# Engineering design is a fundamental consideration in "sustainability" – Where does ergonomics fit?

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## Abstract

"Sustainability" encompasses the agendas of social equity, ecological quality and economic prosperity. It requires that our actions today do not degrade, and strive to improve the quality of life for this generation and generations of the future. Where does ergonomics fit in this equation?

Human error is a significant contributing factor to the cause of accidents and lost productivity. The literature shows that effective human interface design will increase the usability and productivity of a system; and the consideration of human factors in the design process will reduce the likelihood of human error, resulting in a safer, more efficient work environment for all stakeholders. Engineers, as designers of equipment and processes, are integral to the development of safe and efficient design, a human-system interface that is free of latent error sources.

What do engineers know about designing for human use? This research found that engineering educators have a positive attitude toward the inclusion of ergonomic principles in engineering design practice. On the down side, the educators report they do not have the knowledge, skills or abilities to include ergonomic principles in their own practice or to teach these skills to their students. Those surveyed were mostly unaware that cognitive ergonomics existed. Competency standards for professional engineers in Australia include a user centred design ethos but there is little evidence of systematic inclusion of ergonomic principles in engineering design curriculum.

Australian ergonomists were recently found to consider informing the conceptual phase, of the engineering design process, a specialist activity. The question then needs to be asked: who is taking responsibility for optimizing human-system compatibility? This research explores the barriers and challenges to safe and efficient design. The economic, societal and environmental costs of an unsafe and / or inefficient system design are too great to be acceptable, and are not sustainable.

## Introduction

"Sustainability" can be broadly defined as an expectation of practicing engineers to ensure that their work does not degrade and strives to improve the quality of life for this generation and generations of the future. It should include consideration of the agenda's of social equity,

ecological quality, and economic prosperity in relation to one another. This paper explores the notion of sustainability and the integral nature of engineering design in achieving this vision. The significance of sustainability in the context of this research is the interrelatedness of the human, economic and other resources in systems planning and designs. It can be argued that a system design, which leads to user injury, user avoidance and therefore waste or underutilisation through lack of usability, or inefficient in design leading to increased inputs or reduced / more expensive outputs, is not sustainable.

Effective human interface design will increase the usability and productivity of a system (Jordan, 1998). Consideration of "human factors" will reduce the likelihood of human error resulting in a safer, more efficient work environment for all stakeholders (Sanders and McCormick, 1993). It follows that engineers will need to draw on the scientific discipline of ergonomics if they are to achieve sustainable design. Engineering, as a profession globally, is experiencing a paradigm shift (Messer, 1998). Global conferences have called for the development of generic attributes in engineers, which encompass the societal context of engineering practice.

This research was borne of a desire to try and discover the link between these concepts. What did engineers need to know about ergonomics to problem solve design issues effectively utilizing a holistic framework? Did engineers believe ergonomics was important to sustainable engineering design practice? How could engineering students and graduates benefit from this finding to enhance their professional practice and move toward sustainable engineering design? A subsequent extensive search of relevant literature revealed minimal explanation as to why engineering education in Australia did not systematically include, even at a basic level, coverage of ergonomic principles.

**What did the engineers say?**

This section reports the findings of a cross-sectional study that explored the relationship between ergonomics and engineering education. Members of the Australasian Association for Engineering Education were asked to complete the survey, which included open-ended questions and a five point Likert scale.

Some of objectives of the study were:

- to determine the attitude of professional engineering educators in Australasia toward ergonomic principles in engineering practice;
- to determine if the intensity of the attitude response was related to previous exposure to ergonomic training; and
- to ascertain if engineering educators would support the inclusion of ergonomic principles in undergraduate engineering curriculum.

There was a significantly greater positive attitude response toward ergonomic principles in engineering practice given by those who had been exposed to ergonomic training compared with those who had no ergonomic training. A respondent commented in relation to this point "Engineering is principally about improving the human condition. If

you don't know what the human "condition" is, how can this be achieved? Not only are the physical dimensions and characteristics of an "average" person important, engineers must address such issues as cultural background, level of education, common disabilities (e.g. Colour blindness)."

Human error is known to be a major contributing factor in industrial accidents in Australia (Feyer and Williamson, 1991; Williamson and Feyer, 1990). Researchers have found that a high rate of human error can be related to design error (Reason, 1990). Survey responses relating to the relationship between engineering design and human error resulted in a mean score of 4.7 for those with some ergonomic training compared with a score of 4.2 for those without ergonomic training. This may be evidence of a knowledge gap in the theory of human error and latent design deficiency. Forty-seven percent of participants strongly agreed with the statement, 'user safety should be the highest priority in the development of a product / system'. An explanation for the higher deviation of observed values from the mean score (4.1 [+ or - ] 1.5) may have been hinted at in the recommendations arising from the pilot study. Participants in the pilot study argued that 'safety' was a distraction, they expressed concern that concentrating on 'safety' as an issue would not be the way to convince engineers that ergonomics was important, that engineering practice was tied in safety 'red tape' already.

Those who had some ergonomics training indicated, with a greater positive attitude response, an understanding of the cost / benefit analysis of ergonomics. The majority of engineering educators, who replied, indicated a positive attitude response to the notion that the productivity of a system can be improved through ergonomic intervention. Many supplemented their response with anecdotal observations of experiences where they had noted productivity improvement.

Pheasant (1986) found that many designers are intuitive in their approach to design. He argues that "…by empathetically casting oneself in the role of the user, the act of designing for others becomes an extension of designing for oneself and the traditional subjective approach becomes valid…" (Pheasant, 1986:10). Ward (1990) continues this theme, suggesting that those involved in the design process are mostly unaware of the problems faced by users. The respondents in this survey indicated a positive attitude with regard to the need for data in the application of ergonomics, although those with no previous training indicated a less positive attitude response than those who had some training. This may be indicative of an intuitive approach to design without the benefit of ergonomic knowledge.

Of the three who believed that 'ergonomic principles are already taught in undergraduate engineering programs', two went on to qualify their response by adding "at this institution". Many of the respondents who chose 'uncertain' in response to this statement also qualified their answer, indicating that they believed it could be included in some programs but they were uncertain that it was included in all programs.

The majority of the participants (56%) indicated that ergonomics was not taught to undergraduate engineers. As sixty-four percent of participants had already indicated that they had never received any ergonomic training or education (formal or informal) in the demographic data, it can be assumed that the majority of undergraduate engineering programs do not systematically include ergonomic principles in their curricula.

Over sixty percent of the participants, disagreed or strongly disagreed that engineering educators have the skills / knowledge necessary to teach ergonomic principles. Given that a similar number of participants indicated that they have never been exposed to any ergonomic education; it could be expected that they might believe that they don't have the knowledge necessary to teach the subject. Many participants qualified their answer by stating that although they didn't have the necessary knowledge now, they could develop the skills / knowledge necessary to teach ergonomic principles in the future. Yet another disagreed with the statement and went on to include that the "training should start with them…(that) unless they are taught by engineers, the students will not see the teaching as relevant…(that) they are heavily into role modeling".

One participant provided an interesting and detailed analysis of some of the pertinent issues. He stated "I have involved both colleagues with a background in ergonomics and staff from industrial design … in engineering design to present ergonomics and human factors issues … some teaching in this area myself based on my reading and my own consulting work in this area. Many engineering academics are essentially engineering scientists, with little experience or awareness of design / practice issues like ergonomics, so they are not aware of their importance or adequately prepared to teach them. The problem is, of course much broader than this, hence the importance of the IE Australia requirements for inclusion of contextual material in engineering courses."

Finally, to the question of whether ergonomics should be included in the curriculum of undergraduate engineering programs. Participants indicated a positive affirmation that the principles should be included. Over eighty percent of participants agreed or strongly agreed that it should be included. Some participants offered advice with regard to how best facilitate the inclusion of ergonomics in engineering curriculum: "… three lectures on the 'the human specification' in an engineering course is sufficient for graduating engineers. The idea is to trigger student minds, after this there are many good books on the subject…"; yet another stated, "… I have been lucky enough in the last year to have a colleague (from another faculty) who is qualified to teach ergonomics, and has readily given her time. I feel this has been a benefit to not only the students but myself too. While it is always difficult to 'add' to curriculum in such a full degree, I feel it will be vital for the engineers of the future to be aware of these issues, and not be afraid to use the expertise of those who study ergonomics. It is all

part of the necessity for engineers to be team players instead of individual experts."
In support of the inclusion of ergonomics participants cited experiences in Australia and overseas which emphasized the importance of the topic. From an international perspective one participant commented on the European recognition for many years of the importance of ergonomics in engineering practice.
Those from a diversity of disciplines added their perspective to the discussion; many information technology and telecommunications engineers rated ergonomics as essential to that discipline; mechanical and biomedical engineers also commented on the necessity of ergonomics to their field.

**Sustainable engineering design**

As stated earlier, the significance of sustainability in the context of design is the interrelatedness of the human, economic and other resources in systems planning and designs to optimize quality of life. The engineering profession has embraced environmental and economic responsibility within engineering design. The profession now needs to understand the importance of humans as an integral component in system design. It should no longer be acceptable to develop unsafe or inefficient design that will in the future require retrofit. Designers can not be divorced from the use of their designs. Ethically and legally they are required to take social responsibility for their decisions well into the future.
Moves have been made toward addressing the human component by the Institution of Engineers, Australia with the introduction of the most recent competency standards for design. This research has shown, however, that nothing exists within the current curriculum of most Australasian engineering faculties, which would support these competency standards. More pressure needs to be brought to bear by industry and user groups to ensure that safe design is included in curriculum. One of the complicating factors is that engineers report that they do not have skills and knowledge in the area of occupational health and safety, and would need to first learn themselves about ergonomic principles of design.
Engineers are taught verbatim the Australian standards and legislation, what is missing? The knowledge to allow them to, as Nelson and associates (2000) suggest, "design the system to fit or take advantage of the strongest and most effective human characteristics related to system requirements and not design a system that makes demands on human performance that are near or outside the areas of human strengths or the most effective human capabilities." (Nelson, 2000).
It was found that preaching safety to engineers is a distraction to encouraging effective design. Engineers think they are already doing the right thing by designing to the existing standards. Good design can no longer be seen simply as developing a technically good solution to a problem. The designer of the future must aim to design a socio-technical solution. This will require a cultural change, a paradigm shift

and the courage to commit to that shift. This will be most easily achieved through integrating human factor knowledge with engineering design at an undergraduate level. Consideration must also be given to the needs of the professional engineers currently practicing by way of professional development. In light of Carmichael's (1997) findings, which highlighted that ergonomists saw informing engineering design at the concept stage as a specialist activity, the ergonomic profession needs to change emphasis to proactively encourage input at the design stage rather than retrofitting. The profession must accept this as a generalist activity. Occupational health and safety professionals must also take responsibility for ensuring safe design by lifting awareness of the importance of their input to the multi disciplinary design team.

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