Session 1359

Instrumentation & Control – a new degree for Australia

S P Maj, D Veal
Department of Computer Science
Edith Cowan University
Western Australia

Abstract

Despite the fact that Western Australia (WA) has a predominately mineral extraction and mineral processing based economy, investigations by the education sub-committee of the WA branch of Institute of Instrumentation and Control Australia (IICA) indicated a lack of suitably qualified engineers in Instrumentation & Control (I&C). A subsequent detailed survey found that this lack of specialist I&C engineers was having a significant impact on the operations of major companies in the region. The IICA education sub-committee comprised of senior engineers from major processing companies but only a few selected representatives from the education sector. Accordingly the agenda was to design and develop, independent of any university, a new degree in I&C within 2 years to meet the needs of industry. As such the proposed degree was designed to provide not only conceptual knowledge of the discipline but also the appropriate procedural knowledge based on standard industrial systems and practices. Furthermore, this award must also be fully articulated to technical education at pre-degree level. The education sub-committee conducted an international survey of degree programs in I&C to determine international best practices and to find if possible a template that could be used. Despite extensive investigations no suitable degree program could be found – none offered the suitable emphasis being sought. This paper presents details of this investigation and the results of the curriculum design through to final adoption and implementation of this curriculum by a university within WA.

1. Introduction

The Institute of Instrumentation & Control Australia (IICA) is the national professional body dedicated to promoting the theory and practice of industrial and scientific instrumentation, automatic control and associated technologies. The IICA education sub-committee was established to promote the development of industry relevant courses in Instrumentation, Control and Automation within both the university and technical college sectors. Thereby ensuring that any such curriculum could be developed by means of close liaison with industry and educational institutions. As such the education sub-committee provides a focal point for all interest groups wishing to be involved in course development, and equally importantly, subsequent course monitoring. Optimally the education sub-committee is designed to comprise of representative from Universities, technical colleges, industry,

consultants and vendors selected on the basis of them having both a comprehensive and detailed knowledge of the field of Instrumentation & Control (I&C). Given the considerable commitment of time required of busy professionals the core of the education sub-committee consisted of one representative from the university sector, one from the technical education sector and three principle engineers from the local process industries.

The field of Instrumentation and Control has been subject to rapid changes due to the advances in technology over the past 20 years. Currently Mechanical or Electrical Engineering graduates who have an interest in the area take on the role of 'Instrument Engineers'. However preliminary investigations by the education sub-committee indicated that that specialist engineers with appropriate knowledge are required by industry within Western Australia (WA). Furthermore the committee found some evidence that electrical, electronic, mechanical and chemical engineering graduates are not adequately prepared for this complex and multidisciplinary engineering field in the detail that is necessary to become a productive addition to an instrumentation or controls engineering team without further intensive and costly training. The education committee therefore elected to conduct a market analysis of industries within WA to determine specific requirements within the field of I&C. Prior to curriculum design the education sub-committee conducted an extensive international analysis of Instrumentation & Control curriculum within the university sector. Furthermore the education sub-committee determined that any such university curriculum must be fully articulated to awards offered within the technical college sector. Thereby providing an easy and seamless award structure to Instrument Technicians. It is the experience, certainly with WA, that full credit is not give to technical college awards. The committee determined this was an unnecessary disincentive to Instrument Technicians and the development of the profession. Additionally it was decided by the sub-committee that B.Eng and technical college award students could benefit greatly from the integration of the curriculum i.e. engineers have too little practical experience and technicians inadequate theory in some areas. After graduating the aim is that an Instrumentation/Control Systems engineer would have a thorough grounding in the basics of Instrumentation, Control and Automation so that they would have the 'tools' necessary to undertake the tasks appropriate to this discipline with minimal supervision and additional training.

2. Market Analysis – Industrial Survey

The sub-committee adopted a market-based philosophy rather than the more traditional asset based methods. Accordingly an exploratory market audit was conducted with the associated identification and profiling of market segments. A regional survey of industry provided support for a proposed new degree in Instrumentation & Control. However industrial support was provisional on the new degree having a strong focus towards industrially relevant knowledge and skills based on the use of standard industrial components and systems. It should be noted that Western Australia (WA) has a predominately minerals extraction and minerals processing based economy (Mineral sands, Nickel, oil, gas, precious metals etc). The manufacturing sector within WA is small. Newell conducted a survey of process control education in Australia and reported that:

> "a second strong chemical process control department is needed, that industrial implementation topics are poorly covered in the curriculum, that investment is needed in

> computer and software tools, and that there are too few continuing education courses" [1].

Furthermore, from the results of a national survey of engineers Bitcon [2] concluded that:

> "The skills in most urgent need of attention were found to be in the following areas:
>
> - Theory Skills in Cross-Discipline Areas
> - Practice Skills
> - Management Skills
> - Personal and Interpersonal Skills" [2].

3. Market Analysis – University Sector in Australia

There are five universities within WA - Curtin, UWA, Edith Cowan, Murdoch and Notre Dame. At the time of this initial market analysis only Curtin and UWA offered degree programs in Electrical and Electronic Engineering. Edith Cowan was in the process of implementing a degree structure with an emphasis on Very Large Scale Integration circuit design. Murdoch University had a well-established award structure in mineral science and engineering. Notre Dame University offered no awards in engineering. According to the Directory of Higher Education Courses 1992, and received literature from advertised courses, there appeared to be no undergraduate specialist studies in Instrumentation & Control in Australia. This conclusion was confirmed by a search of the Australian Tertiary Handbooks Computer Output on Microfiche (ATHCOM).

4. Market Analysis - Worldwide

An analysis of a wide range of universities was conducted using the Instrument Society of America (ISA) database. The degree programs of over five hundred universities in the USA, Canada and Europe were analyzed for content and relevance to the WA process industries. Of the degree programs analyzed the majority were primarily focused on Electrical and Electronic Engineering degrees with units in Instrumentation and Control. Alternatively those degrees with a significant I&C content had a strong bias towards mechanical engineering. However of particular interest was the three-year full time, B.Eng (Hons) in Instrumentation & Control Engineering offered by the University of Teeside in the United Kingdom. The course is also offered as a four-year sandwich degree, which gives students the opportunity to spend their third year either on industrial placement or on study placement in Europe or North America. The Institution of Electrical Engineers and the Institute of Measurement and Control accredited the degree. The University of Teeside is located in a region of the country with a very high concentration of the chemical industry. Accordingly the University of Teeside had strong links with industry in particular the local chemical and aeronautical industries. The University of Teeside also offered a two-year Higher National Diploma (HND) in Instrumentation & Control Engineering. Successful completion of the HND allows students to enter the second year of the B.Eng degree program.

The HND award was aimed at those who wish to develop a career at a senior technical or supervisory level in this field of activity. It combined theory, practical work and presentation

techniques with the associated industrial management problems. The focus of all modules was industrial applications, ranging from basic electronics to control systems theory. The Institution of Electronics and Electrical Incorporated Engineers, leading to Incorporated Engineer status, accredited the course. In both years of the course students undertake project work. Projects include investigations of materials to be used, costing, standards and codes of practice. An important part of the course is the development of a range of common skills. These included communication skills, numeracy, creativity, teamwork, managing tasks and problem solving. First Year topics include: Electrical Principles, Mathematics, Electronics, Control & Instrumentation, Industrial Studies, Electrical & Electronic Principles and Project. The Second Year topics included: Programmable Logic Controllers, Fault Diagnosis, Physical Measurements, Signal Conditioning, Plant & Process Control, System Reliability, Process Measurements, Options and Project. Diplomates were prepared to seek employment in a wide range of industries, including the chemical, process, food, metals, water, electricity, gas and aerospace industries.

The university provided full details of the B.Eng award to the IICA education sub-committee. The course was designed to provide students with the knowledge and ability to develop advanced systems for the monitoring and control of a wide range of processes, plant and machinery. The award had two areas of emphasis - measurement and control. Furthermore, there was a strong emphasis on design throughout the course; using modern software packages students were able to tackle real-life problems. A range of options was also available and included Language, Electrical Engineering, Networks & Fields, Communications Principles, Electrical Machine Control, Management and Power Electronics. In the final year students undertake a project. The awards in Instrumentation & Control Engineering from the University of Teeside were used as a template for the work of the IICA education sub-committee.

5. Knowledge and Skills

The survey clearly demonstrated that industrial support was provisional on the new degree having a strong focus towards industrially relevant knowledge and skills based on the use of standard industrial components and systems. The sub-committee therefore investigated the educational foundations of providing practical skills in conjunction with the more traditional theory based curriculum. According to Ramsden: [3]

> "Many students can juggle formulae and reproduce memorised textbook knowledge while not understanding their subjects in a way that is helpful for solving real problems".

Rather then lowering academic standards Professor Lowe argues:

> 'the complexity of the real world is more intellectually taxing than living in imaginary worlds of friction-less planes, perfectly free markets or rational policy analysis'" cited in by Armitage [4].

It is submitted that technical expertise is an enhancement of theoretical knowledge. According to Cervero:

> "the popular wisdom among practicing professionals is that the knowledge they acquire from practice is far more useful than what they acquire from more formal types of education" [5].

Cervero further argues that the 'goal of professional practice is wise action' and that 'knowledge acquired from practice is necessary to achieve this goal'. Both declarative and procedural knowledge are necessary for professional practice. Declarative knowledge is knowledge *that* something is the case; procedural knowledge is knowledge *how* to do something. Cervero clearly makes the point that:

> "A major difference between experts and non-experts in any field is that experts have far more procedural knowledge. That is, they know how to perform their craft" [5].

According to Cervero, 'procedural knowledge underlies skilled performance, and that procedural knowledge is acquired through practice'. [5]

According to Goldsworthy skill:

> "refers to a person's ability to do something well. It relates to expertness, a practiced ability, a dexterity in performing a task. It is an outcome that flows from knowledge, practice, inherent abilities and an understanding of the task to be performed" [6].

The committee concluded that a good educational case could be made for a curriculum with a significant practical component. Significantly the 1996 Edith Cowan University (ECU) Orientation Student Survey (Faculty of Science, Technology and Engineering) rated job prospects as the most important factor in choosing to study at ECU.

6. Instumentation & Control Curriculum

Given the impetus provided by the market analysis it was decided by the sub-committee to design a degree in Instrumentation & Control. In particular this degree should be 'demand driven' with considerable emphasis being placed on providing practical, generic and marketable skills. The committee recognized the increasing interdisciplinary nature of I&C due to the introduction of reliable, low cost electronics. Key topics identified included:

- Process control, advanced process control
- Applied chemistry, analytical techniques and equipment
- Applied Physics and Mathematics
- Electronics, Information Technology
- Pneumatics, hydraulics
- Control system configuration (PLC, DCS etc)
- Cybernetics, robotics
- Codes, standards and instrumentation documentation
- Batch/continuous processing
- Instrumentation and control system maintenance

The demands placed on members of the sub-committee were considerable – even during the initial part of this work. In the final analysis the core of the education sub-committee consisted of one representative from the university sector, one from the technical education sector and three principle engineers from the local process industries. The senior engineers on the committee in effect provided market oriented and outcomes based objectives. These objectives were then converted to a curriculum with the associated pre-requisite streams. Early in the design stage it was recognized that there should be a significant management component to the new degree. It recognized that graduates would gravitate to managerial status rather than remain in junior technical positions. According to Collins, Gardiner, Heaton, Macrosson and Tait:

> "Technology of itself does not produce commercial results - this comes from its application. Successful applications derive from the marriage of the technology with a range of other activities, particularly those concerned with human behaviour, organisational and management issues, marketing, economic and financial considerations, legislation, regulations and other government issues" [7].

A management component of not less than 10% is consistent with the accreditation requirements of The Institute of Engineers, Australia [8]. The importance of a management component is illustrated by Bitcon who, as a result of a survey of engineers within Australia recommended that:

> "Institute of Engineers Australia review its current policy of 10% minimum management content in undergraduate engineering courses with a view to further broadening the education of engineers" [8].

The education sub-committee, not constrained by any issues other than industry requirements, therefore designed a new degree in Instrumentation & Control - the first in Australia and one of the few in the world. However, it exited only on paper. Key features include

At this point, unknown to the committee, other significant developments were occurring. In 1993, the Western Australian Universities were approached on behalf of two city councils to establish a new regional campus. This coincided with a decision by the Federal government to redirect capital away from the established metropolitan campuses to other, more rural areas, designated as high growth regions. The submission by Murdoch University, which included establishing a new engineering program, was selected. This was followed in 1994 by the WA state government decision that Murdoch University should develop new campuses in the designated areas. Murdoch University, at this stage, had decided to design a new degree in Software Engineering. Furthermore, given their well-established programs in mineral science and engineering Murdoch decided to design a another new degree in Process Control.

The IICA education sub-committee invited all the universities for expressions of interest in the proposed new degree in Instrumentation & Control. Murdoch University responded and given their fortuitous circumstances were ideally placed to take advantage of the work done

by the IICA education sub-committee. A working party was then formulated consisting of the IICA education sub-committee and academics from Murdoch University.

The original design proposed by the IICA education sub-committee was modified to accommodate the requirements of Murdoch University. In particular Murdoch required that there should be both a common first year and common management stream shared with their new degree in Software Engineering. This has various advantages in that it allows students to transfer between streams with no penalty at the end of the first year and also maximizes teaching resources. Accordingly, on completion of the first year, students are given the opportunity to make their preference for the award they wish to study. Two consultants evaluated the final curriculum – Professor Darryl Williamson of the Australian National University and Professor Michael Brisk of Monash University. The curriculum has obviously been modified since its initial introduction. The current curriculum outline is provided in table 1.

The common first year curriculum is typical of many engineering degrees and provides a broad base of mathematics, physics, chemistry, engineering and computer science. The second year has common mathematics, computing and engineering management units with software engineering but offers core units in I&C engineering. The third and fourth years have common engineering management subjects shared with software engineering but provides core subjects in I&C engineering. The mathematics includes: differential equations, multivariate calculus, statistics and transform methods. The computer science units address issues that include computer architecture, networking and communications, operating systems, programming principles and techniques. The process module provides an introductory, broad overview to a range of manufacturing processes typical to the minerals processing industries. The first module in control is an introduction to simple industrial control systems. It should be noted that considerable emphasis is placed on providing students with practical experience. The third year of the curriculum provides the basis of engineering thermodynamics through theory, measurement and practical applications.

On completion of the award in I&C, a graduate should be:

- Able to design, specify and commission instrumentation systems and devices for a given measurement application

- Able to apply a range of classical and advanced control methods and techniques to regulate and drive the performance of particular systems for maximum economic return within environmental and safety constraints

- Able to develop and describe relationships that describe the underlying behavior of classes of physical systems.

7. Technical College – Articulation

The two-year, full-time or equivalent part-time Diploma of Engineering (Instrumentation & Control) at the associated technical college (South Metro) provides students with three options. Students may exit with this qualification and work in industry at the Engineering Associate level. Students may extend their studies to a three-year Bachelor of Technology

program (B.Tech, Instrumentation and Control) at university. Students are guaranteed acceptance into the third year of this award on the basis of prior satisfactory progress. Finally students may choose to complete the professional engineering degree (BE) at university. This requires a further two years of study, which includes six months of, approve work experience. The Diploma course contents includes: Electrical principles, Occupational Health & Safety, Measurement techniques, Mathematics, Engineering computing, Workshop practices, Amplifiers, Digital electronics, Soldering, Circuit analysis, DC power supplies, Process characteristics, Control concepts, Engineering chemistry, Engineering management, Data communications, Analogue electronics, Instrumentation & Control.

8. DEVELOPMENTS

The Australian National Training Authority (ANTA) invited the National Utilities Industry Training Advisory Body to submit a proposal to develop generic competency standards to meet the needs of electrical and electronic skills of workers irrespective of the industry. The aim of the generic standards is to move away from the traditional labels of activities in order to reflect the current flexibility and diversity of electrical and electronic workers. The generic cross-industry standards aims to ensure consistent and quality education that is portable within a nationally recognized qualification and to for the basis for a core national framework. The standards were developed in two phases. The first phase was to conduct a national skills audit survey. The second phase involved state based workshops with representatives from all industries. Representatives from the IICA education sub-committee were responsible for the development of the generic competency standards in Process Control.

Murdoch University began teaching the degree in Instrumentation & Control in 1996 with an initial intake of 16 students. During 1996 construction began of new engineering buildings and infrastructure at another site, which have since been completed. The award has gained accreditation from the Institute of Engineers Australia. Graduate Instrumentation and Control Engineers are accredited at Level 2 by the Australian Computer Society and are expected to gain accreditation from the Institution of Instrumentation and Control Australia (IICA) when this society formalizes its requirements.

Bibliography

1. R. B. Newell, “Australian Education in Process Control,” presented at The Fourth Conference on Control Engineering, Gold Coast, 1990.
2. J. G. Bitcon, “The Future Employment of Professional Engineers,” Department of Employment, Education and Training, Canberra 1993.
3. P. Ramsden, *Learning to Teach in Higher Education*. London: Routledge, 1992.
4. C. Armitage, “'Irrelevant Degree Factories' must change with times,” in *The Australian*, 1995, pp. 23.
5. R. M. Cervero, “Professional practice, learning and continuing education: an integrated perspective,” *International Journal of Lifelong Education*, vol. 11, pp. 91-101, 1992.
6. A. W. Goldsworthy, “IT and the Competency Debate - Skill vs Knowledge A Major Issue,” *The Australian Computer Journal*, vol. 25, pp. 113-122, 1993.
7. G. Collins, P. Gardiner, A. Heaton, K. Macrosson, and J. Tait, “The Mangement of Technology: an essential part of training for engineers and scientists,” *International Journal of Technology Management*, vol. 6, pp. 568-593, 1991.

8. The Institute of Engineers, “Accreditation Policies and Procedures Relating to Professional Engineering Undergraduate Courses,” The Institute of Engineers, Australia, ACT 1991.

Year	Semester	Modules
1	1	Engineering Computing I Engineering Mechanics Engineering Mathematics I or Engineering Methods B Engineering Methods A University Foundation Unit
	2	Engineering Computing II Engineering Electrics Engineering Mathematics II Engineering Chemistry Engineering Methods C
2	1	Engineering Computing III Data Communications Engineering Economics Engineering Mathematics III Engineering Fluids & Actuators
	2	Engineering Statistics Computer Systems Architecture Engineering Mathematics IV Process Characteristics Engineering Electronics Control I
3	1	Control II Thermodynamics Instrumentation Modeling & Simulation Technical Communications Engineering Accounting
	2	Embedded & Industrial Computer Systems Chemical Thermodynamics Process Engineering Project and Operational Management Special Studies
4	1	Engineering Management & Organization Design & Instrumentation Special Studies Systems and Signals
	2	Advanced Control Systems Special Studies Topic Engineering Law ICE project

Table 1: B.Eng Curriculum

PAUL MAJ

Dr S P Maj is a recognized authority in the field of industrial and scientific information systems integration and management. He is the author of a text book, *'The Use of Computers in Laboratory Automation'*, which was commissioned by the Royal Society of Chemistry (UK). His first book, *'Language Independent Design Methodology - an introduction'* , was commissioned by the National Computing Center (NCC). Dr S P Maj has organized, chaired and been invited to speak at many international conferences at the highest level. He has also served on many national and international committees and was on the editorial board of two international journals

concerned with the advancement of science and technology. As Deputy Chairman and Treasurer of the *Institute of Instrumentation and Control Australia (IICA*) educational sub-committee he was responsible for successfully designing, in less than two years a new, practical degree in *Instrumentation and Control* to meet the needs of the process industries. This is the first degree of its kind in Australia with the first intake in 1996. It should be recognized that this was a major industry driven initiative.

DAVID VEAL

David Veal received his honours degree in Theoretical Physics from the University of York in England. He lecturered in Physics at South Devon college UK for 10 years. He now lives in Westrn Australia where he has taught Computing and Physics at high school level. He is studying for his PhD in Computing Science at ECU in Perth, Western Australia and is investigating competency based techniques in Computing Science as well as the modeling of computers to aid student understanding.