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The Education of Australian Engineers who Achieved Eminence Before 1940

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SUMMARY There is one common denominator in the careers of engineers who were born in the nineteenth century and who made valuable contributions to the development of Australia: they all were exposed to the work situation at an early age. Close examination shows that those who became eminent did study mathematics and basic science by various means. Biographical studies can provide motivation and inspiration for students and indicate the value of continuing education for practising engineers. If those who are responsible for the development of engineering courses have studied the careers of great engineers of the past, they would be able to act with informed judgement and achieve a balance of theoretical knowledge, practical experience and management skills.

1 INTRODUCTION

Engineers who became eminent in the nineteenth century almost invariably were exposed to the work situation in early teenage. This probably gave them a feeling for their particular industry and a basis for their excellent judgement in middle and late life. Some people felt it was all important to put a thirteen year old to work in the foundry, the workshop, the survey camp or perhaps in the drawing office.

The introduction of engineering courses was met with derision from many of the so called "self-made practical men". However a study of biography shows that those who became eminent did in fact study mathematics and fundamental engineering science by various means. Their studies were not confined to one branch of engineering but covered a wide range of engineering. In addition to study, they were curious about what they observed, and persisted with investigations until their curiosity was satisfied. They made it their business to work in as many departments as possible and to try their hand at as many operations as possible, in order to gain experience in a wide range of engineering practice. They participated in continuing education throughout their careers by further reading, by learned society activities, by publishing papers and checking the calculations of other authors' work and by making overseas trips to observe the latest developments. In addition they had to learn how to manage both money and men so that they could grasp the financial, political and human relations realities of their operations.

When an engineering project has achieved excellence, it can be thought of as being mounted on a tripod so that all the world can see and admire it; if any one of the legs fail, it will crash down. The three legs represent:-

(i) Mathematics and fundamental engineering science;

(ii) Trade skills; and

(iii) Management of money, men, materials, and sales.

The publication "Guide Lines on Education for the Engineering Industry" is designed to cross-brace and strengthen both the theory leg and the trade leg of the tripod.

The following sections list the various methods used to acquire knowledge, with biographical examples to illustrate the achievements of well known engineers.

2 LEARNING ON THE JOB

There is such a wide variation of in-service training that it is best considered in categories.

2.1 Foundry and Workshop

Men with trade skills, many of whom served apprenticeships, made notable contributions to the development of Australia. They include the foundrymen and fabricators who mostly contracted to make up other people's designs; and also the inventors and makers of early agricultural machines. To survive in business they had to apply good management and scientific principles. H. V. McKay's company is a good example. McKay combined several inventions into one machine, he made good decisions in the selection of sites for his operations, and his manufacture and after sales service was efficient. When sales fell, he explored more distant markets and exported to South America.

Successful companies established laboratories and research and development sections. Gradually professional engineers were employed to design special purpose machines. Today computer aided design and manufacture is applied.

2.2 Apprenticeship

Some men became engineers by serving an apprenticeship under an established engineering master. C. Y. O'Connor (b. 1843) is a notable example (Tauman , 1978). He served under the chief engineer of the Limerick Waterford Railway in Ireland. Before coming to Western Australia he was in charge of all public works in New Zealand - roads, railways, harbours and buildings. In W.A. he was confronted with public controversy over which of three ways to develop the Fremantle harbour - his solution has proved to be the correct one. Another achievement was to develop the railways to the extent of making them profitable instead of losing money. His main fame came from the Coolgardie Water Scheme for which he was responsible, and which was considered as an engineering wonder of the world at the time (Ferguson, 1981 and Palmer, 1905).

The road bridge over the Leigh River at Shelford (c. 1874) is a fine example of early Victorian engineering (Alsop, 1974). C. A. C. Wilson (b. 1827) was the engineer. He was indentured to an engineering firm in London before coming to Victoria. He surveyed the Geelong to Melbourne railway line and while working for the Central Roads Board he assisted in building the wrought iron box girder bridge over the Barwon River at Geelong (c. 1859). He built 108 bridges in 22 years - 13 of them being concrete. He attributed his success to his training under the Board's engineer - Charles Rowland. In turn Wilson passed on his knowledge to his son.

These facts indicate the importance of engineers in any era, being responsible for the education and training of their subordinates.

2.3 Night School

Attending night school at Mechanics Institutes and Colleges was another method of gaining theoretical knowledge.

James Harrison (b. 1816) studied Mathematics, Science and English at night school while he was serving his apprenticeship as a printer. After he settled in Geelong he invented the refrigeration cycle. With its applications to food preservation, human comfort and many industrial uses, this invention must rank with James Watt's steam engine in importance (Lang, 1982).

2.4 Private Tutors

University graduates in Mathematics and Science were able to pass on skills and knowledge to people who did not have the opportunity to study at a university. Both O'Connor and Lalor probably increased their understanding of mathematics and and physical science by studying privately under graduates of Trinity College, Dublin.

2.5 Private Study

Some remarkable people learned their basic theory by private study. Sir Charles Todd (b. 1826) gained employment as an assistant and calculator at the Greenwich Observatory when he turned 15. Seven years later he was appointed Assistant Astronomer at the Cambridge Observatory. Later, he took charge of the Galvanic Department of the Royal Observatory. During these three periods of employment he learned enough mathematics and science to become not only an astronomer, but also a meteorologist and electrical engineer. His M.A. from Cambridge was an honorary degree awarded late in life. In 1855 he came to South Australia. His major achievements were the building of telegraph lines from Adelaide to Darwin, and to Melbourne and Sydney. In S.A. he established 510 meteorological stations all served by telegraph. He also worked on electric lighting projects and he experimented with sub-marine cables.

G. D. Delprat (b. 1857) was another engineer who studied privately during his apprenticeship with the contractor who built the Tay River Bridge at Dundee (Mawson, 1958). In 1873 when he would have been only 16, he left Scotland and worked as an assistant to a professor of Physics at Amsterdam. He was apparently able to sit in on tutorials. One day the professor set his students a problem which none of them could solve. He was surprised to find that Delprat had solved it, so he asked him to write the solution on the blackboard, and to read it out to the class. Delprat refused. Later the professor asked him why. Delprat explained that he was too embarrassed to read it because he did not know how to pronounce "those little squiggly symbols" - referring to the Greek letters. The professor was astonished to discover that Delprat had made such remarkable progress by private study. Delprat worked for a while in the laboratory of a diamond cutting factory. Then he was a mine manager and mining consultant in many countries. When on leave, or during his travels, he would visit as many plants or mines as he could. He read journals in several languages and he would pick up any mistake and then correspond with the author.

In 1898 he came to Broken Hill as B.H.P. manager. While there he developed and successfully applied the floatation process - a very important contribution to technological progress.

He recommended to the Board of B.H.P. that the company should phase out the Broken Hill mine and develop an integrated steel works at Newcastle using iron ore from Iron Knob. He travelled overseas to observe developments, and engaged David Baker - a steel expert from the U.S.A. Delprat's skill with human relations, and his honesty, enabled him to have a good record in industrial relations. The establishment of the Newcastle steel works was a notable success.

This was in contrast to the steel works at Lithgow, where Rutherford and Sandford were too enthusiastic with the romantic notion of establishing a great Australian iron and steel works (Hughes, 1962). They had not grasped the financial realities of the industry. Units of plant were too small, ore reserves were over-estimated, and no one was sent overseas to note the latest developments. When the Hoskins brothers took over the works they had to cope with both financial and severe industrial relations problems. Eventually Hoskins phased out the production there and transferred the operation to Port Kembla.

George Chaffey (b. 1848) was another great engineer who studied privately (Alexander, 1928). His father built and operated steam ships on the Great Lakes in America. George left school at an early age and learned his engineering by reading text books and talking to the men in his father's workshops. In his 20's he designed and built 20 steam ships. He invented a new design of propellor which enabled his ships to travel at unusually high speed, yet with economical fuel consumption.

When 32 years old, George Chaffey and his brothers established the irrigation colony called "Ontario", some 100 km inland from Los Angeles. The colony comprised a town and irrigated farms which were served by a water storage in nearby mountains, a hydro-electric power station (the first in Western America), and an agricultural college. He called the wide main street of the town "Euclid Avenue", showing his interest in mathematics.

George Chaffey came to Mildura to establish an irrigation colony there. He designed a pumping station to lift 650 t/min of water from the Murray River to a high point from where it could be reticulated in channels. The pumping plant consisted of a triple expansion steam engine - up-to-date technology in 1887. The crankshaft extended from each end of the engine to take a direct coupled centrifugal pump and a pulley each end. Two other pumps were driven by flat belts from the pulleys, so in all the engine drove four pumps at 160 r.p.m. The impellors were just over 1 m. in diameter. Experts in several countries said that Chaffey was making a grave mistake, and Tangyes of Birmingham, who built the pumps, refused to take any responsibility for their performance. The use of centrifugal pumps was revolutionary, but soon became normal practice for similar work. The whole plant worked perfectly for many years. George Chaffey went back to America and irrigated the Colorado Desert in Southern California.

3 LEARNING BY COURSE WORK

3.1 Military Engineers

There were numerous military engineers who were in charge of government departments particularly in the 1850's and '60's. They all entered the Royal Academy at Woolwich at about 15 years of age and graduated as Lieutenants at about 20. They would have studied mathematics and engineering science in addition to their military training.

3.2 British Engineering Schools

It is of interest to note that Peter Lalor (b.1827) probably qualified as a Civil Engineer at St. Patrick's Carlow Lay College (Blake, 1979). This Irish college was affiliated with the University of London from 1793 to 1882. Lalor worked on the Geelong to Melbourne railway, before he went to Ballarat to mine gold and become involved in the Eureka uprising. In May 1856 the Hon. Peter Lalor, C.E., M.L.C. was appointed "Inspector of Works" for the railways in Victoria.

3.3 Australian Engineering Schools

The University of Melbourne introduced a certificate course to be taken after completing an arts course. W. C. Kernot (b. 1845) graduated B.A. in 1864 and M.A. plus Cert. of Civil Engineering in 1866. He went on to gain broad experience, but not without some frustration. In 1865 he went to the Mines Department where they did not know how to employ a graduate, and he felt his qualification was useless. In 1866 he worked on Melbourne's water supply and was alarmed to find that his seniors were not conscious of the physical laws governing the performance of water supply systems. From 1870 to 1875 he worked with the railways where his superior never missed an opportunity to state that university training was useless. After leaving the railways he worked on a wide range of projects:- structures, a steerable torpedo, telephone and telegraphic services, flood control and electricity generation. In 1883 he became the first Professor of Engineering at the University of Melbourne. He continued to work on a wide range of problems including the balancing of locomotives. He made three overseas trips during his career.

In the late 1880's he conducted a lengthy campaign against anti-academic attitudes in the Institution of Civil Engineers and in the Public Service. Apprentices in the foundry, in the work shop, in survey camps and in the drawing office were expected to study text books at night. This was rarely done, and if it was done, three out of four would be incapable of mastering engineering theory without a competent teacher. Kernot went on to conclude that theory and experience are of equal importance. "Theory without experience is like a foundation without a super-structure. Experience without theory is the super-structure without the foundation - the former is useless, the latter is dangerous". (East, 1984)

Sir John Monash and Dr. Bradfield were early graduates of Australian universities. Both were born in Australia and their careers extended into the 1930's. They were both involved in work at "grass roots" level when they were young, and they both worked in all branches of engineering. As time passed, more and more people graduated, more engineering schools were established and course work became the accepted way to enter the profession.

4 CONCLUSIONS

The achievements of eminent engineers over the past 150 years were not just matters of chance. Those who achieved eminence had two things in common; they all studied mathematics and science by some means of other; and they all had "grass roots" practical experience at an early age.

Academics who design courses could benefit from historical study. There are two opposing factors. On one hand historical studies do indicate the value of people being exposed to the work situation at an early age. On the other hand the pressure on year 12 students is so great that they must devote themselves wholly to their studies.

One compromise would be to take two years to do the year 12 work and add courses in engineering drawing and workshop practice. This would make the students employable. In the second year, extra work would be done, beyond year 12 level, on fundamental science topics that are important to engineers:- e.g. statics and dynamics - the basis for both machine and structural theory. They could then do their degree courses and gain practical experience at the same time. There are obvious advantages in co-operative (e.g. sandwich) courses. The equivalent of one semester on management and financial studies would be advantageous (Arndt, 1981). The undergraduate course should be a general course, not specialising in any one branch of engineering at the expense of other branches. Specialisation can follow with post-graduate studies, and continuing education.

Students can be inspired and motivated by historical studies. Biographies of great engineers can be used as resource material in courses which develop skills in writing, speaking and using libraries. Historic structures and machines can be investigated as part of design and practical work. Historical studies can provide worthwhile final year projects and post graduate theses.

Historical studies remind practising engineers of the importance of continuing education, learned society activities, private study, short courses on specialised subjects, courses run by the vendors of new technology, and overseas study tours.

A study of engineering heritage can therefore be a valuable resource which will enable engineers to maintain and enhance the Australian tradition of excellence.

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