
The UICEE - Cape Town Pillar of Science, Engineering and Technology Education Research: 1989-2006

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In this article, the author describes some of the research, development and scholarly activities in science, technology and engineering education that have emerged from a committed 18-year partnership between the UNESCO International Centre for Engineering Education (UICEE) and the School of Education, University of Cape Town. The author also discusses the relevance and impact of these achievements on the local and international communities, as well as their specific roles within and beyond the UICEE global network. In the article, the author notes several milestones and indicates anticipated future developments.

INTRODUCTION

Since 1989, the University of Cape Town in Cape Town, South Africa, has been continuously associated with both the activities and mission of UICEE, as well as its Australian fore-runners based earlier in the then School of Electrical Engineering at the University of Sydney's Faculty of Engineering. These were: the Electrical Engineering Education Research Group (EEERG) (the immediate predecessor of the UICEE); the International Liaison Group for Engineering Education (ILG-EE) and the Australasian Association for Engineering Education (AAEE).

It was more than 17 years ago that the eminent Professor Z.J. Pudlowski – at that time a young and dynamic lecturer – invited the author to present a research paper at the *World Conference on Engineering Education for Advancing Technology* in Sydney organised under the auspices of the Institute of Engineers, Australia. This was the auspicious beginning to a productive academic and research collaboration that has developed and grown from strength to strength.

RESEARCH, DEVELOPMENT AND SCHOLARLY ACTIVITIES IN ENGINEERING EDUCATION

During the last 12 years, the author's association with the UNESCO International Centre for Engineering

Education (UICEE) has generated research outputs in four main areas, which are listed below.

An Analysis of the Nature, Importance and Practice of Inspirational Teaching

As a sequel to earlier published work (see ref. [1]), the author presented a paper entitled, *Challenged, ambitious, fascinated and inspired: a characteristic profile of elite, award-winning S-E-T students in the Exposcience Internationale* at the first *Global Congress on Engineering Education* held in Kraków, Poland in late 1998 [2]. This research, conducted with 121 of the world's highest achieving high school Science Talent Quest (Expo) students from 20 countries, found that being *inspired* by their own competitive scientific investigations was one of four top-ranked factors (out of 70 possible factors) associated with the students' rise to international levels of performance.

Drawing on insights and understandings developed at Monash University, Melbourne, Australia, the author's subsequent analysis of the nature, role and importance of inspirational teaching and lecturing in practice then extended the work of Eichinger, Zakis, and Burke and Nierenberg [3-6].

In more recent years – and at the end of sessions of specifically crafted workshops, lessons and lecture courses that focused on instances of inspirational teaching – the data collection procedure in Cape Town

produced written feedback statements from a total of more than 250 participant teachers and students. In their summative evaluation statements, it emerged that the majority of participants were using the spontaneous, unsolicited words, *inspiring*, *inspirational* or *totally inspired*, to describe or summarise their personal experiences of these courses with time spans that ranged from several weeks to an entire year of instruction in the sciences and technology, as well as in professional studies. The author's reported systematic description of these *inspirational* curriculum materials subsequently pursued an interpretative analysis of the details of the recorded perceptions and comments of students and teachers [3]. The research concluded that there was ample evidence to support the claim of science educator Ratcliffe when she wrote: *Teachers are not necessarily resistant to change. They like well-informed, well-researched, timely and inspirational changes* [7].

A Baseline Study of the Mathematics and Reading Proficiency Levels in 38 Western Cape Schools

Between August and November 2000, the author and two colleagues made assessments of the baseline levels of competence of South African learners in both reading and mathematics. A stratified random sample of 38 schools was then used to represent the entire spectrum of schools in the Western Cape. Data were obtained from a total of 2,077 learners on two standardised tests of mathematics and two standardised reading tests. These were presented and administered in the learners' home languages (Xhosa, Afrikaans and English).

An important finding was that hundreds of the randomly sampled children were still scoring close to zero on standardised tests of mathematics – despite six years of schooling in mathematics. It was clear that many of these learners, who might aspire to become engineers or technologists, might never have the opportunity to attain the necessary entrance-level qualifications.

The complete data was also analysed comparatively in terms of rural learners' versus urban learners' performance scores, with the urban learners scoring significantly lower than their rural counterparts – contrary to expectations. The data was also analysed in terms of the former departmental statuses of the schools (ie the formerly disadvantaged schools previously classified by population grouping as *Coloured*, *African* and *Indian*, and the formerly advantaged schools classified as *European*). Statistically significant differences in achievement

levels between groups were established [8].

The significance of the work was that the simultaneous conduct of the four baseline surveys yielded a substantial amount of data that was then used to identify particular schools most in need of helpful interventions as a matter of urgency.

Nevertheless, on a positive note, several formerly disadvantaged *African* schools were found to be achieving significantly above average on the standardised reading and mathematics tests adopted in this study. Hence, the research was able to identify several impoverished schools that deserved special commendation from the Ministry of Education – because they had excelled significantly and dramatically, despite a long history of adverse local conditions.

An International Comparison of the Education Priorities of Science and Technology Teachers, Lecturers and Students in Three Developing Countries

International comparisons of the science and technology education priorities of science teachers, lecturers and students in Turkey, Lesotho and in several South African provinces were situated within the larger context of Solomon's conceptual framework for science and technology education policy developed at Oxford University [9]. The empirical findings obtained in these three countries by the author's team of ten researchers substantiated and enriched the plethora of considerations set out in Solomon's policies for the development of life skills through science and technology for the 21st Century.

Lesotho and Turkey, for example, are two developing countries, both relatively deficient in educational resources. One of these studies reported and compared the priorities and responses of 172 Turkish science teachers, lecturers and students, and 171 Lesotho science educators and students, to 20 literature-derived recommendations for improving science education in the two countries [10]. Both quantitative and qualitative survey data were analysed. In both Turkey and Lesotho, the most frequently prioritised recommendations were found to be similar. They were as follows:

- To engage *more self-discovery* in science and technology learning;
- To introduce *more real life skills* into science teaching;
- To utilise better *teaching methods*;
- To acquire *more resources* for science and technology lessons.

The findings also proved to be consistent with earlier results obtained with widely diverse samples of more than 1,000 South African teachers and students in several provinces [11-13].

These research findings were subsequently considered in the planning of the content of the new school science curricula for South Africa and Lesotho, and were forwarded to educational planners in Turkey. They were disseminated more widely by the UICEE through its journal and published conference proceedings.

Successful Strategies for Research Student Capacity Development and the Attainment of a High Level of Student Research Output

For the last ten years, the author has also been researching the educational ingredients that combine to ensure almost 100% successful throughput, with credible published outputs, of advanced postgraduate students in education, especially in science and technology.

During a planning visit to Leeds University in 1983, the author was informed that *throughout the world, three-quarters of Masters degree students who commence a dissertation never graduate – either they discontinue or they fail*. For 20 years, no academic or university administrator appeared to have been able to solve this universal problem of high dropout wastage of potential research students. However, by the year 2002, the author was confident that he had an evidence-based research-based solution to this widespread educational concern.

As a sequel to the conference paper presented in Poland in 1996 (see ref. [14]), the author's subsequent journal article described how 25 Masters and doctoral students commenced their dissertations under the author's supervision, and how all subsequently succeeded in graduating, many within a time period of one to three years [15]. With important assistance from the UICEE, these students – mostly in science and technology education – also efficiently produced 18 articles in refereed journals, ten refereed published international conference papers, ten papers published in national conference proceedings, ten published seminar papers and several books as an integral part of the work for their dissertations.

Most of these publications were written, under guidance, by students who either originated in historically disadvantaged backgrounds, or were handicapped by speaking English as a second language, or both.

In this article, the author presents and discusses the research-based teaching strategies, challenges,

interventions, inspirational influences, confidence-building tactics and time management techniques adopted to ensure research student success even under adverse conditions. This resulted in a supervisory career accomplishment of zero dropouts and a zero throughput failure rate under supervision from the early 1980s through to 2002.

This work is educationally significant in the South African context. Lessing and Schulze reported that attrition rates and completion rates of postgraduate students are statistics that are of increasingly vital concern in higher education. At the University of the Western Cape (UWC), for example, only 10% of Masters degree students were completing their dissertations in three years. One university department in South Africa recently orally reported a Masters throughput success rate of only 5%. Another recent report had recorded that 85% of South African students in higher education never graduate [15].

Hence, the importance of the author's published research is that it has explained, presented and discussed the researched teaching strategies, interventions and time management techniques that can be adopted by caring tertiary institutions to ensure credible outputs and success by almost all of its inexperienced research students.

AWARDS AND ACHIEVEMENTS

Fortuitously, more than 20 academic awards and medals have been received by the author. Some of these include the following:

- The Australasian Association for Engineering Education's Medal (International) for Distinguished Contributions to Engineering Education (1996);
- The Silver Badge of Honour Award from the UNESCO International Centre for Engineering Education (UICEE) for distinguished contributions to engineering education (1997);
- The Distinguished Visitors Lecture Award, Monash University (1996);
- The Special UICEE Director's Award for an outstanding paper presented at the 4th Global Congress on Engineering Education, Bangkok, Thailand (2004);
- A visiting lecturer's award, University of Bogazici, Istanbul, Turkey (2000);
- A Mannheim University of Applied Sciences Visiting Lecturer's Award to Germany (2001);
- The University of Sydney's Norman I. Price Visiting Researcher's Scholarship in Electrical Engineering Education (1991);

- The Dick and Dorothy Borchards Prize for achieving the highest standard in Astronomy (1975);
- The Whitton Education Award for the highest achieving student in education at the University of Cape Town (UCT) (1974);
- The University of Cape Town's class medal in Astronomy (1975);
- The George Amos Award for Science Teaching of the Victorian Council of Schools Organizations, Australia (1967);
- Three consecutive formal ratings for peer-reviewed research excellence and the recognised quality of research outputs, by South Africa's National Research Foundation (1994, 1999 and 2005).
- 27 articles in refereed international journals;
- 15 research papers published in refereed international conference proceedings;
- 24 research papers published in national conference proceedings;
- 44 refereed published seminar research papers/regional conference proceedings;
- 95 published conference abstracts;
- 11 books.

It should be noted that more than two thirds of the publications listed above have been authored by black students, either as the sole writer or as a co-author.

Many of the research projects were chosen by students to try to improve the quality of education in their own historically disadvantaged schools, tertiary institutions or communities.

Examples of the topics that produced full-length student-published research papers, include:

- Gender and achievement in mathematics, science and African languages (Mudongo & Ponoesele; Motsemme; Mosoeunyane);
- Learners' understanding of calculations and estimations involving objects (Powell; Swartz; Mullajee);
- Mathematics achievement and assessment format (Abrahams);
- Students' understanding of electrochemical cells (Gallant);
- Socio-economic status, gender and achievement in mathematics (Attwood);
- Historically disadvantaged learners' interpretation of science textbook diagrams (Jacobs);
- The implementation of Curriculum 2005 in schools (Rolls) [16-17].

The author's supervised research students who have become professors, lecturers, textbook writers or high level education advisors include Lesley le Grange, Martie Sanders, Bothlale Tema, Cynthia Ndodana, Janet Condy, Nigel Attwood, Frank Opie and Vagriuah Kariem.

Wider Contributions to Research Capacity Development

In 2004, as the chief judge of the annual Expo for young scientists and technologists in Cape Town, the author initiated and edited the publication of the award-winning research investigations of – among others – eight students from historically disadvantaged schools. This was a first for the South African education system [18].

RELEVANCE AND IMPACT

Maximising Successful Throughput Rates for Graduating Doctoral and Masters Dissertation Research Students

As a research mentor, the author's work has accomplished an almost 100% successful throughput and graduation rate of doctoral and Masters dissertation students – 29 out of 30 students who commenced their dissertations have neither dropped out nor failed to graduate to date.

Almost all of the author's approximately 120 recent honours research students have also graduated successfully.

The processes implemented to attain almost 100% successful research capacity development include the following:

- Low-cost inter-institutional student-organised research conferences for student presentations;
- Mastery learning;
- Daily written feedback;
- Systematic confidence building through mentoring for regular and progressive publication outputs;
- Personalised reinforcement;
- Family support;
- Launching work on the dissertation prior to the consideration of coursework modules [15].

Postgraduate Student Research and Publication Capacity Building

Encouraged by the UICEE, the author's mentored honours, masters and doctoral research students have produced well over 200 publications in recent years – including:

SELECTED PUBLICATIONS

Since 1989, approximately 40 publications have resulted from a personal association with the staff of UICEE, and with international academic organisations linked directly to it. These include 20 published international conference papers, 13 journal articles under the editorship of leading members of UICEE, three book chapters, two articles in newsletters and five invited keynote or plenary addresses.

Within this selection, the author's most important recent publications that have aimed to make a special contribution to knowledge in science and technology education may be summarised as follows:

The development and implementation of a supervision strategy for the efficient and cost-effective case management of inexperienced postgraduate research students in developing countries.

Full details of the successful mentoring strategies, approaches, methods and tactics are presented and described in the references [15] and [19].

SPECIFIC ROLE WITHIN THE UICEE GLOBAL NETWORK

The author's work for the UICEE has included being an active member of the advisory boards of both the *Global Journal of Engineering Education* (GJEE) and the *World Transactions on Engineering and Technology Education* (WTE&TE) since their inception. The author has also been a member of international organising committees of Congresses and Conferences in Kraków, Lodz, Gdynia, Melbourne, Wismar and Glasgow, and encouraged students to attend, present and publish in these conference proceedings and in the GJEE. In 1993, Prof. Z.J. Pudlowski included several of the author's chapters in his book on research into students' understanding of electric circuit diagrams [20].

In recent years, it has also been a pleasure to referee regular batches of 20 conference papers submitted for publication in the proceedings of international conferences organised by the UICEE.

SPECIFIC LINKAGES WITHIN AND OUTSIDE THE UICEE GLOBAL NETWORK

Refereeing and Advisory Board Work

The author's work has included active membership of other international editorial advisory boards such

as the *South African Journal of Higher Education*, the *International Journal of Service Learning in Engineering* and the *South African Journal of Education*. The author has also refereed for the *Australasian Journal of Engineering Education*, the *International Journal of Applied Engineering Education*, the *Journal of the Science Teachers' Association of Nigeria*, *Perspectives in Education*, the *Journal of the Southern African Association for Research in Mathematics and Science Education*, the *African Journal of Research in Mathematics, Science and Technology Education* and the *South African Journal of Science*.

Regional and National Inter-Institutional Linkages

Together with colleague Jean Baxen, the author initiated and guided research students in the organisation of their own Education Students' Regional Research Conferences held annually at the University of Cape Town from 2001-2004, and then at Stellenbosch University as the co-organising institution in 2005.

This has resulted in honours, masters and doctoral students from the Universities of Stellenbosch, Western Cape, Cape Town, PenTech and CapeTech, as well as from overseas universities, publicly presenting their ongoing research work together and publishing more than 230 research papers, dissertations and abstracts in the UCT's Graduate School of Humanities [16][21-24]. It has also created wider networks of students assisting and encouraging each other among the five Cape tertiary institutions.

The resultant journal article offered evidence for the importance and success of the student-led conferences from 2001 to 2003. This research paper received the 2004 Special UICEE Director's Award for an outstanding paper presented at the 4th *Global Congress on Engineering Education*, Bangkok, Thailand [19].

In 2005, the 5th *Annual Education Students' Regional Research Conference* moved from the UCT for the first time. It was co-hosted with the UCT by Stellenbosch University's team of postgraduate education research students, but the organising committee continued to comprise students from all the tertiary institutions in the Western Cape. In addition, preliminary inter-institutional workshops were organised to assist novice research students with the preparation and presentation of their conference papers prior to their first conference presentation. Under this workshop guidance, the number of students presenting research papers grew annually from approximately 50 to 65.

It is planned that the University of the Western Cape will host the 6th *Education Students' Regional Research Conference* in 2006, followed by the Cape Peninsula University of Technology intended in 2007, with the intention that up to 100 students might be presenting their research papers and publishing either their theses, their full papers or their abstracts during the 2008 conference.

The author's extended work and that of his students has also linked regularly with the University of Cape Town's Centre for Research in Engineering Education since its inception in 1996 and, most recently, with the Josephine Mill – a fully operational, educational historical monument.

Previous activities in science and technology education led to the author receiving the following:

- The University of Natal's Visiting Lecturer's Award (1989);
- An Excellence in Classroom Teaching Award of the South African Association of Teachers of Physical Science, Mathematics and Biology (1993);
- The Kwa-Zulu Natal Association of Science and Technology Educators Plenary Guest Speaker's Award (1998);
- Equal first prize for innovative ideas in teaching at the 4th *National Convention for Teachers of Mathematics and Science*, University of Stellenbosch (1971).

Collaborative Research Linkages between Institutions with Emerging Research Cultures

In 2003, together with Prof. M.B. Ogunniyi of the University of the Western Cape (UWC), volumes 3-6 of the UWC Seminar series were produced jointly, featuring 33 refereed and published research papers. In addition to the UWC-UCT research articles, several papers were also contributed by Stellenbosch University and by the University of Bergen [17].

In order to ensure the worldwide publication of students' research articles, collaborating partnerships were also developed with the UNESCO (Supported) International Centre for Engineering Education based at Sydney University and Monash University in Australia (1989-2006), with the UWC UNESCO Science Education Chair scheme (1998-2005), with the South African Association for Research in Mathematics, Science and Technology (SAARMSTE) (1995-2005), with the South African Association for Research and Development in Higher Education (SAARDHE) (1990-2005), with the Australian Science Teachers' Association (in the mid-1990s), with the Australasian

Association for Engineering Education (1990-2004), with the UCT Sports Science Institute (in the mid-1990s), with the Department of Civil Engineering of the Cape Technikon (2000-2003) and with the University of Mining and Metallurgy, Kraków, Poland (1998) and with the Middle East Technical University, Ankara, Turkey (2000-2003).

Productive linkages were formed with overseas universities and other institutions, such as Hochschule Wismar - University of Technology, Business & Design, Wismar, Germany, the Australasian Association for Engineering Education and the University of Ballarat, Ballarat, Australia.

As a result, 11 of the author's historically disadvantaged honours and Masters students succeeded in publishing their research in refereed international journals.

SPECIFIC AND OUTSTANDING INVOLVEMENT IN CONFERENCES ON ENGINEERING EDUCATION

In addition to participating in programmes organised by the UICEE and its pre-cursors, the author's work has been presented at conferences held under the auspices of the Association for Engineering Education in South East Asia and the Pacific in New Zealand; the International Conference on the Quality Assurance within Engineering Higher Education in Poland; the Southern African Conference on the Public Understanding of Science and Technology in Bellville, Cape; the International Conference of the Southern African Association for Research in Mathematics and Science Education, Zimbabwe; the International Conference on Technology Education, Cape Town; the International Conference on Public Communication of Science and Technology, Cape Town; the National Seminars of the Centre for Research in Engineering Education (CREE), University of Cape Town; the Annual Technology Conferences, Cape Technikon; the National Conference for Teachers: Science and Technology Education Conference, Cape Town; the Language Integration Conference, Bellville; and the National Subject Didactics Symposium, Stellenbosch.

This work has involved the author refereeing more than 120 papers for proceedings of local and international conferences on science and engineering education.

FUTURE PLANS

Currently the author's work is involved in extending and completing research reports in the following areas:

- The effective use of fieldwork camps for integrating science, mathematics and technology across the curriculum: a cumulative investigation from 1986 to 2005;
- Students' experiences of inspirational teaching resources in science, technology and mathematics lessons: a ten year study from 1995 to 2005;
- The development of Scientific and Technological Literacy (STL) among science teachers and learners in South Africa – 2004 to 2006: M.B. Ogunniyi (leader), plus seven others;
- The acquisition of practical and applied process skills in science, mathematics and technology by students and learners in astronomy, geology and technology: 2000-2006;
- Shakespeare's use of science, mathematics and technology in his plays.

SUMMARY AND CONCLUSIONS

In the strong and enduring collaboration with Prof. Z.J. Pudlowski, Director of the UICEE, it has been a special pleasure to grow in a lifestyle of research that has brought so much success, satisfaction, joy and inspiration to hundreds of university students and colleagues who have participated in collaborative research-based programmes, both locally and overseas.

Other researchers may have chosen to devote their time to proving that South African school children are among the world's worst performers in TIMMS mathematics and science, as widely reported in 2004. But that has not been the author's choice.

Instead, it has become a delight to be able to collaborate with the staff of Monash and Sydney Universities since 1989 to report on the positive attainments of successful interventions and noteworthy contributions. These achievements – many of which have been published under the auspices of the UICEE and its fore-runners – have occurred by engaging newly researched pedagogies designed to ensure systematic, credible and consistent student successes at a high standard, notwithstanding unjust handicaps in the past.

Let Aydin Inal, for example, have the final word. He was one of the author's UCT Master's students in science and technology education, and English is his second language. He decided to use the dynamic opportunities opened up by the UICEE to publish his ongoing work [25]. Investigating students' process skills with simple manufactured objects and items of apparatus, his output has been more than 20 publications (which is possibly a world record for a Master's student), including three refereed international journal articles. He graduated with distinction for his MEd dissertation in 2002.

From Lesotho, also meet Adelina Moru, another of the author's Master's students in science education. Her recent noteworthy output comprised seven publications, including two articles in cited refereed journals plus a UICEE refereed international conference paper, and so on [26]. Yet women in South Africa have produced only 10% of publications; and, within this small margin, a mere 8% have been black women. So, while there may have been an emphasis on knowledge production, there has been no other systematic research-based strategy to develop student research capacity and output, especially for young black female research investigators.

Yet, these are merely two examples of case stories of students who have served with pride to build and strengthen the UICEE-Cape Town pillar of science, engineering and technology education research that has been carefully nurtured for nearly two decades. However, in an article of this nature, it is impossible for all of the South African research students to convey adequately their gratitude and appreciation to the UNESCO International Centre for Engineering Education (UICEE). After all, it was the alert and enthusiastic staff of UICEE who recognised the worth of earlier work with thousands of engineering students, and who honoured it with special awards [27-37].

It is the author's wish that long may this joint UICEE-UCT pillar of success endure.

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BIOGRAPHY



Kevin Rochford is an Associate Professor of Education at the University of Cape Town. He graduated with a BSc from Melbourne University; then gained a BED with distinction, an MEd with distinction, and a PhD, all from the University of Cape Town. As a student and young teacher in Victoria, he

commenced his career by building a small amateur astronomical observatory with six telescopes in the early 1960s. His publications include 80 conference papers, eight chapters in books, two books as research editor, 21 articles in cited refereed journals, 35 articles in professional journals or university publications, five sets of conference proceedings as co-editor, ten articles in popular magazines and 25 newspaper articles. He has made more than 60 presentations at national or international conferences, and given ten invited keynote addresses or plenary presentations.

His research students have produced more than 200 publications. During the last 17 years, he and his students have contributed more than 30 articles to the *Global Journal of Engineering Education* and its forerunners and associated international conference proceedings.

He is also a member of the editorial advisory boards of several journals of science, engineering and technology education. He was an inaugural member of the International Liaison Group for Engineering Education (ILG-EE) in 1989.

**Conference Proceedings of the
8th UICEE Annual Conference on Engineering Education
under the theme: *Bringing Engineering Educators Together***

edited by Zenon J. Pudlowski

The 8th UICEE Annual Conference on Engineering Education, held under the theme of *Bringing Engineering Educators Together*, was organised by the UNESCO International Centre for Engineering Education (UICEE) and was staged in Kingston, Jamaica, between 7 and 11 February 2005, with the University of Technology Jamaica (UTech) as the host and principal co-sponsor.

This volume of Proceedings includes a range of diverse papers submitted to this Conference that detail various international approaches to engineering education research and development related to the Conference theme, as well as other specific activities.

The 76 published papers from authors representing 25 countries offer an exemplary collection that address fundamental issues, concepts and achievements of individual researchers. The papers have been organised into the following groups:

- Opening and Keynote addresses
- Case studies
- Conceiving – designing – implementing – operating: CDIO initiative
- Effective methods in engineering education
- Important issues and challenges in engineering education
- Innovation and alternatives in engineering education
- International examples of engineering education and training
- Multimedia and the Internet in engineering education
- New trends and approaches to engineering education
- Quality issues and improvements in engineering education
- Research and development activities in engineering education in Jamaica
- Specific engineering education programmes

It is significant to note that, as well as the international input into the Conference, contributions have come from academics representing the University of Technology Jamaica (UTech), as well as from authors focusing on the CDIO initiative. The variation of subjects, concepts, ideas and international backgrounds in this volume of Proceedings demonstrate the global nature of UICEE-run Conferences, as well as its relevance within the worldwide affairs concerning engineering and technology education.

In order to ensure the high quality and value of the Proceedings into the future, all of the papers have undergone assessment by independent international peer referees and have been professionally edited. As such, it is envisaged that this volume will become a useful source of information on research and development activities in engineering and technology education within the context of a collaborative engineering education environment.

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