Effectiveness of Robotics Peer Mentoring Program for Raising Interest in Engineering, Science and Technology

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ABSTRACT: *This paper showcases the Robotics Peer Mentoring Program at the University of South Australia (UniSA) and its effectiveness in increasing the participation of secondary school students in engineering, science and technology. Despite the newest technological developments the number of secondary students electing to study science and mathematics is declining in Australia and some other developed countries. The lack of interest can certainly be attributed to the perception of these subjects as "boring" due to their abstract nature emphasised by the common teaching practices which make these subjects detached from their real world applications. To address this problem the Robotics Peer Mentoring Program has been introduced as a joint project between the UniSA and an award winning South Australian company eLabtronics. The program recruits the University students who are firstly trained for their mentoring role and then assigned to secondary schools to guide their younger peers through the adventures of building and programming intelligent robots. During the program young students learn soldering, fundamentals of electronics and microcontroller assembly programming. The innovative icon based assembler CoreChart, a product of eLabtronics, makes advanced programming more attractive to young students and allows them to gain knowledge normally taught at tertiary levels. The program is already showing very positive results, being very popular among students and in one secondary school the number of students choosing to do electronics has almost tripled. The program is attracting recognition, endorsement and sponsorship from a number of industry, government and community groups. In 2003 the program received the Engineers Australia National Engineering Excellence Award - AusIndustry Award for Innovation, and the team is now working on developing strategies to embed the program into pre-tertiary curriculum and make it sustainable for the benefit of all participants and the wider community.*

1 INTRODUCTION

It has been recognised that the socio-economic prosperity of a nation is strongly linked to the knowledge and skill base of its society. More broadly, the economic growth of a nation is linked to the introduction and strengthening of the knowledge-based economy [1]. There is no unique definition of what constitutes a knowledge-based economy and different authors use this term to describe different concepts. Some authors simply define it as an economy that strongly relies on the use of information and communication technology (ICT). However, we adopt the knowledge-based economy concept in its broader context as "an economy that creates, disseminates and uses knowledge to enhance its growth and competitiveness" [2].

There are a number of modern economic theories that propose a framework for developing and quantifying the knowledge-based economy [3-4]. They also formulate measurable performance indices that can be correlated with the economic growth of a nation. The World Bank Group proposes a framework with four pillars [3]:

- **Economic Incentive and Institutional Regime**
- **Education and Human Resources**
- **Information Infrastructure**

- **Innovation System**

The above model proposes 12 performance indicators, three for each pillar and an additional two indices (annual Gross Domestic Product (GDP) and Human Development Index (HDI). Through its interactive web page http://info.worldbank.org/etools/kam2004/home.asp [4] the model can be used to benchmark and compare the performance of a national economy within the region or on with the global world trend. We used the toolkit to compare the most recent Australian economy performance with its 1995 performance as shown in Figure 1.

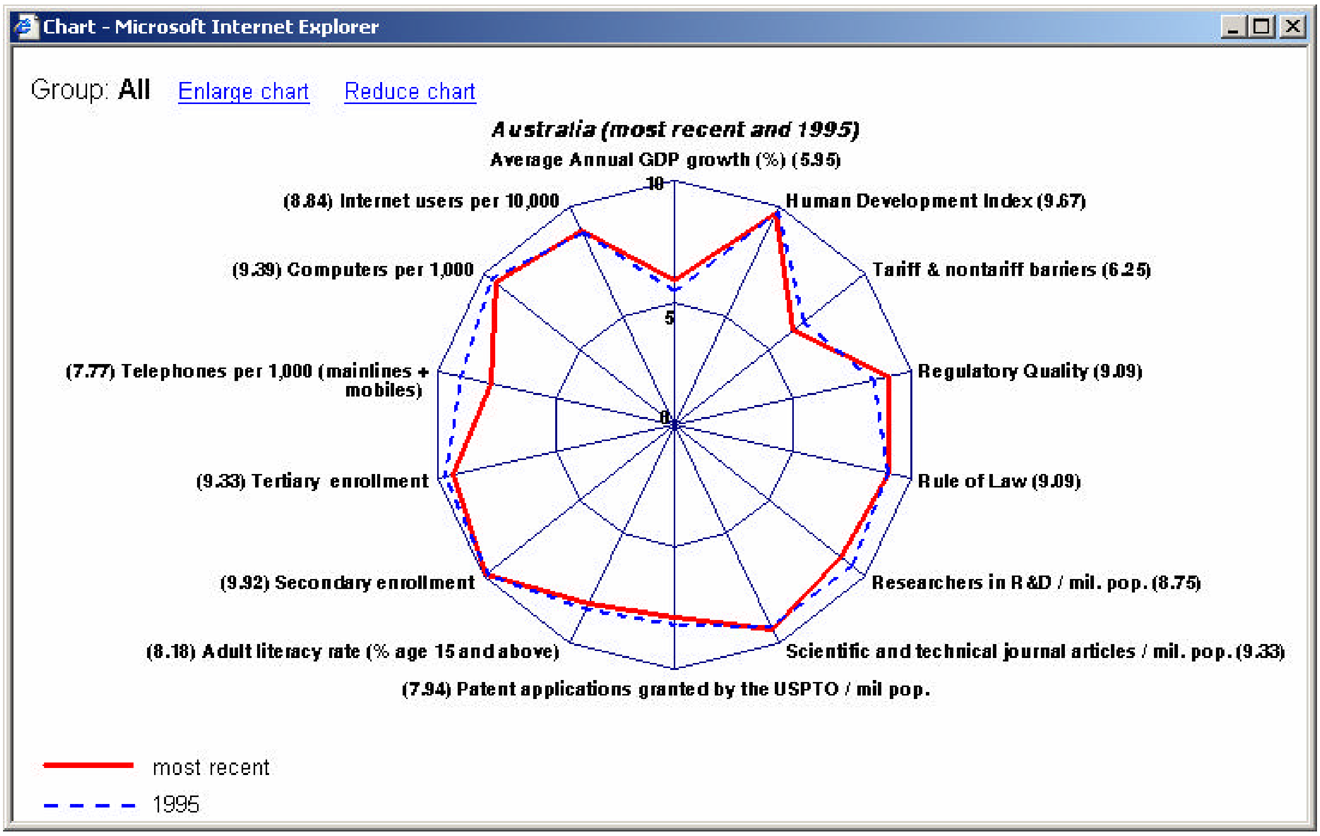


Figure 1. The Knowledge-Based Economy Performance obtained using Knowledge Assessment Methodology (KAM) toolkit provided by The World Bank Group [5]. “All countries” setting was used as a normalisation group.

The Australian national framework model for the knowledge-based economy [4] formulates five dimensions: three core dimensions and two supporting dimensions. The core dimensions are:

- Innovation and entrepreneurship
- Human capital
- Information and communications technology.

The supporting dimensions are:

- Context
- Economic and social impacts

The model further defines characteristics which describe each dimension. It also proposes more than 100 indicators that provide a quantitative measure for each characteristic. The human capital dimension is mainly characterised by the education and skills of the population and in that aspect is similar to The World Bank Group model. The proposed characteristics of human capital model are:

- Stock of skilled people
- Flow of skilled people
- Investment in human capital
- Life long learning and access to education and training.

Although the human capital dimension is listed as a separate core dimension in the model, the other dimensions are not exclusive of the need for creation and application of human knowledge and skills; the paper [4] notes the overlap of the dimensions. The importance of the human resources development is highlighted in other knowledge-based economy (KBE) frameworks and models like APEC KBE and OECD KBE [6, 7]. Therefore, if a nation is committed to the economic growth it has no choice but to strongly invest in education of its population.

2 AUSTRALIA'S POSITION AS A KNOWLEDGE ECONOMY

Australia is certainly concerned about its future and its economic growth. Consequently, it follows the world trend to develop strategies for strengthening its knowledge-based economy. As discussed above education plays a crucial role in this process. It is broadly recognised that Australia faces a significant problem in attracting sufficient students into the tertiary study of Science and Engineering.

In respect of the general % of the population with tertiary level education, recent statistical data illustrate Australia is well placed among other OECD countries as shown in Figure 2 [8]. However, the graph on Figure 1 shows that globally Australia is now worse placed than in 1995 with respect to tertiary enrolments. In addition, Science and Engineering (S&E) degrees account for less than 20% of the total degrees awarded in 2001 as shown in Figure 3 [8]. The alarming fact is that in the near future Australia will further fall back in the percentage of S&E graduates as the percentage of year 12 students electing to study science and technology subjects has been declining over the past decade as shown in Table 1, [9]. Consequently the number of students enrolling in engineering and science degrees is also declining as shown in Table 2 [10]. This has raised serious concerns amongst the academic and wider community in Australia and world-wide as this trend is not only specific for Australia.

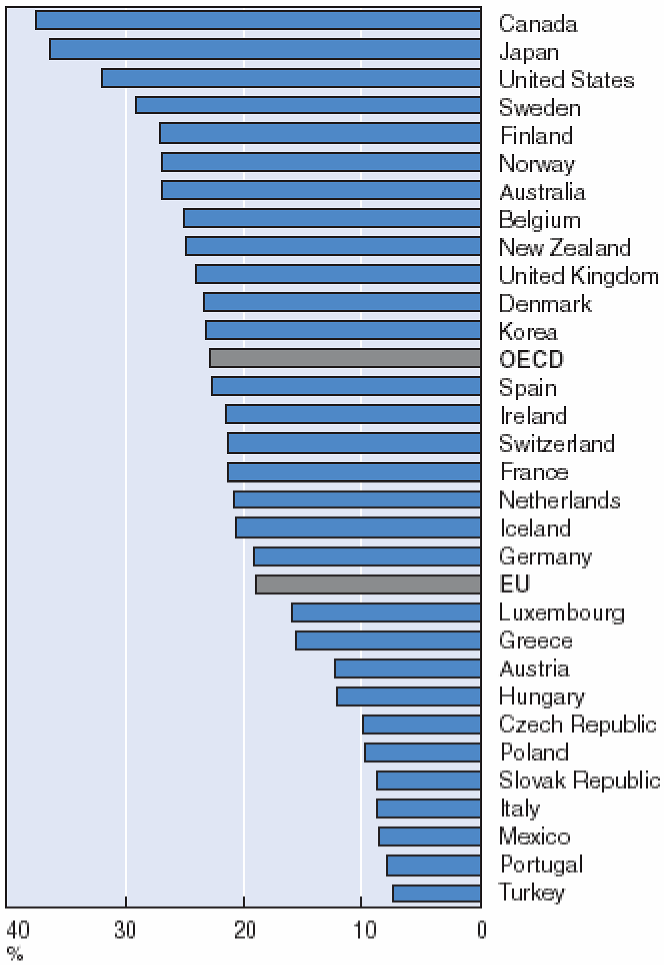


Figure 2 Persons aged 15-64 with tertiary-level education, As a percentage of the population, 2002 (adapted from [8]).

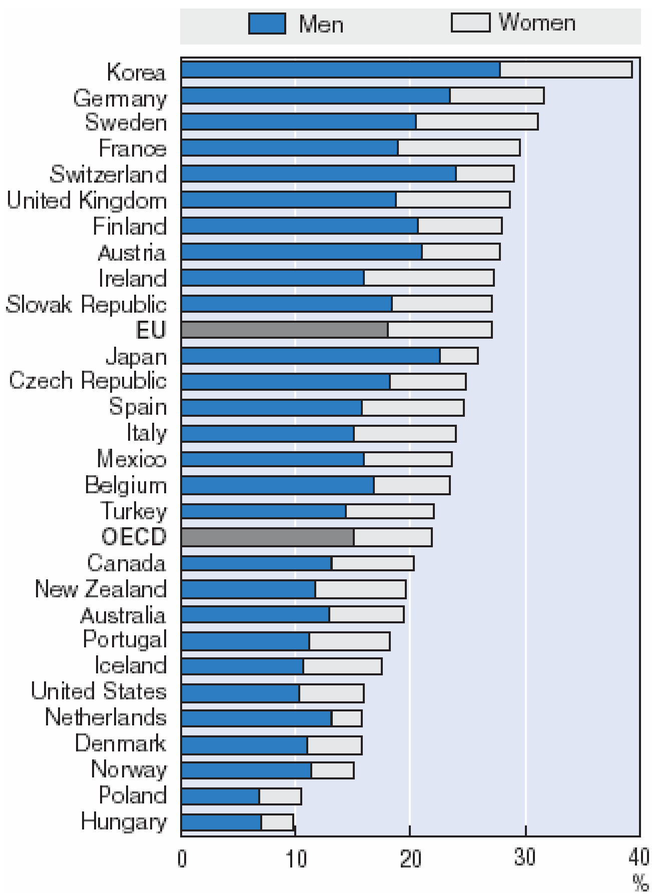


Figure 3 Science and engineering degrees, As a percentage of total new degrees, 2001(adapted from [8]).

Table 1. Year 12 students, rates of participation in science and technology subjects (Source: Fullarton, S., Walker, M. & Ainley, J *Longitudinal surveys of Australian youth—research report 33*, July 2003. Table 9. Australian Council for Educational Research, cited in [9])

	Percentage of year 12 students		
	1993	**1998**	**2001**
Mathematics	86.3	87.5	84.3
Chemistry	22.6	20.3	17.8
Physics	20.4	20.0	16.6
Biology	31.7	25.2	25.4
Computer studies	20.7	27.7	27.0
Technical studies	16.9	23.2	16.4

Table 2. Commencing Australian domestic students by broad field of education (extracted from [10])

	Commencing Domestic Students		
	2001	**2002**	**2003**
Natural and Physical Sciences	18,951	19,056	19,063
Information Technology	15,124	13,672	11,561
Engineering and Related Technologies	12,603	12,554	12,362

There is strong evidence which directly links activity in Science, and Research and Development (R&D) to levels of national productivity [11]. The high costs of R&D activities and the protection of innovations from being copied, raises the question as to: "whether a small country like Australia can adopt the global free-rider position – sit back and let other countries invest in R&D, then just copy their innovations". The research [11] shows that people who perform their own research can better assimilate and interpret the research findings by others. Therefore, a country needs to invest in its own R&D if it is to take the full advantage of the international innovations as the knowledge absorption capacity increases with the intensity of the country's own R&D activities.

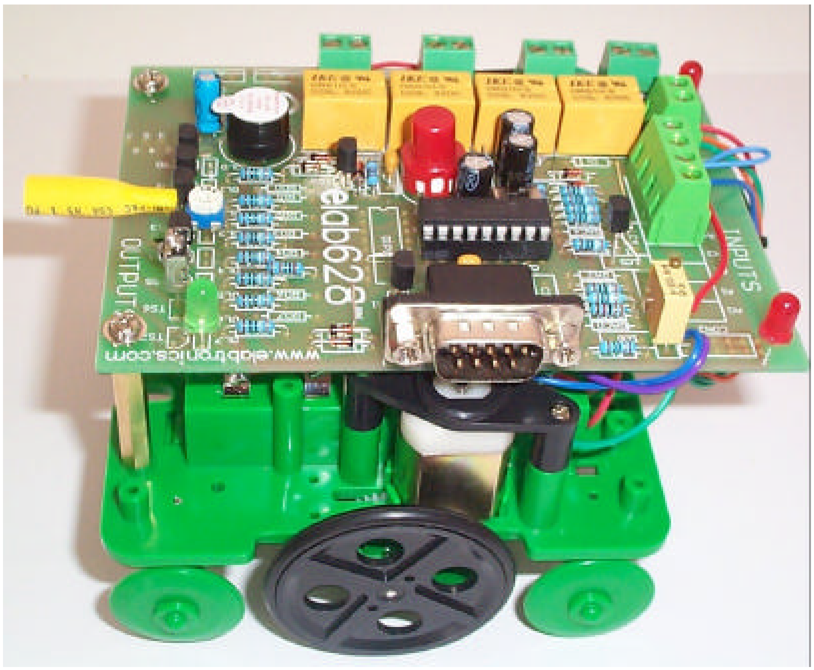
From this section it is clear that Australia will not be able to sustain its economic growth if it allows the number of young students participating in Science and Engineering to continue to decline..

3 ROBOTICS PEER MENTORING PROGRAM

To address the problem of the declining number of students enrolling in S&E degrees and participation of young students in S&E in general, the University of South Australia formed a close partnership with a local company eLabtronics to introduce the Robotics Peer Mentoring Program in two schools for the first time in 2002. The Program vigorously expanded in 2003 due to the funding of A$50,000 received from the Department of Business, Manufacturing and Trade - Centre for Innovation, Business and Manufacturing (DBM-CIBM) and a number of industry sponsors (A$12,000). The University recruited 22 mentors. The mentors received technical training from eLabtronics and educational training at the University. Some of the mentors elected to enrol in the University Broadening Undergraduate Education (BUGE) course Peer Tutoring where they improved their teaching skills. (For all UniSA programs it is compulsory to include two BUGE courses outside the specific field of study).

Structure of the program

The curriculum of the program was highly structured around 10 weeks with 2-hour sessions per week delivery. In the first 3 weeks students completed the hardware platform of the robot – Buggy6281 shown in Figure 4. Through this part of the program, students learned basic soldering technique while soldering peripheral components of the microcontroller electronic board and assembling the mechanical part of the robot.



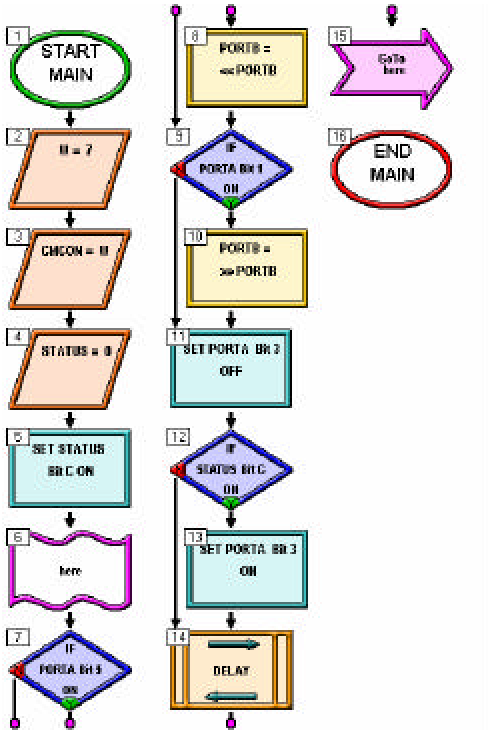


Figure 4. Hardware platform: Buggy6281 (product of eLabtronics)

Figure 5. Software platform: CoreChart (product of eLabtronics)

The next 4 - 5 weeks were allocated for students to learn basic microcontroller programming using the innovative icon based assembler CoreChart, developed by eLabtronics. CoreChart is a suitable software platform for the mentoring program because of its graphical nature that allows very young secondary school students or even primary school students to master programming of embedded systems normally taught at the university level. A sample program, which tests for the correct operation of the microcontroller board "written" in CoreChart is shown in Figure 5.

The last 2 - 3 weeks were devoted to the science extension of the program with the aim to stimulate students' interest in science and therefore, increase the science enrolments in the following years of secondary education. In this module students learned the physics or the sensors and actuators (light sensor and motor) and how to apply the learned knowledge to control motor speed and to tune the light sensor for its optimal performance.

The program annual activities culminated in a showcase of students' work. In this event all participating students had a chance to test their robots and to enter a competition for the best performing robot. The competition imposed a goal towards which students focused their activities and encouraged them to develop analytical skills, understand planning of the design process, practice precision in their work and to learn that pursuing excellence leads to rewarding achievements.

Student Evaluation of the Program

A questionnaire was designed to capture information from the students who participated in the program. Questions related to their interest in the program, the organisation of the program, the extent to which the program demonstrates the relevance of Science and Electronics and the impact of the program on their interest in electronics / engineering as a possible career and their overall satisfaction with the program. A number of open ended questions sought their opinions on the main things they had learned and what improvements might be usefully made to the program.

Evaluations were sent to all Schools with the tutors during the last couple of sessions of the program. Responses were received from 80 students from 7 schools. The following is a summary of the responses to the 8 closed questions that were asked. All figures are shown as percentages.

This data represents a very positive response to the students who experienced the program. The rate of agreement of 86% with the overall satisfaction with the program is very pleasing. Other very high percentages are noted for the extent to which the students enjoyed this form of learning, found the program interesting and believed that the University students presented the program effectively. The agreement rate with the question about the organisation of the program is a little lower although still reasonable at 71%. Some comments from the students point to a number of issues here including the difficulty for some in getting the robots to work. This will be addressed next year by including some specific trouble-shooting sessions in the curriculum.

The 49% agreement rate with the question about whether the program has stimulated their interest in a career in electronics / engineering is very encouraging. Similarly the 65% agreement with the question about whether the program has helped them to see the relevance of Science and Technology is also very encouraging.

Table 3. Robotic Peer Mentoring Program evaluation by secondary students

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Average Score	%Agree or Strongly agree
The program was well organised	1.25	5.00	22.50	47.50	23.75	3.88	71
I found the program interesting	0.00	1.25	12.50	38.75	47.50	4.33	86
The program has stimulated my interest in a career in electronics / engineering	8.75	12.50	30.00	32.50	16.25	3.35	49
I have benefited from my involvement in the program	0.00	7.50	23.75	43.75	25.00	3.86	69
The program has helped me to see the relevance of Science and Technology	2.50	8.75	23.75	36.25	28.75	3.80	65
I enjoyed learning like this	0.00	0.00	11.25	38.75	50.00	4.39	89
The university students presented the program effectively.	0.00	3.75	8.75	41.25	46.25	4.30	88
Overall I am satisfied with the program	0.00	2.50	11.25	50.00	36.25	4.20	86

Teacher evaluation of the program

A questionnaire was sent out to all teachers involved in the program. A range of open ended questions covered the impact of the program on staff, students and the School, the most successful aspects of the program, areas of improvement and plans that the teachers had for the future of the program in their school.

Responses were received from 6 teachers who gave very enthusiastic support for the program. The following is a comment from one of the teachers which summarises the overall tone of the responses:

“A very positive and outstanding program which has been well organised and supported by the University and Industry.”

Teachers report significant engagement by students in the program. The hands on approach to learning a leading edge technology is very popular. Students are developing skills in an area where significant career opportunities exist. The use of undergraduate students as tutors / mentors is proving to be very successful. The opportunity to interact with undergraduate University students provides secondary students with information about what courses are available in the area and what it is like to be a University student. For students from economically disadvantaged areas, where there are not many role models of people who have attended a tertiary institution, this is a particularly important aspect of the program. Links with employers and a range of tertiary providers (Universities and TAFEs) are being provided to illustrate the connection between the program and a range of future technical, science and engineering career opportunities.

Teachers highlight a number of positive aspects of the program. In particular they identify the undergraduate peer tutors as being a crucial part of the success of the program. A range of comments indicate that the tutors have made a significant contribution to the development of staff skills and interest in the area of robotics / electronics and that the program would not have been able to have been offered without the skills of the undergraduates. For a number of teachers the program has opened up a new area of Science for them and gave their students the opportunity to experience a leading edge technology. A couple of teachers also commented on the value for the secondary school students of being able to spend some time with University students from a mentoring perspective. The competition at the end of the program was also mentioned as being an important part of the program.

The teachers comment almost universally on the positive impact of the program on the High School students, particularly in terms of their interest and skill development. They indicate that there has been a significant increase in the interest of students in undertaking further study in electronics. At Salisbury High, for example, enrolments into the Year 10 Electronics class have nearly trebled to approximately 80 students in 2004. At Nuriootpa High most of the Year 10 students who did the program have decided to continue with electronics in year 11 and 12. A number of the teachers indicated that the program has lead to interest in creating Vocational Education and Training (VET) and University Pathways for students in electronics / engineering. In particular the teachers are keen to incorporate the program into mainstream curriculum in Science, Technology and Information Technology.

The University of South Australia is very proud of the Program achievements and currently showcases the Program on its main web page, shown in Figure 6, with a secondary students posing with his robot.

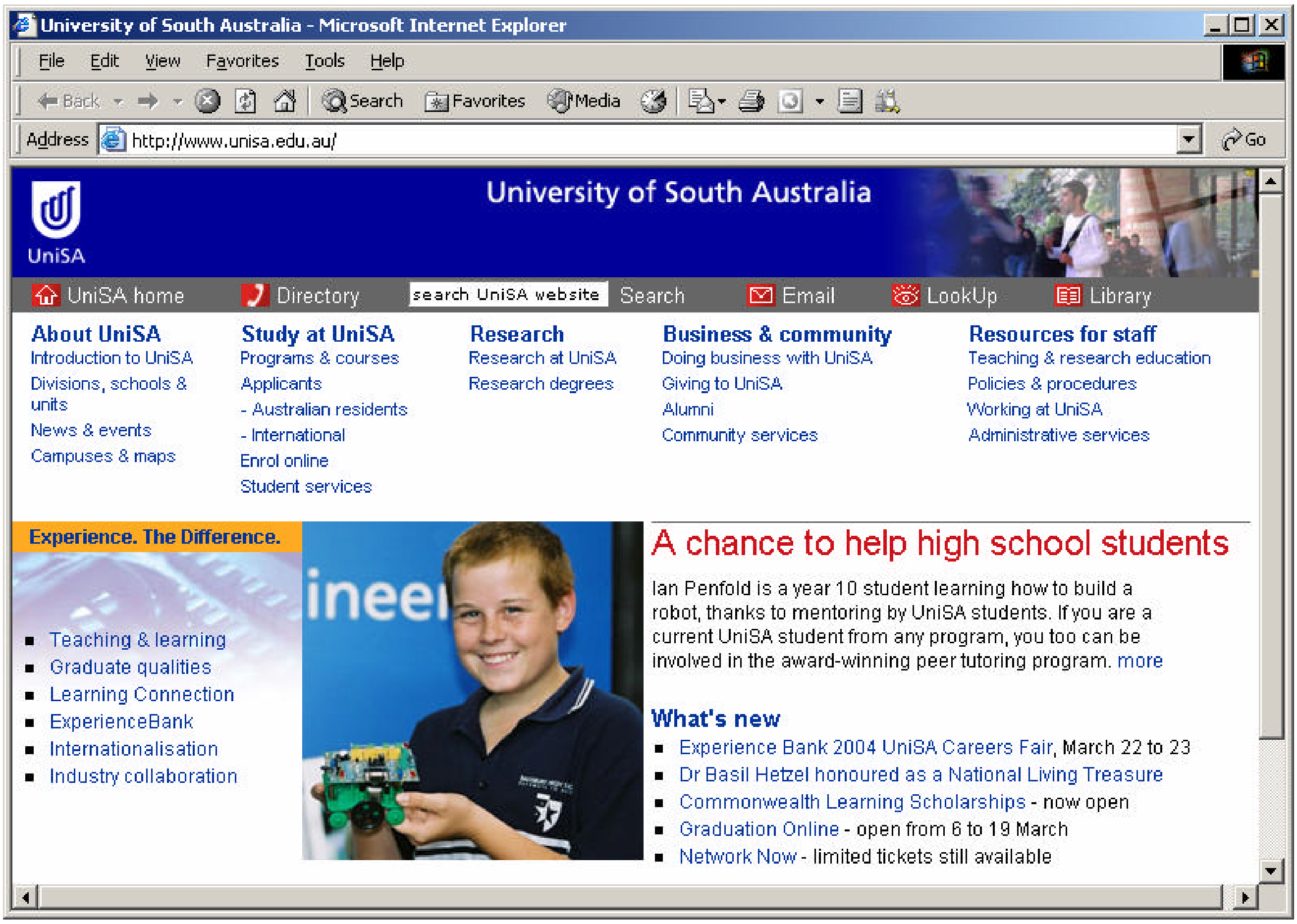


Figure 6 – The UniSA main web page with a secondary school student showing his robot

4 CONCLUSION

In this paper we presented the Robotic Mentoring Program introduced by the University of South Australia with the aim of raising the interest in engineering, science and technology among secondary school students and increasing their participation in the modern technology fields.

The program has been evaluated and from the student data and the enthusiastic response from teachers and peer mentors it is quite clear that this program has been an outstanding success. There is firm evidence that students have found that the program has stimulated their interest in careers in electronics / engineering and has been an enjoyable way to learn about technology and science. The teachers have indicated that the use of peer mentors in their class room has allowed them a unique form of staff development and has allowed for a program to be run that would normally be very difficult. The peer mentors report significant personal benefits from their involvement in the program and satisfaction in being able to present an interesting area of knowledge to secondary students.

The program was formally endorsed by the Electronics Industry Association of South Australia and received numerous letters of support from other organisations during the year. The program also received the Engineers Australia, 2003 National Engineering Excellence Award - AusIndustry Award for Innovation and the University of South Australia 2002 Chancellor's Award for Community Service.

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