EDUCATING THE RESPONSIBLE ENGINEER: SOCIALLY RESPONSIBLE DESIGN AND SUSTAINABILITY IN THE CURRICULUM

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ABSTRACT

Engineering should serve the community in a socially responsible and sustainable manner.

In order to achieve this, the engineering profession must progress from the role of technical service provider, to a profession that leads change through understanding of the human, environmental, societal and cultural challenges and the consequences of professional activity.

Environmental and social considerations need to be integrated early into the product development process; as early as in the education of the next designers and design engineers. Tomorrow's engineering graduates will need not only awareness, but an embedded ethical philosophy that forms the foundation of their engineering learning. Designing for our complex global societies requires cultural understanding and anticipation of future human needs. Product design teams must address the societal needs of those at the base of the pyramid, rather than the material needs of first world consumers. The needs of those in developing nations, the other 90 percent, should be the target of a new engineering conscience, led by pedagogical change within engineering faculties.

Sustainability and socially responsible design will be only achieved by a paradigm shift which directs the way business, communities and individuals make decisions that contribute to the realisation of broad social goals. The Product Design Engineering program at Swinburne University of Technology seeks to contribute to this new paradigm by integrating sustainability and socially responsible design throughout the engineering curriculum.

As engineering and design educators we have the opportunity to drive a new pedagogy and determine attitudinal change through well considered curricula.

Keywords: Socially responsible design, sustainability, engineering curriculum

1   INTRODUCTION

Designers and engineers must turn their attention to design for need, not want.

The focus of design and engineering activities must shift from servicing only the needs of business to servicing the needs of society, particularly those in developing nations. The provision of the basic living essentials; clean drinking water, sanitation, heating, lighting, healthcare and education can be determined through targeted, sustainable and appropriate product development. Tomorrow's engineering graduates (the 'next engineers') must be responsible, ethical and aware not only of the cultural and environmental impacts of their professional activity, but cognisant of the contribution engineering design can make to societies and quality of life.

Design and engineering education must include significant pedagogy in the areas of ethical behaviour, social responsibility and sustainability. The 'next engineer' will be in a unique (and hopefully informed) position to drive the inevitable changes in the product design and manufacturing environment as companies struggle to deal with new and complex challenges. Diminishing natural resources, restricted consumption of energy and materials, carbon taxes and emission controls, the development of more sustainable processes, emerging markets and significant changes in consumer behaviour must be addressed. Engineering pedagogy can be influential in determining attitudinal change amongst the student cohort and developing sustainable and socially responsible professional practices in its graduates. Educators need to complement engineering proficiency with a social conscience and environmental and cultural sensitivity; "technical virtuosity is often necessary, but never sufficient" [1]

Engineering graduates must have the ability to make sound ethical judgments and assess the long term

consequences of their professional activities. "Because of the intrinsic connection of engineering design with values, the engineer as designer shall not only be answerable for his/her engineering capabilities, but also and always for his/her ethical conceptions and behaviour as a moral person." [2]

2 THE SOCIAL ROLE OF THE 'NEXT ENGINEER'

"Engineering appears to be at a turning point. It is evolving from an occupation that provides clients with competent technical advice to a profession that serves the community in a socially responsible manner." [3]

2.1 The new engineer

Identifying a new underlying principle (and subsequently a new educational position) for the engineering profession is supported by engineering regulatory bodies worldwide. The Institution of Engineers Australia report 'Educating Engineers for a Changing Australia' (IEAust., 1996) identified the need for "a high level of understanding of the broad human, economic and environmental consequences of the professional tasks engineers have to face today." This view is supported by many; "In this evolving world, a new kind of engineer is needed, one who can think broadly across disciplines and consider the human dimensions that are at the heart of every design challenge." [4] and "...it is clear that engineering must go beyond pure technology...and address matters that are imbedded in the social and economic fabric of society." [5]

Yet there is still significant revision required in engineering curricula if the 'next engineers' are to be thoroughly prepared for the challenges that lie ahead. Typically graduates lack understanding of environmental, social and economic impact, are insensitive to cultural idiosyncrasies and are not cognisant of human-centred design practice.

The 'next engineer' will need not only awareness, but an embedded ethical philosophy that stems from the foundation of their engineering learning. This broad social context of understanding should address the mandatory generic attributes specified by the Institution of Engineers Australia including;

- understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
- understanding of the principles of sustainable design and development
- understanding of and commitment to professional and ethical responsibilities

2.2 Sustainability

2005 -2014 is the United Nations 'Decade of Education in Sustainable Development', an initiative that aims to 'encourage changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic viability and a just society for present and future generations'.

Former National President of Engineers Australia, Julie Hammer states "Sustainability cannot be conducted on the sidelines. It can only be achieved by a paradigm shift which results in sustainability becoming part of everyday life, directing the way in which communities and individuals make decisions that contribute to the realisation of broad social goals. As members of the engineering team we are uniquely placed to contribute to the development of this paradigm shift." [6]

The 'next engineers' must take the lead in addressing the challenges faced by the manufacturing sector; energy conservation, carbon emissions, consumption of resources, and emerging technologies. However their biggest challenge will be addressing the needs and aspirations of those who are not part of the first world consumer society; those who currently lack the basic elements that contribute to a healthy, safe and equitable lifestyle.

2.3 Social responsibility

More than one billion people worldwide lack access to clean safe drinking water and 2.6 billion are without basic sanitation. [7] Many lack the necessary resources for education and healthcare, and are denied the tools for self determination. Communities desperately need sustainable energy provision, clean-burning cooking stoves, adequate shelter, communication and transport infrastructure.

These are complex and substantial problems, which are being addressed in limited capacity by the UN, governments, humanitarian aid agencies, and organizations such as Engineers without Borders. These issues need design and engineering solutions, however are often ignored by manufacturers seeking commercial gain. Nevertheless the engineering profession has a responsibility to address the needs of less fortunate global communities. A new approach is essential, one that is "clearly distinguishable from the present market based approach" [8].

What is required is a more responsible and efficient use of resources, a more balanced distribution of resources and opportunities between developed and developing nations (a common ground) and socially responsible design solutions that "not only fulfil specific individual needs, but also enhance the social and collective capacity of a community to develop its own solution." [8]

This will only be achieved through a strategic approach to sustainability and social responsible design that is implicit through educational pedagogy, in short a new "social model" of design practice. [9]

The UN has estimated that 80 percent of all product-related environmental impacts are determined during the product design stage. Consequently product design teams must be fully aware of the environmental and social considerations of their professional activities and possess the knowledge and skills to develop appropriate, sustainable product solutions. However it is not sufficient for designers to merely develop sustainable products that have low embodied energy, reduce the use of hazardous materials and meet the WEEE Directive – these products still feed the material needs of first world consumers. Engineers need to commit to improve the lives of those in developing nations, through a focused agenda of design for need.

This action will require a multi-faceted approach. Engineers and product designers must:

- respond to environmental issues- climate change, water shortages, bio-diversity
- address the impact of their own activities and manufacturing on other communities,
- develop appropriate technologies to assist in the provision of clean water, sanitation, sustainable agriculture, healthcare and disease prevention services
- develop renewable energy production systems
- support the development of self sufficient and sustainable systems for aspirational nations
- involve the community in the problem framing process
- respect cultural diversity and protect traditional values and ways of life
- encourage security and equity and maintain local manufacture/employment
- extend their professional responsibilities from that of service provider

To achieve these objectives a fundamental change must occur; within the engineering profession but more importantly within the education sector. It is the next generation of engineers who will drive the change; they must be prepared for the challenges that lie ahead.

2.4 Human-centred and culturally sensitive

It is crucial that design engineers have a true human focus to their practice. They must endeavour to fully understand the requirements, roles and community status of the users and be respectful of customs and differing expectations to their own. "To better serve humanity, engineers must at least attempt to understand the human condition in all its complexity." [4]

Social research combined with community engagement affords significant cultural understanding and sensitivity to the value systems of differing communities. Engineering students must learn the value of thorough investigation into the user, the culture and environment where the product will be used, how it will be used and why it is required.

The design engineer must ensure that the cultural context of the solution is that of the user and their community and does not contain projected personal values. Designers and engineers should not always view their role purely as a product outcome (as the benefit is limited to the product lifespan) but rather view the customer as a resource rather than the problem. In this sense, design becomes a facilitating tool with power of suggestion, resulting in community enablement and lifelong solutions. [10]

3 A NEW ENGINEERING PEDAGOGY

"A better response lies in changing the scope and significance of what engineering is, and more important, who engineers are – namely, adept people who serve humanity through the application not simply of math and science, but of a wide array of disciplines. This new breed of engineer will be not only be a truly comprehensive problem solver, but a problem definer, leading multidisciplinary teams." [4] This is an admirable aspiration, but significant reform of engineering curricula will be required to prepare engineering graduates for their new responsibilities.

3.1 Curriculum intent

"Engineering education has to prepare young engineers to accept sustainability as a basic design requirement for the development of products and processes …it has to provide the older generation of engineers with a reformation process in order to adjust to a technology that is in harmony with the

environment" [11] It is not sufficient just to provide knowledge and awareness; understanding must be nurtured through a fully integrated approach to the engineering education process. Engineers need to play central roles in developing acceptable technical roles, however educating a new generation of engineers who are capable of problem framing and working in multi-disciplinary environments is a major challenge. Whilst engineers occupy key roles in innovation their practice is limited by the current discourse of their profession; which emphasizes problem solving, but fails to involve the community in framing the problems. [11]

The Australian Universities Community Engagement Alliance position paper [12] states that "exposure to curricula that are informed by real world problems and solutions promises many benefits for students and their communities." Conforming to this position is the Product Design Engineering program at Swinburne University of Technology which is based on a teaching and learning model that imbues students with an understanding of their societal role as engineers and designers through constant exposure to real world learning opportunities.

This engineering design course aims to integrate sustainability and socially responsible design agendas throughout the four-year undergraduate curriculum in a tailored program that develops awareness and understanding through project based learning. Sustainable design is introduced in the second year, whilst socially responsible design is the focus of third and final year studies. Project work is expected to demonstrate a high level of understanding of sustainability issues with appropriate renewable material and process selection, design for disassembly and low embodied energy as indicators of a successful design outcome. Students are asked to address real world scenarios, often working directly with community organizations and humanitarian aid agencies such as World Vision Australia, a non–government organization providing community development and disaster relief worldwide. These projects encourage human-centred research examining the contribution of the design engineer, facilitate collaborative working with communities to realize appropriate sustainable solutions, develop sensitivity to cultural issues and barriers, and demonstrate the importance of appropriate technologies.

By adopting a Socially Responsible Design (SRD) philosophy throughout the course, the course aims to engage in community aid projects that generate design solutions to help the socially and economically disadvantaged. Project objectives require a user-centred approach that addresses not only the needs of the user, but proposes ways to utilize local materials, technologies and expertise in the production of appropriate solutions. Teaching socially responsible design encourages students to shift their focus from glamorous consumer products (an unsustainable model) to design solutions that respond to the user's lifestyle and survival needs, through real world 'design for need' projects.

"In the design perspective, a socially-responsible design solution is a solution that not only fulfils a specific individual need but also enhances social and collective capability of a community to develop its own solution. Socially-responsible design should therefore aim at generating solutions based on a mix of products and services with high cultural and social significance." [8]

This can only be achieved though understanding the user and their needs within their social and economic context and engaging in community activities and humanitarian projects. This is not always possible in an educational context; however the involvement of organizations such as World Vision and the introduction of real world scenarios have lead to a significant broadening of student understanding. Engaging in the development of appropriate solutions has helped develop a culture of social responsibility, sensitivity to cultural values and an ethical approach to design, within these groups of future engineers.

3.2 Project examples

The product design engineering curriculum incorporates a learning sequence that integrates sustainability and social responsible design throughout all course levels. This is an embedded pedagogic philosophy that fosters appropriate and culturally sensitive design, ensures sustainable products and processes and achieves far-sighted solutions.

3.2.1 2nd year – Introduction to sustainability

In this environmental design project students are introduced to the principles of sustainability, Life Cycle Analysis, ethical design and eco-design methods. Students research the electronics industry, examining the implications of domestic e-waste in order to develop environmentally sustainable communication devices. In this process students are required to apply environmental design tools at early concept stage, so that eco-design is systematically integrated in the outcome – 'band-aid' solutions are not permitted. It is important to note that the 'purpose' of the device must also be

sustainable; devices without a 'genuine need' are discouraged.

Design outcomes are assessed for adherence to the "Ten Golden Rules of Eco-Design" [13], life cycle analysis using Eco-Indicator software and a considered 'end of life' scenario.

3.2.2 3rd year – Social responsibility World Vision project

In 2008 World Vision Australia were approached and agreed to participate in this third year project through the provision of real world scenarios requiring a product solution. It was intended that students would have the opportunity to work closely with humanitarian aid workers to gain valuable insights into the cultural and technical issues to facilitate in the development of appropriate solutions. World Vision supplied four scenarios from their global humanitarian relief activities as follows:

- low birth outcomes in Makwanpur, Nepal,
- child survival in Uttar Pradesh. India
- health service reconstruction in Banda Ache, Indonesia (post tsunami)
- Kala Azar (Leishmaniasis) disease prevention in Somalia.

Addressing these scenarios, students adopted a user-centred philosophy and were encouraged to analyse the social, environmental and economic implications of their design outcomes. The many innovative project solutions included fully resolved and appropriate designs for:

- solar powered, portable baby incubators
- locally produced ceramic autoclave
- portable transpiration greenhouse to generate clean water
- solar powered food drying/preserving system
- vaccine and syringe transportation unit
- recording stethoscope for untrained healthcare workers
- solar powered sand fly eradication device and
- bicycle and yak powered patient transportation devices

Response from World Vision has been particularly encouraging, the project is now in its second year and the teaching staff involved were awarded a Vice-Chancellors Award for community engagement.

3.2.3 final year – 2030 carbon neutral vehicle project

In this project students worked with industry partners to develop a future commuter transport concept that utilized an alternative low carbon power source and was intended for shared public ownership, based on a 'base station' infrastructure of recharging/collection centres. The designs aim to alleviate problems caused by car dependency; traffic congestion, green house emissions, fossil fuel consumption and urban sprawl. The proposed vehicles were not dependent on traditional fuel sources utilizing closed loop energy (where possible) and sustainable material and production processes.

Students were required to spend a significant amount of time on research, examining commuter behaviour, the impact of vehicles on urban infrastructure and alternative power source technologies. Research findings were incorporated together with 'cradle-to-grave' philosophy in the final designs. Project outcomes were well received by industry and local councils, and facilitated sponsorship of from Sustainability Victoria, a state government body.

3.2.4 final year: major project – addressing a social need.

The fourth year 'professional project' is self initiated and directed. Projects outcomes must address humanitarian, environmental, medical and/or sustainable needs and represent innovative human-centred design and creative engineering. Students undertake extensive research to identify social needs and potential product solution, and then collaborate with industry partners to develop their designs.

Design outcomes must be sustainable, social responsible and appropriate for the target user/ community. Projects are critically analysed for adherence to these principles and assessed against a criteria which includes design for assembly/disassembly, design for the environment (including a full life cycle analysis), adherence to product design specifications and conformance with social and technical research findings. Recent project examples include: drinking water purification, solar and wind energy generators, a grey water toilet system, mobility aids for the visually impaired, a music therapy instrument for teaching children with disabilities, self powered lighting for remote African communities, a disaster relief cooking stove and a humanitarian aid air drop system.

3.3 Learning outcomes

Whilst the intent of these and other projects is to achieve a successful and appropriate engineering solution to address the challenges of the brief, the learning objectives are of far greater importance. It

is just as important to install the next generation of engineers with an embedded philosophy of ethical and sustainable responsibility as it is to imbue them with the professional skills and knowledge expected by industry. It is these 'next engineers' that has the task of correcting unsustainable development and creating technical solutions that will secure the future. Encouraging and nurturing attitudinal change amongst the student cohort is an essential element in educational pedagogy and must be led by innovative and responsible curricula.

4   CONCLUSION

The engineering profession must be accountable not to the needs of business but to the communities and environments that are affected by its professional activities. Design engineers are faced with many challenges to prevent further environmental degradation, alleviate the impact of climate change and ensure future development and manufacturing is sustainable and appropriate. This will require a paradigm shift in the *modi operandi* of the design, engineering and manufacturing sectors combined with cultural change in first world consumer behaviour. This paradigm shift must be led by educators, through balanced curricula that integrates the principles of sustainable design and socially responsible design at all levels of the learning process.

It is fair to say that most engineering courses cover sustainability and social responsibility in some form. However these theory based subjects are rarely inadequate to develop a graduate with the knowledge, skills and motivation to advance quality of life through sustainable and appropriate design. Creative awareness, understanding and passion to facilitate change emerge only from a consistent approach that embeds a new ethical philosophy in student and lecturer. This requires an experiential model of learning afforded through student engagement in real world projects, with product design outcomes. We must address the social and environmental impact of products not just at the design and manufacturing stage, but also at an educational level if we are to make significant change.

It is hoped that the product design engineering program contributes to this paradigm shift through a new engineering pedagogy that imbues its students with a strong understanding of the importance of their future contributions to society and the impact of appropriate professional behaviour.

The world is in the hands of the 'next engineer'; we must prepare them well.

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