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Engineering Awareness Raising through High School Mentoring*

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Recent decades have witnessed a steady decline in the number of enrolments in science and mathematics courses in high schools, along with a dramatic reduction in the number of students entering into professional engineering education programmes at universities. This has been variously attributed to a number of factors ranging from antagonism towards technology to a lack of awareness of what engineering is about. In this article, the authors present a high school mentoring programme that has been established by the University of South Australia (UniSA), Adelaide, Australia, in collaboration with an Adelaide-based company, eLabtronics, which is aimed at increasing engineering awareness among high school pupils and the Australian community in general. The authors describe the programme and its main features. They present experiences gained in training engineering students to act as mentors in high schools, exposing their younger peers to the excitement of engineering activity by helping them to achieve a measurable outcome in leading-edge technology by building and programming intelligent mobile robots, while also training their technology teachers through active engagement.

INTRODUCTION

The University of South Australia (UniSA), Adelaide, Australia, in collaboration with eLabtronics, an Adelaide-based company, has initiated a programme of engineering awareness-raising, which targets secondary school pupils in the first instance.

This programme is the centrepiece of an initiative that has been designed to raise awareness of engineering among secondary school pupils in South Australia and, indeed, in Australia, with a view to encouraging secondary students to consider tertiary study in engineering because of the critical importance of this field to Australia's future as a *smart nation*.

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FROM GENESIS TO THE PRESENT DAY

This initiative goes back to mid-1990s when a concerted campaign was mounted by the then engineering schools at the UniSA to raise awareness of engineering among school-goers so as to attract them into engineering education [1]. This initiative was supported by a generous grant from the University. Engineering students participated in the scheme enthusiastically and unselfishly on a totally voluntary basis!

One of the main tenets of the initiative was that enthusiastic engineering students were indispensable if the scheme was to succeed in promulgating the message among school communities.

Two important conclusions were reached, namely:

- A visible personal commitment, motivation and excitement on the part of engineering students, as presenters are of crucial importance;
- Secondary pupils are much more likely to take note of the views and advice presented by

enthusiastic students of engineering than that of engineering academics [1].

Efforts continued. In 2002, eLabtronics emerged as an enthusiastic supporter of the scheme. Engineering students were recruited into the programme on a voluntary basis. The programme evolved in the direction of providing motivation and training for both science and technology teachers and their pupils.

2002 was also the year when, in the authors' own State, the South Australian Science and Technology Awareness Raising (SASTAR) Task Force was formed with representation of major stakeholders, including universities, technical institutes, high schools, professional organisations, industry and government departments. The SASTAR sees its role as that of formulating and recommending initiatives so as to counteract the prevailing apathy and lack of awareness in the community towards the engineering profession.

In 2003, the programme was expanded with a funding support of A$50,000 from the South Australian Centre for Innovation Business and Manufacturing (CIBM), with a further A$10,000 in total from organisations including Codan Ltd, Holden Ltd, Playford Partnership, Tenix Defence, Entech Group of Companies, Autotherm Pty Ltd and Microchip Technology Inc (USA). Some 220 pupils from 20 schools were involved with more than 20 UniSA engineering students acting as mentors. The schools were mainly situated in the socio-economically disadvantaged northern region of Adelaide, an object of attention of the Commonwealth Government's Sustainable Regions initiative [2].

In 2004, the State Government of South Australia awarded a grant from the Premier's Science and Research Fund for a *Robotic Peer Mentoring Programme,* collaboratively conducted by the University of South Australia, eLabtronics, Flinders University and the Australian Science and Mathematics School. The award represents a funding support of some A$350,000, to enable the scheme to be further expanded. The target is to include some 1,000 high school pupils in the scheme within the foreseeable future.

THE GLOBAL CONTEXT

The steady decline in engineering and science enrolments has caused widespread concern. For instance, the meeting of the OECD Committee for Scientific and Technological Policy at the Ministerial level, held from 29-30 January 2004, stated in its final communiqué:

> *Against the background of growing demand for human resources in science and technology, Ministers expressed concern that the recent decline in the number of science and engineering graduates could hamper the long-term growth prospects of OECD countries. The challenge of meeting demand for S&T talent is made all the more difficult by waning interest in science among youth …* [3].

A number of studies have aimed at identifying the factors at the root of the *waning* interest in the study of engineering [4]. Universities worldwide have responded by introducing a variety of schemes. Many of these target either the teachers or the pupils (or both) and are conducted with the support of industry and community partners.

For instance, at the University of Nevada, a course in Science and Technology for High School Teachers is being run to encourage teachers to include engineering content and problem solving skills in the curricula. In the case of the University of Alabama in Huntsville, a similar programme targets pupils with an aptitude for science and mathematics, but not necessarily considering engineering as a career choice. Pennsylvania State University exploited a computer-aided bridge design competition to outreach high school students. Several other initiatives have also been reported, aiming to achieve enhanced awareness for engineering [5-10].

The project at UniSA measures up most favourably against other schemes that have similar objectives in Australia and abroad. It is innovative and unique and incorporates features well beyond those considered to constitute world's best practice. This is due to a variety of factors, which include the use of enthusiastic student mentors, as compared with engineering academics in similar schemes. It is project-based and poses an intrinsic challenge for pupils. It effectively addresses the currently prevailing attitudes of apathy towards, and lack of interest in, engineering and technology.

Unlike some similar schemes elsewhere, this project is focused on producing a tangible product as the outcome of the mentoring sessions, utilising engineering methodology. There is a major emphasis on analytical thinking and creative problem solving. State-of-the-art components and an intuitive programming approach are the vehicles in keeping participants engaged, spurring their interest and capturing their imagination.

The project has led to the creation of educational resources in the form of courseware, software and hardware. These have proven to be highly effective with participants.

NATIONAL IMPERATIVES

In respect of the general percentage of the population with tertiary level education, Australia is well placed among other OECD countries [3]. However, Australia is now worse placed than in 1995 with respect to tertiary enrolments. In addition, science and engineering degrees accounted for less than 20% of the total degrees awarded in 2001[3]. The alarming fact is that, in the near future, Australia will further fall back in the percentage of science and engineering graduates as the percentage of year 12 students electing to study science and technology subjects has been declining over the past decade [11]. Consequently, the number of students enrolling in engineering and science degrees is also declining. This has raised serious concerns among the academic and wider community in Australia. Not surprisingly, the trend is observed worldwide and is by no means specific to Australia [12].

There is strong evidence that directly links activity in science, and research and development (R&D) to levels of national productivity [13]. 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*. It is argued that people who perform their own research can better assimilate and interpret the research findings by others [13]. 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 a country's own R&D activities. Consequently, it may well be 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.

Strong national economies are the building stones for global welfare. From an Australian perspective, the UniSA project promotes the creation of a skills base within the context of a Federal Government initiative, namely: *Backing Australia's Ability* to consolidate Australia's potential [14]. Naturally, this enhances employment opportunities for the youth. This approach also addresses the perceived shortage of skilled workers in Australia. The project must be seen within the context of complementary initiatives taken at different levels in Australia, ranging from the Federal Government to the profession [15][16].

This project strongly encourages young people to become entrepreneurial and creative problem solvers. The skills learned through the project are at the leading edge, being sought globally. The emphasis is on creative problem solving. Coupled with the state-of-the-art skills, which they are helped to acquire, this creates the basis of genesis of initiative for innovative new industries.

THE PROJECT

At present, the project is driven by the School of Electrical and Information Engineering (EIE) at the UniSA. Students from the EIE act as mentors. They are selected on a competitive basis and are trained by the industry partner with input from the EIE. The scheme serves several purposes in addition to raising engineering awareness among pupils. For instance, UniSA engineering students can satisfy the requirement for having completed a prescribed number of weeks in industrial placement – a compulsory part of the degree programme.

In addition, they can meet the requirement to have undertaken a broadening undergraduate elective (BUGE) by doing the *Peer Tutoring* course. This is a fully accredited academic study unit that comprises formal lectures on the pedagogy of classroom instruction in peer tutoring, practical placement as tutors in high schools and creative assignments. Two BUGE courses are mandatory in engineering curricula at the UniSA.

In this particular case, it was deemed that the vehicle of peer tutoring should be mobile robots. Robotics is particularly appealing to young minds as an exemplification of advanced technology with futuristic connotations. Robotics involves all of the exciting elements of electromotion, electronics, computing, control and artificial intelligence, thus creating a potent attraction. This has proven to be the case; the response has been overwhelming (see Figure 1).

The student tutors were carefully selected, trained and educated (see Figure 2). Their enthusiasm and commitment have been critical to the success of the

Figure 1: Pupils in action.

Figure 2: Dedicated participation of a UniSA student mentor.

project. In addition to providing peer tutoring for pupils, they have become a major force in delivering professional development for technology teachers at school, who have embraced the opportunity to be empowered in order to lead technology education. Initially, the project was entirely on a voluntary basis. Currently, student tutors are modestly rewarded monetarily due to external funding.

The course materials were prepared collaboratively by academics and industry partners. A proprietary iconic assembly language programme developed by eLabtronics, brand-named CoreChart, along with mobile robot kits, have been used as the main vehicles in implementing the Programme. The emphasis was on creative problem solving and the development of hands-on skills, such as electronic circuit prototyping and physical construction (see Figure 3).

ASPECT OF INNOVATION

The project is thoroughly innovative. It recruits university students to mentor high school pupils through a structured programme of building and programming intelligent robots. The programme culminates in a unique inter-school robotics competition annually (see Figure 4). The competition imposes a goal towards which students focus their activities and encourages them to develop analytical skills, engineering precision and to pursue excellence in their work. In this way, the programme inspires creativity and promotes endeavour towards excellence and high achievements.

It is not compulsory for students to enter the competition. However, all participating students are encouraged to attend the end of year event, showcase their work and participate in various activities during the day. In addition to certificates for the competition achievements, all students are presented with a certificate of achievement for their active participation in the programme in order to encourage their further interest and proactive involvement in science, engineering and technology.

At this final event, all industry sponsors are invited to exhibit their company displays and talk to students about the engineering profession and career opportunities in their companies. All students receive a UniSA package with information on engineering degrees, programmes and alternative career pathways in engineering.

The presentation of certificates, awards and trophies for winners is performed at the formal part of the event, during which pupils are addressed by industry representatives, government officials and university academicians.

UniSA student mentors are also presented with certificates for their role in the programme. Their motivation, enthusiasm and leadership skills are thus recognised as being an invaluable contribution to the programme and for the guidance of pupils. Student mentors are seen to be in the best position to effectively and enthusiastically provide information to their young peers on engineering programmes in a tertiary educational environment.

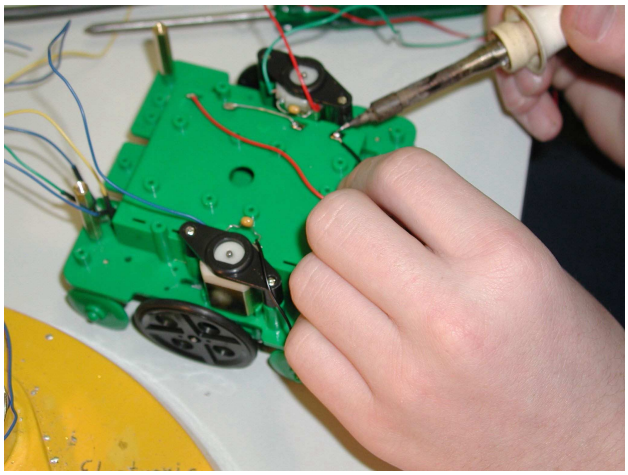

Figure 3: Hands-on development of skills.

Figure 4: Pupils preparing for robot competition.

BENEFITS

The programme is showing signs of having a significant impact, especially on pupils from the socio-economically disadvantaged regions where there are not many role models of people who have attended a tertiary institution, let alone studied engineering. Enrolments in the EIE engineering programmes have been showing an upward trend. Gratifyingly, many are the beneficiaries of the Programme. The tiered list reaches from secondary pupils to society at large.

Secondary pupils benefit because they learn new skills in a benign, yet highly motivational setting, providing them with an opportunity to apply knowledge, while also developing analytical and problem solving capabilities. The approach inspires creativity and the pursuit of excellence. They are encouraged to develop interest in science, technology and engineering. Furthermore, they are introduced into a realm that may not have existed for them before: the realm of engineering, which is to be seriously considered as a career choice!

Secondary teachers involved in the programme benefit because the Programme is tantamount to a professional development scheme. It provides them with a platform for teaching science, engineering and technology in a fun way, while also upgrading their own knowledge. Hardware, software and courseware development is made available. It also offers an opportunity for networking and sharing experiences and teaching materials. Further, there is the promise of ongoing support within the *alliance*, including that from industry.

UniSA students as mentors benefit as they develop their prowess in communication, their leadership skills and advance their technical knowledge. Through the programme, they develop a sense of social responsibility, a tenet of the engineering profession, which can be difficult to teach in a classroom.

A spin-off of the programme is the development of friendship and bonding among UniSA student mentors across various undergraduate programmes and years, with junior students rubbing shoulders with senior students towards common goals. This undoubtedly enhances the quality of their university experience.

The enthusiasm among mentoring EIE students has resulted in their taking the initiative to form a Campus Chapter of *Students in Free Enterprise* (SIFE), a global non-government organisation that is active at more than 1,700 tertiary institutions in 42 countries and territories. Their motive has been to further develop innovative and entrepreneurial skills for their own and the society's benefit. The team has since successfully participated in annual competitions, getting the 1st Runner Up position in this year's Australian competition. This is all the more remarkable since they have been the only team of engineering students participating in the national event: twice in a row now!

The programme provides benefits for the industry by facilitating a sustainable skill-base development, thus broadening the pool of skilled young people. It is a motivational scheme inculcating in young people a desire for further advancement. Industry can hope for extended export opportunities by being able to produce superior commodities by virtue of having a smart workforce.

Society at large benefits since the scheme addresses the shortage of skilled workers, especially in areas of critical importance to the future positioning of Australia as a *smart nation*. It raises the profile of the engineering profession to where it rightly belongs. It also influences a cultural paradigm shift and attitude in socio-economically disadvantaged regions, contributing to their development.

Links with employers and other stakeholders, including a range of tertiary providers of engineering education, are being forged in order to strengthen the effectiveness of the programme and to expand it towards achieving its objectives, which reach beyond raising awareness for engineering as a professional endeavour of critical importance to the well-being of the society.

The project has attracted several accolades to date. These include a UniSA *Chancellor Excellence Award for Community Service* in 2002 for *Enhancing Engineering and Technology Awareness*, as a joint contribution of academic and general staff and students of the School of EIE (see Figure 5). A commendation from the South Australian Division of The Institution of Engineers, Australia, was also received in 2003, which was followed by the Australian Engineering Excellence Award of The Institution of Engineers, Australia in 2003 (see Figure 6). It attracted further recognition from the Australian Government (see Figure 7) and a major award from the Government of South Australia in 2004.

CONCLUSION

Apathy towards engineering, which has prevailed in the Australian society for a decade or so, has to be counteracted and reversed, since engineering is the contributing force to the prosperity and welfare of contemporary societies. Indeed, the very existence of civilisation as it exists would be in jeopardy without

Figure 5: Recognition of ahievements with the UniSA 2002 Chancellor's Award for Community Service.

Figure 6: Australian Engineering Excellence Award.

Figure 7: Project briefing with the Hon. Dr Brendan Nelson, Minister for Education, Science and Training, Federal Government of Australia (third from right).

daily engineering contributions taken for granted, such as the electricity supply. Society at large needs to be made aware that without engineering, the current level of prosperity is unsustainable.

Engineering awareness-raising initiatives by reaching out into schools promises to be a step in the right direction.

REFERENCES

1. Göl, Ö., Nafalski, A. and Lesniewski, P., Enhancing awareness of engineering and science to attract students into engineering education. *Proc.*

9th Annual AAEE Conv. & Conf., Ballarat, Australia, 223-227 (1997).
2. Commonwealth of Australia, Sustainable Regions Programme (2004), http://www.sustainableregions.gov.au/index.aspx
3. Organisation for Economic Co-operation and Development (OECD), Science, Technology and Innovation for the 21st Century. Final Communique, Meeting of the OECD Committee for Scientific and Technological Policy at the Ministerial Level, 29-30 January (2004), http://www.oecd.org/document/15/0,2340,en_2649_201185_25998799_1_1_1_1,00.html
4. Hudson, R. and Göl, Ö., An analysis of factors affecting preparation of pupils in high school for engineering courses. *Proc. 11th Annual AAEE Conv. & Conf.*, Adelaide, Australia (1999).
5. Robinson, M., Fadali, M.S., Carr, J. and Maddux, C., Engineering principles for high school students. *Proc. 29th Annual Conf. Frontiers in Educ. (FIE '99)*, Vol. 3, 13A7/20-25 (1999).
6. Claire, L., McCullough, M.C. and Thomas, D., Adventures in engineering: a unique program to attract under-represented groups to engineering. *IEEE Trans. on Educ.*, 37, **1** (1994).
7. Cottrel, D.S., Computer Aided Design for introducing high school students to engineering. *Proc. 32nd Annual Conf. Frontiers in Educ. (FIE '02)*, Vol. 1, T3C-1-6 (2002).
8. Yates, J.K., Voss, M. and Kuei-Wu, T., Creating awareness about engineering careers: innovative recruitment and retention initiatives. *Proc. 29th Annual Conf. Frontiers in Educ. (FIE '99)*, Vol. 3, 13D7/9-14 (1999).
9. Torres, K., Loker, D. and Weissbach, R., Introducing 9-12 grade students to electrical engineering technology through hands-on laboratory experiences. *Proc. 31st Conf. Frontiers in Educ. (FIE '01)*, Vol. 2, F2E12-16 (2001).
10. Anderson-Rowland, A.R., Reyes, M.A., Jordan, C. and McCartney, M.A., A model for academia, industry, and government collaboration for K-12 outreach. *Proc. 29th Annual Conf. Frontiers in Educ. (FIE '99)*, 13a7-2 (1999).
11. Commonwealth of Australia, Backing Australia's Ability: The Australian Government's Innovation Report 2003-04 (2003).
12. Department of Education, Science and Training (DEST), Commonwealth of Australia, Students 2003 (First Half Year): Selected Higher Education Statistics. Web Publications: Higher Education Statistics Collections, Table 9 (2003), http://www.dest.gov.au/highered/statistics/students/03/tables.htm
13. Dowrick, S., A review of the evidence on science, R&D and productivity. Paper Prepared for Department of Education, Science and Training (DEST), Australian Government (2003), http://www.detya.gov.au/science/analysis/pdf/economicgrowth.pdf
14. Commonwealth of Australia, Backing Australia's Ability: An Innovation Action Plan for the Future (2001), http://www.austms.org.au/Jobs/backing_Aust_ability.pdf
15. Department of Industry, Science and Resources, Science and Technology Awareness Program (2002), http://www.austehc. unimelb.edu.au/asaw/biogs/A000905b.htm
16. The Institution of Engineers, Australia, Engineering in Schools, http://www.ieaust.org.au/careers/schools.html

BIOGRAPHIES

Özdemir Göl has had extensive experience as an engineering educator in addition to his substantial industrial experience. His academic career has included appointments in electrical engineering at universities in Turkey and Australia. He is the holder of MESc, ME and PhD degrees, all in electrical engineering. He is currently an Associate Professor and discipline head of Electrical Engineering at the University of South Australia, Adelaide, Australia.

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He has a strong interest in innovative approaches to engineering education and has published widely in this field. His teaching responsibilities have included courses in electrical machines, engineering design and virtual instrumentation. He is the author and co-author of some 150 publications.

Andrew Nafalski's career spans over 30 years in academic and research institutions in Poland, Austria, the United Kingdom, Germany, Japan and Australia. He holds BEng(Hons), MEng, GradDipEd, PhD and DSc degrees. He is a Chartered Professional Engineer and Fellow of the Institution of Engineers, Australia, Fellow of the Institution of Electrical Engineers (UK) and Senior Member of the Institute of Electrical and Electronic Engineers (USA). He is currently a Professor and Head of School of Electrical and Information Engineering at the University of South Australia in Adelaide, Australia.

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Zorica Nedic received her BE degree in electrical engineering, specialising in electronics, in 1984 from the University of Belgrade, Yugoslavia. She obtained her ME in electrical engineering (control) in 1997 from the University of South Australia (UniSA), Adelaide, Australia. She worked for six years as a design engineer at the Institute Mihajlo Pupin in Belgrade, Yugoslavia.

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Kevin McDermott is a graduate of Adelaide University, Kettering University and the University of Southern Queensland. He is a Fellow of the Institution of Electrical Engineers, the Institution of Manufacturing Engineers and the Institution of Engineers, Australia. He worked in the electronics, telecommunications and automotive industries before being allured to academic life in 1973. Among other positions, he was Chair of the Curriculum Committee of the South Australian Institute of Technology from 1988 to 1990. In 1996, he resigned from his position as Head of the Engineering Discipline and Deputy Campus Director of the Whyalla Campus of the University of South Australia.

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