Increasing Safe Design Practice within the Engineering Curriculum

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CONTEXT
The Australian Work Health and Safety Strategy 2012-2022 contains two national Action Areas of direct relevance to Engineering Educators: Healthy and safe by design and Health and safety capabilities. The need for designs to be safe, and for student engineers to develop competencies in this area, is not new. However, poor design of machinery plant and powered tools continues to kill and injure Australian workers. Safe Work Australia (2014) reports that between 2006 and 2011 63, work-related deaths were determined to be caused by the unsafe design of machinery, plant and power tools, or design-related factors contributed to the fatality. A further 125 fatalities were considered as possibly design-related. It is sad fact that many of these deaths were preventable with existing design solutions.
Good design can eliminate (or minimise the impact of) the major physical, biomechanical and psychosocial hazards associated with work. From an engineering education perspective it is necessary to increase awareness amongst educators and students of these processes such that consideration of safe design is inherent to the engineering design process and not simply an added regulatory requirement.

PURPOSE
Safe design is not a separate activity or series of activities, but is integral to the engineering process regardless of sector or discipline. This paper reviews the role of engineering educators in understanding, promoting and embedding safe design principles within the engineering curricula.

APPROACH
The paper explores how safe design has been incorporated into engineering education since the early 1990s, and assesses the effectiveness of available resources and teaching practice. Changes to the legislative environment throughout this time are also described, to provide context and articulate implications for engineering educators.

RESULTS
The importance of safe design is recognised and resources do exist to support engineering educators to embed safe design principles within curriculum. The paper provides a series of recommendations to mainstream the available resources, highlights characteristics of effective practice and identifies areas for further professional development of engineering educators who are not familiar with safe design principles.

CONCLUSIONS
In order to develop graduates who are safe design practitioners, the model of engineering design introduced within the engineering curriculum must demonstrate that safe design is an inherent user requirement for all projects. This requires engineering educators to be familiar with human centred engineering design and how this impacts traditional technical design outcomes.

KEYWORDS
Safe design, safety in design, engineering management system, work health and safety.

Introduction

The Australian Work Health and Safety Strategy 2012-2022 is based on two principles: all workers have a right to a healthy and safe working environment; and well-designed, healthy and safe work will allow workers to have more productive lives (Safe Work Australia, 2012a). Engineers have a fundamental role in, and responsibility for, the design of safe environments, plant, structures and systems of work. This responsibility extends to the full life-cycle of a design, from its initial conception through to its decommissioning and disposal. Engineering educators have a fundamental role in designing contemporary curricula, which will enable the engineers of the future to develop the necessary competencies, and mindset, to mainstream Safe Design practice. This includes developing an appreciation of: the engineering lifecycle, and the steps within it; the role of Engineering Management; and the value of critical forward thinking.

The need for Safe Design practice to be included within the engineering curriculum was first identified in the late 1980s, and nationally funded resources have been available to engineering educators. However, it is timely to review whether engineering educators have the capabilities and resources necessary to effectively develop the work health and safety capabilities of our future engineers. Over the past five to ten years, the role of the engineering educator has changed: outcomes-based curriculum design has progressed; modern pedagogies provide new opportunities for the integration of socio-technical skill development; Safe Design practice is better understood; and, the harmonisation of Work Health and Safety (WHS) legislation across Australia has re-emphasised the responsibility of the designer.

This paper reviews the current environment in relation to Safe Design practice, legislative requirements, and the resources available to engineering educators. Its intention is to raise awareness of the role that engineering educators, and engineers, have in progressing towards the 2022 targets of the Australian Work Health and Safety Strategy.

For the purpose of this paper, Safe Design practice incorporates the terms Safe Design, Safety in Design, Healthy and Safe by Design, Safe by Design and Prevention through Design (PtD). The first four terms are used within an Australian context whereas PtD is used by the National Institute for Occupational Safety and Health (NIOSH) in the United States. The paper also uses Work Health and Safety (WHS), in preference to Occupational Health and Safety (OHS), to reflect the model Work Health and Safety (WHS) Act.

Background

An appreciation of WHS requirements, and the associated responsibility, is innate to the engineering profession. This is reflected in the Engineers Australia Code of Ethics (Engineers Australia, 2010) and the full suite of Engineers Australia's competency standards. Within the Stage 1 Competency Standard for the Professional Engineer (Engineers Australia, 2013), the range of indicators of competency attainment related to WHS extends from basic cognitive knowledge of requirements, through to application ability and higher level appreciation (and valuing) of the core principles.

This range is also representative of practice. WHS related Australian Standards (e.g. *AS/NZ 4801 Occupational Health and Safety Management Systems*) and the model Work Health and Safety (WHS) Act require engineers to apply a diverse range of skills while having concurrent WHS responsibilities. These responsibilities extend from an individual duty as a worker to duties of persons conducting businesses or undertakings under the Act. It is the latter responsibilities, particularly with regard to design responsibilities within the Act (Section 22), which are of relevance to this paper. While all responsibilities are important, there are typically overt WHS requirements in relation to oneself and others within a workplace. Safe Design practice on the other hand is complex, requires an appreciation of a different field

(human factors), and competes with other contextual constraints such as social, cultural, functionality and environmental imperatives within the design process. It requires human-centric designers to reasonably foresee interdependencies with connected systems, and consider end-user requirements. This is a skill that requires development through repeated application.

Although Safe Design featured in the 2002-2012 national WHS Strategy, its prominence in the Australian Work Health and Safety Strategy 2012-2022 is indicative of the necessity to continue to work towards the 2022 outcome of reducing the incidence of work-related death, injury, and illness. Engineering Educators can have a leadership role within the Strategy by addressing the Action Areas of *Healthy and safe by design* and *Health and safety capabilities.*

Within the profession, continued professional development activities increased in 2012 with the harmonisation of WHS legislation. This legislation saw the introduction of a model Work Health and Safety (Act) and a series of model Codes of Practice. While the new legislation essentially did not change designer's responsibilities, it did re-emphasise the responsibilities and successful prosecutions under the previous Act were starting to appear. E.g. *Simpson Design Associates Pty Ltd v Industrial Court of New South Wales [2011] NSWCA 316.*

The national strategy, harmonised legislation, prosecutions and renewed emphasis on Safe Design within the profession all confirm the need for reviewing the adequacy on Safe Design curricula within engineering programs.

Safe Design

Safe Design Practice seeks to eliminate or control hazards early in the design phase (Safe Work Australia, 2012b). The design phase provides the greatest opportunity to eliminate the hazard and, where reasonable and practicable, is the preferred control measure within the standard hierarchy of controls (Figure 1). By eliminating the hazard, less effective control measures such as isolation (e.g. physical guarding) become redundant and the resultant risk can be reduced.

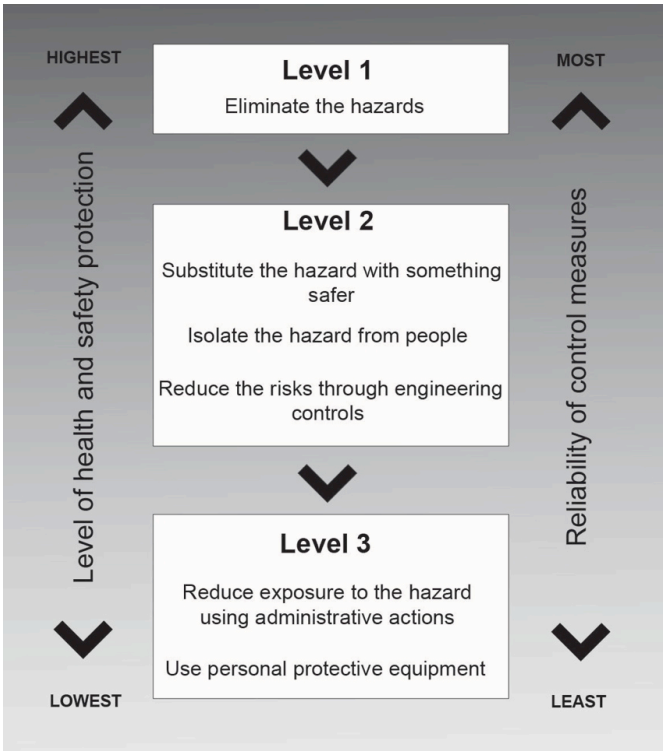

Figure 1: Hierarchy of controls (Safe Work Australia, 2013)

The role that poor design can have in workplace injuries and fatalities is well established and there is an increasing understanding of the nature of the incidents and how they could have been prevented (Australian Safety and Compensation Council, 2005, Australian Safety and Compensation Council, 2006a, Bluff, 2015, National Occupational Health & Safety Commission, 2004, Safe Work Australia, 2014). However, attributing the root cause of an incident to its design is difficult, as often there are other contributing factors. What can be more difficult is recognising a potential hazard at the design stage. This is because the design hazard may only be apparent for particular end-user behaviour or when manual intervention is required.

Safe Design within Engineering Curricula

The need to incorporate Safe Design practice within engineering curricula has been recognised for more than twenty-five years, with the first national teaching resource being provided to engineering educators in 1990 by the National Occupational Health and Safety Commission. This resource was provided prior to the first set of accreditation competency standards being released by Engineers Australia in 1993, and its use would have been directly related to who it was distributed to. Each review of Engineers Australia's competency standards has seen a greater emphasis placed on WHS knowledge, Safe Design and application ability, with the 2011 Standards (Engineers Australia, 2013) being the most comprehensive. The recognition of Safe Design practice within the competency standard requires educators to review and consider how the relevant competencies are being developed through the regular accreditation cycle. While this is positive, the nature of the education system is such that changes can be slow to materialise and are often piecemeal by nature.

Reviews of how Safe Design practice (and the development of WHS capabilities more generally) is incorporated into curricula have been undertaken in the United Kingdom (Care, Jary and Parnell, 2012), Europe (European Agency for Security and Health at Work, 2010), the United States (Popov, Blunt, McGlothlin, Young-Corbett, and Heckel, 2013) and Australia (Wallis, 2012). With the exception of Wallis (2012), each review uses case studies to demonstrate how Safe Design or WHS is incorporated within given disciplines and then offers recommendations in relation to improvements. Common themes for improvement include: a need to further integrate/embed practice across all levels of a program; a need to further share best practice examples; a need to be mindful of language, to destigmatise WHS; and, a need to develop the WHS skill sets of both the educators and students.

Within the Australian context, Wallis (2012) undertook a study of building, design and construction qualifications to examine the extent to which WHS and Safe Design is embedded. The review included VET and higher education qualifications and found that the VET sector included more WHS units in the qualifications offered than the higher education sector. The review did not include all disciplines and needed to rely largely on publicly available material and focus groups. Explicit reference to Safe Design practice was included in less than 10% for the qualifications examined in the study. While this is evidence that there is a need to increase Safe Design practice within engineering curricula, it does not mean that there are not exemplars of practice that should be shared. In addition, common approaches to raising WHS awareness, such as learning from disasters, can often be embedded within other courses and therefore may not be as apparent in such reviews.

Looking more broadly, the extent to which Safe Design practice is incorporated into engineering curricula appears to be related to discipline-specific needs and/or interest areas of individual engineering educators. For example, units of study related to process and system safety can be found in Australian chemical and/or risk engineering programs. These units develop specialist WHS expertise to participate in hazard and operability studies

(HAZOP), undertake risk assessments and conduct functional safety reviews in high-risk environments.

The need for Safe Design practice is not limited to high-risk environments, Safe Design practice applies across all engineering disciplines, and this is where the interests of individual educators can be seen. Safe Design is not unique in this regard. Male and King (2014) collated exemplars of effective industry engagement within engineering programs and found that often examples of industry engagement practice occurred in isolation, and depended on the networks or interests of particular educators. Examples of Safe Design practice within curricula include transdisciplinary partnerships (Toft, Howard and Jorgensen, 2003, Toft and Howard, 2009); scaffolding of Safe Design awareness within a program (Behm, Culvenor and Dixon, 2014); increasing industry engagement (Male and King, 2014); and, use of adapted industry management system processes (Wood, 2013, Foley and Willis, 2015).

Available resources

Resources available to assist engineering educators integrate Safe Design within curricula have in the past been developed by national bodies (with engineering input) and are often complementary to resources provided to the profession. The *Safe Design for Engineering Students* (Australian Safety and Compensation Council, 2006a) was the last resource published by a government body for engineering educators. It provides useful case studies, curriculum notes, and insights into the complexity of Safe Design. It has a companion guide for the profession (Australian Safety and Compensation Council, 2006b), which affords authenticity for the material being presented to undergraduate students. While much of the content remains relevant, the harmonisation of WHS legislation and changes to Engineers Australia competency standards renders the resource out of date.

The release of the Australian Work Health and Safety Strategy 2012-2022 together with the harmonisation of WHS legislation has seen many of the previously available resources updated and/or additional resources created with regard to Safe Design practice. These resources include many Codes of Practice (e.g. Safe Work Australia, 2012b), WHS handbooks (e.g. Safe Work Australia, 2015), industry-sponsored resources (Consult Australia, 2012), and online education resources such as virtual seminars (http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/vss/pages/2016-vss). In addition, regulators such as Safework SA also have online education materials of potential relevance.

These more recent resources were not developed *for* engineering educators but provide authentic resources, upon which modern learning activities can be based. This is an advantage over past resources, as it provides exciting opportunities to embed and/or scaffold Safe Design practice within a program, particularly through project-based learning. By doing so, it demonstrates that Safe Design is integral to the engineering design process and not something being required by others. The examples referred to in the previous section demonstrate this approach and other tools enable an assessment of curricula to be undertaken (Rothmore, Pisaniello, and Stewart, 2011).

Embedding Safe Design resources within curricula requires engineering educators to be aware of the resources, have knowledge of their application in industry, and be willing to support the development of Safe Design (and WHS capabilities more broadly) throughout a program. While this in itself is a challenge, embedding Safe Design needs to complement the development of other professional practice skills and/or contextual imperatives (e.g. sustainability), which are also inherent to good engineering design practice.

Conclusion

Safe Design practice is not an optional extra for engineers. It is integral to good engineering design practice, a recognised area of national priority, and mandated through legislation. Engineering educators have a responsibility to create curricula which enable the engineers of the future to engage with Safe Design practice and, while there are many available resources and exemplars, *further action is required*. This action includes reviewing the adequacy of existing practice, sharing good practice and further developing the WHS capabilities of engineering educators through promoting critical forward thinking and an understanding of the engineering lifecycle.

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