Training Needs for Civil Engineers: A University Perspective

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The new technologies and new problems of the past 25 years have caused changes in engineering practice. Changes in engineering education have not kept pace with the changes in practice, which has created a demand for more training of professionals. Skills where the demand appears to be greatest are in the areas of written communication, project management, and computer-aided practice. At the present time, the profession does not have an organized framework to ensure that high-quality training is available. Therefore, the profession needs to adopt some standards and develop guidelines for training to ensure that the needs of the profession are met. One path to improved training would be to make better use of the new technology of instructional television. The profession should also ensure that training involves education, not just skill enhancement.

In order to properly address the training needs for engineers, it is important to define and distinguish between the terms education and training. Education, as used herein, is the process of imparting knowledge, where knowledge is the sum of what has been perceived, discovered, or inferred (*1*). The word "education" will be used herein most often when referring to formal instruction in an institution of higher education.

Training herein means the specialized instruction that includes problem solving for the purpose of making the participants proficient at a specific skill. Use of the word "training" usually infers that the instruction deals with a limited aspect of a broad topic. For example, training on the use of a computer package would instruct the audience on the way to get data into the computer and where to find results on the computer output; it would not include a thorough discussion of the concepts and underlying assumptions behind the computer program.

When discussing training needs for engineers, there are several important questions that need to be addressed. Why has the need for training increased in recent decades? Is current civil engineering (CE) education relevant to the needs of engineering practice? What skills of recent engineering graduates are the most deficient? What proportion of training sessions sponsored by industry should be education oriented rather than just skill enhancement? How can advances in technology improve training effectiveness and efficiency?

EFFECT OF CHANGES IN EDUCATION AND PRACTICE ON TRAINING DEMAND

CE practice has changed considerably in the last 25 years. Problems must now be addressed that the engineers of the previous generation did not have to contend with. Although hazardous wastes existed, the problems associated with them were not understood, so abating them was not a standard part of practice. The hydrologic effects of urbanization were just beginning to be recognized, but stormwater management was not a primary design responsibility of the engineer as it is today. We now have many safety and public health regulations that significantly affect engineering practice. New technologies have created new demands. Computer-aided design is one example. Hydrologic modeling capabilities have improved, greatly influencing engineering practice. Projects such as shopping malls are much bigger now than they were 25 years ago. These changes to engineering practice have made it necessary for the practicing engineer to have greater knowledge and improved skills.

How has engineering education changed to fill this need? The academic course load has not increased in the last 25 years; in fact, the number of credit hours required for graduation may have decreased. Program specialization is one of the major changes to the CE curriculum. In the 1950s and 1960s, all CE students had the same course requirements for graduation; for example, the author had only one technical elective. The CE students of 1990 have a senior year that is almost all electives, and they must elect a technical specialty within CE, e.g., structures, transportation, or hydrology; when the author was an undergraduate, it was not possible to select a major within CE.

The increase in specialization that characterizes current CE curricula has not kept pace with the increase in knowledge and skill needs associated with the changes in engineering practice. Engineering education has improved, but it has not been able to keep pace with demands. The inability of education to keep pace with the increasing need means that, until changes are made to CE education, the demand for postbaccalaureate training will increase significantly.

IS CE EDUCATION RELEVANT?

Over the past 25 years, criticism of CE education has increased. CE practitioners argue that CE education is becoming too research oriented, while losing the desired orientation towards practice. They point towards a research-oriented faculty and a system that rewards research, not the teaching of engineering design. There is some validity to the practitioner's concern.

In response to this criticism, the faculty argue that a primary goal of CE education is the development of problem-solving skills. The problems 25 years into the future will be different

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from the current problems and the classes of the 1990s will need to be able to solve the future problems, not just design for the conditions of the 1990s.

Faculty also argue that society has a larger goal beyond the development of design practitioners. Specifically, they cite research funds provided by institutions such as the National Science Foundation, which are unmatched by the design community. They argue that research is necessary to keep pace with the ever-changing problems and for the United States to maintain economic competitiveness in the global economy of the 21st century.

Just as the practitioner's express some valid concerns, the educators also make valid points.

What does this debate imply for the demand for training? Unless the drastically uneven balance of payments can be changed, it appears that CE education will continue to be research oriented, at least into the early part of the 21st century. Thus, the demand for practice-oriented training is going to increase. Instead of the CE industry putting their resources into the educational system, they will support a training industry. This has several advantages. First, the training will be ready on demand to meet immediate needs. Second, the training can be oriented towards a specific need. Third, it will be less costly. The small firm will be capable of actively participating in the training activities; a large resource base will not be necessary to stay abreast of current practice requirements. In general, the CE practitioners will have greater control over their profession. The educational institutions will provide a pool of educated employees, with industry responsible for meeting the direct training needs for practice.

SKILLS REQUIRING INCREASED EMPHASIS

Water resource educators and practitioners were questioned about skills that need greater emphasis in higher education (*2*). An open-ended question produced four clear needs. Specifically, the respondents listed communication skills, computers and modeling, statistics, and management as the areas requiring increased emphasis (see Table 1). Educators responded to these skill needs with different proportions than practitioners, but these skills were the dominant ones mentioned. Practitioners emphasized communication management and skills whereas educators put greater emphasis on using computers and modeling. Practitioners identified project management, project planning, leadership and motivation, and ethics as the management skills needing greater emphasis.

Recent pressure from the Accreditation Board for Engineering and Technology (ABET) for CE programs to include a capstone course may cause improvements in the abilities of graduates in project management and project planning. Many programs are incorporating ethics into CE curricula, which should help meet this need identified by water resource practitioners.

COMMUNICATION SKILLS

What is the greatest deficiency of engineering graduates? A strong argument can be made for communication skills. A study by Kimel and Monsees (*3*) indicated that CE practitioners believed that it was the most important expertise in CE practice, but it was, by far, their most deficient skill. As Table 2 indicates, approximately 60 percent of the respondents rated communication skills as being important but 65 percent indicated that recent CE graduates had inferior communication skills.

Davis (*4,5*) conducted a study to determine how much time prominent engineers spend either writing or working with materials that others have written, how important it is in their positions, and how important the ability to write effectively might be to someone who was being considered for advancement. The results of a questionnaire that was completed by 245 prominent engineers indicated that they spent an average of 24 percent of their time writing and 31 percent of their time working directly with material that others have written. Furthermore, the respondents believe that the writing they do is important, often critical, to their positions and that young engineers are often deficient in their ability to communicate on paper.

The ASCE study (*2*) agreed with the findings of Kimel and Monsees (*3*). As indicated in Table 3, report writing and oral communication received some of the poorer ratings on the educational preparedness of recent B.S. graduates. Table 4 presents the writing skills required in engineering practice.

TABLE 1 INCREASED EMPHASIS REQUIRED

Response	Percent of Respondents (%) Educators	Practitioners
Communication skills	18	27
Computers and modeling	27	11
Statistics	16	5
Management	7	13
Hydrogeology and ground water	4	9
Water resources courses	29	16
Other science courses	15	11
Other nonscience courses	20	25
Techniques and design	35	15

Note: Responses below the broken line are combinations of responses into broad categories.

TABLE 2 CAPABILITIES OF RECENT CE GRADUATES (*3*)

Importance to Civil Engineer Practice			Area of Competence	Capability of Recent C.E. Graduates (1-5 years)		
Most Imp.	Impor-tant	Less Imp.		Super-ior	Ade-quate	Infer-ior
137	86	9	Writing and speaking	7	69	142
106	127	9	Structural analysis and design	25	160	28
72	156	13	Soil mechanics and foundation	9	157	46
62	125	47	Water and waste-water treatment	13	144	27
55	131	38	Fluid mechanics, hydraulics, hydrology	10	136	42
53	153	32	Computer and numerical methods	42	139	30
50	132	49	Economics, finance	4	96	106
47	147	54	Construction methods and equipment	9	107	95
46	105	70	Law, labor, management	4	81	120
20	148	67	Surveying and measurement	4	139	65
19	110	92	Transportation, highways, traffic	5	161	30
14	124	51	Materials	6	153	35
13	85	132	Social sciences and humanities	12	137	53

TABLE 3 EVALUATION OF EDUCATION PREPAREDNESS OF RECENT BACHELOR DEGREE GRADUATES BY DISCIPLINE

	Mean Response[a]		Percent Inadequate	
Discipline	Educator	Practitioner	Educator	Practitioner
(a) Engineering and Science				
Structures	1.13	1.43	1.6	7.2
Soil mechanics	1.19	1.62	9.8	3.8
Physics	1.22	1.29	2.4	2.6
Mathematics	1.26	1.20	1.0	4.2
Surveying	1.32	1.75	19.1	6.2
Chemistry	1.40	1.40	5.0	5.2
Computer Science	1.43	1.43	5.7	5.7
Thermodynamics	1.47	1.57	14.3	9.7
Electrical circuits	1.52	1.64	17.5	10.9
Engineering drawing	1.56	1.85	26.7	12.5
Statistics	1.88	1.76	14.4	23.2
Biology	2.07	1.62	27.0	40.1
Mean	1.45	1.55	-	-
(b) Water				
Fluid mechanics	1.14	1.64	5.1	2.6
Hydrology	1.32	1.59	13.8	4.7
Environmental	1.33	1.64	10.8	4.2
Water resources	1.40	1.59	6.9	4.8
Mean	1.30	1.62	-	-
(c) General				
Economics/finance	1.65	2.14	33.5	9.5
Social	1.93	2.00	26.4	25.0
Report writing	2.05	2.48	42.4	27.5
Oral communication	2.11	2.44	43.8	30.0
Contracts/legal	2.21	2.27	47.2	38.9
Mean	1.99	2.27	-	-

[a]Scale: 1 = Sufficient, 2 = Marginal, and 3 = Inadequate

TABLE 4 EMPHASIS NEEDED IN TECHNICAL WRITING SKILLS

Skill	Average Response[a] Educators	Practitioners
Clarity of thought	1.1	1.1
Report organization	1.6	1.7
Grammar and syntax	1.9	2.0
Sentence structure	1.9	2.0
Vocabulary and spelling	2.0	2.1
Rewriting of drafts	2.2	2.5
Use of visual aids	2.3	2.5
Writing for nontechnical audiences	2.4	2.2
Letters and memos	2.6	2.4

[a]Based upon scale of 1 (essential) to 5 (unimportant).

What messages do the findings of Kimel and Monsees, the ASCE committee, and Davis convey?

First, there wasn't much improvement in the decade between the studies by Davis (*4,5*) and Kimel and Monsees (*3*) and that by the ASCE (*2*). Engineering schools may not have the resources to improve the situation. Given high enrollments in engineering programs and the even greater national need to increase the number of engineering graduates, it is unlikely that the situation will improve during this decade. Improving writing skills is labor-intensive and requires skills that engineering faculty often lack, especially when English is often not the native language of many of the faculty. Also, there is a hesitancy to bring English faculty into the engineering curriculum to meet this need.

Second, the capability for computer-aided grading of written reports needs to be developed. This procedure would reduce the resource requirements by reducing the need for engineering faculty to correct spelling, grammar, and syntax. Instead, they could concentrate on helping students improve their ability to organize a report and express technical ideas in a clear way.

Third, the viewpoint of students on the issue of writing must be changed. In a survey of students, McCuen and Berman (*6*) found that 43 percent indicated that most students would object to a technical writing course requirement. Many respondants indicated an objection because of the heavy load of required courses in their program. Contrary to the results of the questionnaires distributed to educators and practitioners, most students believe that basic grammar, syntax, and sentence structure was not a major problem. Most students may believe that technical writing training should concentrate on library searches and the process of putting together the final document. Thus, it would be difficult for a technical writing program to be effective until the students are made aware of their deficiency in basic writing skills.

Fourth, industry must gear up for training in technical communication. Industry cannot rely on higher education to fulfill this need. Communication needs and formats differ considerably from company to company and from locality to locality. Thus, training needs will be company-specific and they need to develop training programs that meet these specific needs.

EDUCATIONAL PHILOSOPHY AND TRAINING NEEDS

Two questions in the ASCE survey addressed the issue of the philosophy of water resources education. Specifically, the questions sought the level of emphasis that should be placed on (a) facts and principles; (b) critical thinking, analysis, and problem solving; and (c) ethical, social, and moral values. Table 5 presents a comparison of the current emphasis and the perception of what would represent proper emphasis by both educators and practitioners. Both educators and practitioners believe that the current educational process does not place proper emphasis on the three categories. Both of the groups believe that more emphasis should be placed on Categories 2 and 3 than is currently done, with facts and principles receiving less emphasis than it currently receives.

How would a shift in emphasis affect the need for training of graduates? If problem solving is interpreted as the solution of practice-oriented problems, then the shift of an educational philosophy towards Category 2 would reduce the need for postdegree training. The decision, of course, is to identify facts and principles that can be sacrificed to provide greater emphasis on problem solving.

PROFESSIONAL CONTROL OF TRAINING

It appears that training needs will increase dramatically in the next decade. As the diversity in problems increases and as the societal importance of these problems exhibits a corresponding increase, the demand for training will also increase. But the profession has a problem. Although there is some quality control in the academic community, there is an almost complete lack of quality control in training. There are some good short courses, but many are ineffective. In order for training to better serve the profession, it is important for the profession to take the steps that are necessary to ensure that training is more effective than it currently is. This is not necessarily a call for a bureaucracy within the training commu-

TABLE 5 CURRENT AND PROPER EMPHASIS IN UNDERGRADUATE EDUCATION

Area	PERCENT OF CURRICULA Current Emphasis Educators	Practitioners	Proper Emphasis Educators	Practitioners
Facts and principles	54	63	46	47
Critical thinking, analysis, and problem solving	37	28	42	37
Ethical, social, and moral values	9	9	13	15

nity, but for the adoption of some standards and guidelines to ensure that the needs of the profession are met.

This call for improved quality control in training must take into account the variation in regional problems. Irrigation is important in some areas, but not in others. Snowmelt flooding is important in some areas, but not in others. Wetland preservation is important in some areas, but not in others. Design methods also exhibit regional variations. Some areas use Soil Conservation Service hydrologic methods; other regions use the rational method, whereas others use locally calibrated models. This diversity creates regional training needs and thus the need for regional quality control of training.

Although there are regional needs, there are some national solutions. There exists a national instructional television (ITV) system that is currently underused for training. Training programs could be presented on the ITV system so that the best training is available nationally. The ITV solution has the added advantage that greater quality control would be possible. It would be easier to develop more uniform criteria for relating continuing education units (CEU) to the content and level of effort required if the training process were handled through a national organization like the ITV system. The ITV system can meet both national and local needs, so it would be possible to include training for localized problems and local design methods.

If it becomes more common to use CEUs as a criterion for professional registration, then the demand for training will increase and the need for improved quality control will be much greater. It will no longer be proper for a company to send one employee to a short course, with the others left to learn by on-the-job training by the employee who attended.

ETHICAL CONCERNS IN TRAINING

The author is frequently asked to offer short courses on computer packages such as the SCS TR–20 flood hydrograph program and the HEC–2 water surface profile program. Employers requesting the training want instruction for their employees on the proper format for the input. When employers are asked whether or not the employees understand the hydrology or hydraulics that forms the basis of the computer package, they exhibit a lack of concern for instruction on the knowledge base of the program. This raises an ethical question: Is it proper for software training to be devoid of the conceptual basis of the method? The user's manuals for the software rarely provide educational material on the underlying methods, so if it is not presented as part of the training, then the employees will be left to apply the method without an adequate understanding of what they are using.

Training is frequently used to instruct nonengineers in the use of computer tools for engineering design. Frequently, the largest portion of those in the short courses that the author teaches does not have an engineering baccalaureate degree; degrees in environmental science, geology, and zoology predominate, with little exposure to engineering hydrology and almost no education in hydraulics. Yet those with nonengineering degrees are performing functions that have, in the past, been performed by individuals having engineering degrees.

CONCLUSIONS

Societal problems that require technical input during the solution have increased both in number and in complexity. Given that higher education does not have the resources or support to expand to fill this need, the profession will have to expand its capacity for training. In the past, there has been little quality control of training programs and no professionally sponsored organization responsible for oversight of training. This must change if the training needs of the profession are to be met.

The following are some specific conclusions based on the discussion herein:

1. There is a critical need for oversight responsibility of training, including the development of criteria to assess training quality and guidelines for the development of training programs.
2. Formal educational programs are not expanding to meet the need for training, thus the practitioners will have to act to meet the demand.
3. Specialization in educational programs has not kept pace with the increase in the complexity of engineering problems, which will increase the demand for training.
4. Engineering education has become more research oriented and less practice oriented, which is increasing the demand for training.
5. There is a need to make greater use of new technology, such as ITV, to improve both the availability and quality of training.
6. Training in communication skills appears to be the greatest need, followed by project management, computers and modeling, and statistics.
7. Training should include knowledge development, not just skill enhancement.

It is worthwhile mentioning some of the recommendation made in the ASCE (*6*) report:

1. A forum should be developed to provide a systematic means of collecting and organizing the ideas of practitioners and transmitting these ideas to the academic community.
2. Practitioners should be involved in practice-oriented instruction at both undergraduate and graduate levels by developing case study material, serving as consultants to students, and providing resource material.
3. Formal education beyond the bachelor degree should be required for initial professional engineering registration.
4. Continuing education or professional society activity should be required for renewal of professional registration.
5. Necessary adjustments should be made so that those in practice can be more involved in continuing their education and training.
6. Those in practice should be assigned lighter work loads while they are actively and successfully pursuing advanced degrees or continuing education programs.
7. Universities should be attentive to the needs and desires of part-time students in planning and scheduling graduate courses and other forms of continuing education.

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