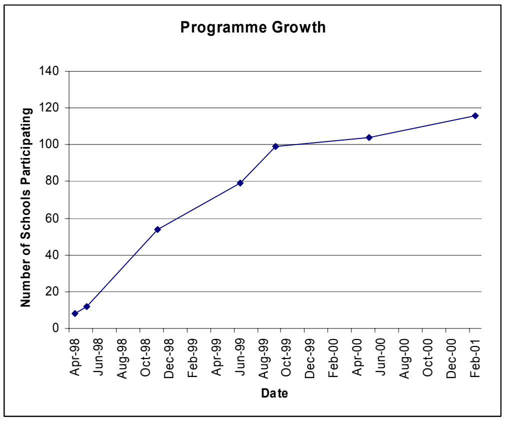
(d) High school student mounting detector circuits along a frictionless air track.

Figure 3. Students making electronics projects supported in this programme.

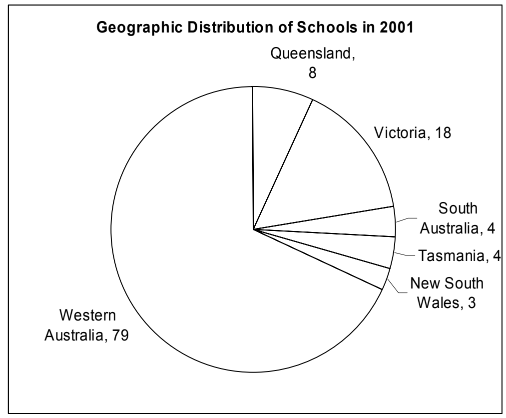
An interesting but subtle outcome is the increase in cross-curricular cooperation between departments within schools. In many schools this was the first time that the science department and technology department had worked together closely. Many teachers are so busy with their own work that they do not see what else is available in their school, yet sharing this knowledge between teachers is important so that they are aware of what the students see.

Programme Growth

The programme grew to 60 schools within the first 6 months then maintained a growth rate of around 30 schools per year. Around two thirds of the schools were located in Western Australia, the home state of the programme, whilst the remainder of the schools came from across Australia. When the programme closed after three years, there were 126 schools registered.



(a) Growth in registered schools



(b) Geographical distribution of schools

Figure 4. Growth and distribution of registered schools.

Despite the rapid growth, the integrity of the programme was maintained by strict adherence to the rules for project inclusion, and concentration on quality rather than quantity of projects.

There is no record of the number of students who have been touched by the programme. The programme was aimed at teachers, so the number of schools is documented but not the number of classes and students at each school.

Closure

This initial programme was set up at The University of Western Australia in response to a request from a school. It grew so fast so unexpectedly that it became a challenge to the university when the author resigned to take up a position overseas in industry. The greatest weakness of this programme was its reliance on individual staff.

In an academic environment where voluntary outreach is not linked to promotion or reward, there were no staff members willing to maintain the programme, let alone drive it forwards. Within a year the web site had been closed by the staff member who had been assigned (somewhat reluctantly) to look after it. The teaching resources still exist but the access to them has been revoked.

Future Direction

The challenge now will be to build an even better programme, with a strong and sustainable structure, at Murdoch University. Ultimately the programme must be bigger than the individual staff members involved. Murdoch already has several successful high school programmes such as the STAR peer tutoring programme and the annual Science Summer Schools, and it may be possible to build on to one of these.

For a benevolent programme to survive and prosper, it must provide recognition and rewards to academic staff beyond the mere enjoyment and satisfaction of a job well done. This requires a change in thinking from the typical academic reward structure of promotion from research and publication. Without clear recognition and rewards, the disincentives of running such a programme are visible in that it takes time away from the activities that do provide rewards. The establishment of any new programme structure must therefore be made in parallel with the recalculation of load and rewards.

Conclusions

An electronics programme was established at The University of Western Australia to provide technological project support to high school teachers. With more than 120 schools registering, the programme has benefited many thousands of students across Australia. The teacher-oriented structure of the programme, plus the availability of free teaching resources and university support, ensured the success of the individual electronics projects.

Figure 5. A regular classroom teacher uses material from this programme in his class.

Through this programme, students have demonstrated learning outcomes seamlessly across several curriculum areas including Science, Computing, Technology and Electronics. School departments have worked together in new ways and many thousands of students have been introduced to electronics.

Acknowledgement

The author is grateful to Mike Trlin, Head of Design and Technology at Swan View Senior High School, whose vision and innovation have helped shape this programme.

Biography

Keith Godfrey gained his Bachelor of Engineering from The University of Western Australia in 1988 and then lectured the first-year programme there for 12 years, whilst also establishing annual engineering summer camps for high school students and an electronics programme for 120 high schools across Australia. After leaving UWA in 2000 for a job in industry, he worked around the world on meteorological telemetry projects, becoming the technical lead and project manager for wind shear alerting systems, airport weather observation systems and national networks of weather stations. After starting a family in 2004 he chose to return to academia, joining Murdoch University in 2005.