Ethical Engineering Practice & Creativity: Educating Younger Engineers in a Computer Society

Old means of providing the apprenticeship of engineers can no longer keep apace with the benefits in time, cost and creativity that computerization brings.

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In recent years, advances in technology have had a tremendous effect on the design profession. With the advent of the greater availability of powerful, inexpensive computers and effective software, engineers can now directly solve technical problems in a few hours, ten times as fast as the old manual solutions, which were less accurate.

Much attention has been focused on the technical application of these significant advances in computer science within the profession of civil engineering. Less has been said about another aspect of this subject that is having as great, if not greater, effect on the way engineers do their work. Computers are not only changing the technical quality of civil engineering work, but they are also changing the way engineers go about the business of their profession. This change affects engineers both individually (in terms of how they perform their own work) and collectively (in terms of how they work with and report to each other), especially with regard to the training of new engineers. The question of the conflict between creativity and ethical engineering is integral to this change. It is of particular interest to younger engineers, the ones who are most involved with, and affected by, computer use.

The Apprenticeship Method

Traditionally, civil engineering education has been handled, in a broad sense, by a master engineer-apprentice format. For most design offices, newly-graduated engineers need to acquire several years of that magic, all-important ingredient called "experience" to complete their education. The key elements of civil design could not be learned solely through four or more years of formal education. Only through a period of informal on-the-job education could the younger engineer gain the skills needed to make the jump from engineering graduate to design professional by a sort of "osmosis." The length of this apprenticeship period varied according to the young engineer's chosen discipline within civil engineering and the nature and structure of the organization taking a chance on completing his or her education. This arrangement served the design industry well for many decades.

In the past, all branches of civil engineering design have required weeks of manual calculations to solve design problems. Over the years, clever engineers developed short-cut methods, rules of thumb, and effective approximations to get at the required information. Despite the use of these short cuts, the brunt of the work remained: days of tedious moment distribution, days of tedious processing of geotechnical lab results. For the experienced engineer, this problem was actually an opportunity. Younger engineers were assigned the task of completing these manual calculations.

The basic assumption of this method was that in the process of trudging through this work, the new engineer would indirectly gain the required knowledge that defines experience. By working through different analyses, the younger engineer learned not just how to perform the analysis, but also determined which method was most appropriate to solve a particular design problem. By manually marking up drawings, the engineer not only helped complete the work, but also learned about appropriate details and how drawings were put together. For the senior engineer, it was a good arrangement: the cumbersome manual work provided a format to train inexperienced engineers, and the availability of the younger engineers to do this work freed the more senior engineers to conceptualize the problem and guide it to its solution.

The Effect of Computerization

However, computers — especially the proliferation of the new cheap and powerful personal computers (PCs) — are changing the traditional process of completing design work. In minutes, computers can solve problems that used to require days to complete. For example, an inexpensive PC-based frame program can analyze the whole frame and even select the appropriate members. In this way, a week's worth of the young engineer's time is reduced to a few hours. Lengthy manual calculations are no longer necessary. On the other hand, no longer will the junior engineer gain that intangible — "experience" — by plowing through a mountain of tedious manual work.

Ethics & Creativity

In general, ethical engineering practice requires that engineers provide their clients with safe, economical, utilitarian designs that take into account the various constraints that are recognized to affect the design. In the American Society of Civil Engineers *Code of Ethics,* two of the Fundamental Principles state that engineers should uphold and advance the integrity, honor and dignity of the engineering profession by "using their knowledge and skill for the enhancement of human welfare" and by "striving to increase the competence and prestige of engineering."[1]

With the widespread availability of computers, what is possible in design has been expanded dramatically both in terms of the quality as well as the quantity that can be generated. It can be viewed as being unethical not to provide clients with the type of service that the use of computers can provide, now that that capability exists. In addition, there is the issue of competition to address. Firms employing computers might be better able to compete with firms that use more highly-skilled labor-intensive methods. Organizations with half the personnel of larger firms may be now able to compete effectively.

However, it is equally unacceptable to inadequately train younger engineers. Because the new technology is making impractical the way junior engineers were trained in the past, the design profession must find new ways for young engineers to gain experience.

As the structure of engineering design changes and engineers seek a new format to train inexperienced engineers, the profession, as a whole, should consider the following points:

- Using computers to train new engineers
- Developing standards for computer use
- Motivating younger engineers

Computer Training

First of all, computers can be used to help train younger engineers. Junior designers can learn through the process of iteration, because computers make iterative design a speedier and, therefore, more feasible process. For example, in the same amount of time it takes to solve a complicated building frame by moment distribution, the young designer can run ten frames on the computer, varying assumptions and learning, by trial and error, how the structure behaves. Also, civil engineering software writers can incorporate artificial intelligence methods into the programs so that not just analysis techniques, but the decision-making process itself can be learned.

While it is unlikely that computers will replace human beings in the design office, the machines, when creatively used, can speed the learning process, the gaining of experience. For this process to be successful, management must provide the apprentices with the time to do it. Previously, junior engineers involved in the preparation of manual calculations, however tedious, were considered to be performing "billable" work. This same accounting approach must be provided for periods of education. Successive iterations and a "master-apprentice" analysis of these iterations should be viewed as integral to the design process and be, therefore, billable.

Standards & Guidelines

Consultants and professional societies should develop detailed standards and guidelines for the use of computers within the field of design engineering. Such standards can help form the framework not only for civil engineering computer use, but for the new, computerized education process for younger engineers. When prepared and applied properly, these standards should help fill the gap in the development of engineering expertise. These standards might cover such areas as:

- Recommended or authorized application software (for example, spreadsheets or moment analysis or statistical manipulation);
- Guidelines or instructions on how to use the application software for specific tasks;
- Standard, minimal or average expectations for work performed using computers;
- Standardized formats for data exchange (for example, for computer-aided design file transfer); or,
- Standardized interfaces for applications to reduce the time required to learn new application programs.

While these standards should help engineers avoid repeating past mistakes and provide a means to evaluate work produced using computers, they must not be allowed to become too rigid. Because of the rapidly changing nature of engineering software and hardware, designers must be free to creatively adapt developing technologies to their needs. Computer standards must grow and adapt with the engineers, not stifle creative computer use.

Motivating Younger Engineers

Junior engineers must adopt a more aggressive approach towards the gaining of experience. The days of leisurely, tedious manual calculations are ending, along with the framework in which new engineers learned their profession. In this period of change, with no firmly established process for gaining experience in place, young engineers must seek out engineering knowledge and not wait for it to fall into their heads.

The new environment in consulting offices will provide less and less need for engineering "dog work," and, thus, less and less need for lazy junior engineers, or those who are content to perform such "dog work" and not rise beyond it. On the other hand, the situation provides a great opportunity for industrious young engineers to gain professional insight and make substantial contributions to the design process sooner than in the past. Managers and senior supervisors must encourage this kind of contribution, and not fall back on the old, manual procedures as a way of maintaining control of younger engineers.

Liability & Computer Use

Any change in design and construction methods makes liability a serious concern. As the use of computers has become more widespread, some engineers have had difficulty incorporating automation into their work. All sorts of improper structural designs, construction failures, and even bidding mistakes have been blamed on the machines. These engineers have concluded that the computers, and not their own ignorance, is at fault.

Likewise, as computers are relied on more and more to help train inexperienced engineers, engineers will suffer through the laments of the old timers who claim that, if only those youngsters had done it the old, "correct" way, then they would know how to do it properly. The key point here is to remember that a computer is a tool. Members of a profession are expected to be able to use the tools of their profession in a competent manner. When they do not, they can be liable for negligence. When used correctly, excellent designs and competent engineers are the result.

Summary

Computers present a special challenge to younger engineers who are at the forefront of the new automation technology.

It is ethically required of the younger engineer to contribute more to the design process sooner in his or her career. Just as senior engineers and managers can no longer have the luxury of assigning weeks of "baby-sitting" manual calculations, junior engineers can no longer sit back and enjoy the luxury of allowing design experience to "seep in." It is ethically required of younger engineers to learn their profession more quickly. It is ethically required of younger engineers to actively help redefine the way design work is done, because, with their knowledge of computers, younger engineers know better ways of getting the work done.

This type of contribution requires tremendous flexibility on the parts of both younger engineers and more senior managers. The results of this contribution would be faster, more economical and more creative solutions to design problems whether they be complex or simple. Given the current state of the engineering profession, not to make such a contribution deprives the client of the best possible engineering work, and, thus, can be seen as being unethical.

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REFERENCE

1. American Society of Civil Engineers *Code of Ethics* (adopted Sept. 25, 1976), *ASCE Official Register, 1989*, p. 295.