# Human factors in engineering education

by Kim J. Vicente, PhD, P.Eng.

**Why did Ontario Power Generation shut down seven nuclear plants, despite the dire economic and environmental consequences? The reason teaches us about what's missing in engineering education.**

As in the following case, costly decisions made by professional engineers in industry sometimes show us how engineering education can be improved. On August 13, 1997, Ontario Power Generation or OPG (formerly Ontario Hydro)–one of the largest electrical utilities in North America–announced that it had decided to shut down seven of its 20 nuclear power plants at an estimated cost of $8 billion. Consequently, it would have to increase production from coal- and oil-fired power plants, which was expected to lead to a huge increase in greenhouse emissions, especially carbon dioxide. The increase in emissions was estimated by some to be equivalent to adding seven million cars to the existing five million already on Ontario roads.

These drastic steps were taken based on the recommendations of a group hired by OPG to conduct an independent, external audit of its nuclear operations (Andognini, 1997). This thorough performance assessment involved a team of 75 experts from various disciplines, and consisted of approximately 35,000 person-hours of effort.

OPG should be commended for taking these proactive steps on its own initiative, rather than waiting for a severe accident to happen and then making changes. Having said that, I believe that what happened at OPG is indicative of a latent problem with undergraduate engineering curricula. The following explanation shows why.

## Why the shutdown?

In the absence of an accident or a regulatory mandate, what caused OPG to shut down some of its plants? Clearly, there must have been very good reasons, given the $8 billion price tag and the negative impact on the environment. The obvious candidate is technology; perhaps there were several deep flaws in the design of these plants? In fact, this was not the case. Canadian-designed CANDU technology has several advantages over other types of nuclear power plant designs, such as those used in the United States. These advantages include:

> "Today, I am more than ever frightened. I wish it would dawn upon engineers that, in order to be an engineer, it is not enough to be an engineer."
>
> *José Ortega y Gasset (Spanish writer and philosopher)*

- ◆ the use of digital automation technology, which is much more reliable than its analogue counterpart;
- ◆ a design that allows refueling without shutting down the reactor, thereby saving money;
- ◆ the availability of extensive redundancy, thereby improving reliability; and
- ◆ the use of heavy water as both a moderator and a coolant, thereby creating a passive safety system.

Therefore, technology does not appear to have been the problem and, in fact, was not cited in the Andognini report as a cause of concern. Instead, the primary threats to safety that were cited in the report and that justified the $8 billion decision were human and organizational factors. Many worrisome examples were documented by Andognini (1997). For example, the report noted that insufficient attention had been paid to training and control room design:

- ◆ "Human factors shortcomings ... place an unreasonable burden on operators."
- ◆ "Management has not effectively resolved long-standing problems, which have a negative impact on operator performance."

The report concluded that plants were designed and operated with insufficient consideration of human capabilities and limitations, thereby making the operators' job more difficult than it need be and inadvertently increasing the likelihood that human error would threaten plant safety. The report also noted an organizational tendency to put production concerns ahead of plant safety. It states that:

◆ [There was a] "lack of commitment to the establishment and maintenance of a strong safety culture."

◆ "It's acceptable to cut corners. It is not acceptable to make waves."

◆ "Those who have made waves have been fired or sidelined. The messenger with the bad news will be told to fix the problem."

◆ "The erosion of station performance is well documented in peer evaluations and AECB reports, yet senior corporate services management has failed to grasp the reality of the situation, voice its concern with executive management, and redirect the corporate resource. The generally relaxed atmosphere at headquarters ... does not reflect the level of intensity that the [audit] team expected to find, given the reported conditions that exist at the stations."

The report concluded that plants were also designed and operated with insufficient consideration of the interaction between people and technology. Again, the result was an inadvertent threat to plant safety.

## Implications for engineering education

Human factors engineering is the design discipline that examines the interaction between technology and people, broadly defined to include the anatomical, physiological, psychological and social-organizational issues relevant to the safe and productive operation of engineering systems.

The failure to pay sufficient attention to human and organizational factors in this case (and many other cases in industry) is indicative of a significant gap in engineering education. Our students receive excellent technical training that prepares them well for creating innovative technological designs, such as the CANDU reactor. However, the vast majority do not take a single course devoted solely to human factors in contemporary engineering projects. As a result, they are sometimes ill-equipped to deal with the challenges imposed by sociotechnical systems, of which nuclear power plants are only one example.

This gap in engineering education can have profound economic and environmental implications, as the OPG case study shows. Systems may be designed very well from a technological viewpoint, but they may nevertheless be ineffective because of the critical impact that human factors can have on safety and productivity.

The rationale for the inclusion of human factors in all engineering curricula can be made through an analogy. Every engineering undergraduate is usually required to take one course in engineering economic analysis. This does not make these students expert accountants or economists; specialists will always be needed. However, such a course exposes students to the relevance of economic factors to project management. Students are required to take this course because, no matter what the industry, every engineering project involves economic considerations somewhere along the way. The very same argument applies to human and organizational factors: Every engineering project involves the interaction between technology and people, as well as organizations. Yet, there is no requirement for all engineers to be exposed to this important set of considerations.

The fundamental lesson of this, and many other, case studies is that human and organizational considerations cannot be divorced from technology. When we design a system, we are not just designing technology; we are also designing people's jobs and an organizational structure. For the technology to achieve its desired objectives, all of these pieces of the puzzle have to be seamlessly integrated. To prepare for this challenge, all engineers should be exposed to human factors engineering. We will know that we will have succeeded in effecting the required changes when all professional engineers take to heart the fact that if technology does not work for people, then it does not work (Lund, 1996). ◆



## References

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2. Lund, A.M. "Advertising human factors," *Ergonomics in Design*, 4(4), 5-11, 1996.

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