Assessment of Realistic Design Constraints in Engineering Programs

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Abstract

The Accreditation Board for Engineering and Technology (ABET) has adopted a revised set of criteria for accrediting engineering programs. According to the new regulations, departments will be required to demonstrate that various design constraints listed in the professional component section of the criteria are utilized by students in their design sequence.

This paper investigates the level, according to construction related students, at which the constraints have been considered in a specific curriculum. In particular, the findings suggest that both undergraduate and graduate students believe that 3 design constraints have been incorporated into the civil engineering program at a high level. These include: engineering codes and standards, manufacturability (constructability), and ethical considerations. In contrast, 3 areas have been rated at a lower level. They include: social ramifications, political factors, and legal issues.

Introduction

Over the years there have been recommendations for employers and various technical/professional organizations to revise the engineering curriculum to ensure that students are prepared for the professional practice of engineering.[3, 4, 10] Practicing engineers and educators have also indicated that they are not completely satisfied with the average engineering program.[5, 6, 7]

This paper reviews a number of recent recommendations involving engineering education and presents the results of an investigation of the perceptions of a group of undergraduate and graduate students. The data for the study was obtained from a survey instrument which was distributed to students enrolled in construction related courses taught in civil engineering degree programs. Respondents were requested to indicate whether, and at which level, various design constraints have been incorporated into the curriculum. The constraints chosen are those that have been adopted by the Accreditation Board for Engineering and Technology (ABET) as criteria that must be satisfied for a program to be accredited. The findings of the investigation could be utilized, for comparative purposes, by other institutions and departments that may wish to study their curriculum.

Engineering Curriculum

Recently, engineering educators have indicated that, overall, effective teaching is rated as their highest priority.[1] Nevertheless, the question of breadth vs. depth in engineering education is

presently being debated by the engineering profession. Numerous executives believe that it was

their breadth of interests, not necessarily their initial technical depth at graduation, that gave them the background to succeed in management.[9] They also perceive that in today's global economy it is vital for engineers to have the broad background to be able to assess and understand the economic, environmental, and ethical effects of their work. This is especially applicable to the construction industry.

It has also been mentioned in the literature that the skills required by a typical employee tend to vary during an engineer's career.[8] For example, basic technical skills are extremely important directly after graduation. Later in life, knowledge of communication, organizational, managerial, and social skills may be more significant to an individual employed by an engineering/construction firm.[11]

To satisfy changing industrial needs and support, in part, the aforementioned concepts, the Accreditation Board for Engineering and Technology (ABET) has adopted a revised set of criteria for accrediting engineering programs.[2] In particular, it is required that, in the future, engineering programs must demonstrate that their graduates have considered various constraints in the design portion of the curriculum. These include, in part, the following:

- Engineering Codes and Standards
- Economic Factors
- Environmental Effects
- Sustainability
- Manufacturability (Constructability)
- Ethical Considerations
- Health and Safety Issues
- Social Ramifications
- Political Factors
- Legal Issues

In addition, each program must develop an assessment process and document the results. Specifically, the outcomes should be utilized to further develop and improve the engineering program(s) at the institution.

Undergraduate Perceptions of ABET Recommended Design Constraints

As a segment of a continuing review of the curriculum, a survey instrument was distributed to students enrolled in a required senior and typical construction related graduate course offered by the Civil Engineering Department of Lamar University. Thirty-eight usable forms were returned, the tabulated results of which form the data base for the investigation. Specifically, the questionnaire listed various design constraints and requested respondents to indicate at which level -- high, average, low, or unsure/none -- each presently is incorporated into the curriculum. The constraints chosen are listed in a recently adopted set of criteria for accrediting engineering programs. They were included in the professional component section of the recent "Engineering Criteria 2000" report and are listed in the previous section.[2]

Table 1. Undergraduate Students' Perceptions of Present Level of Design Considerations and Constraints

	Level of Undergraduate Student Design Constraints, As a Percentage of Respondents					
Design Consideration or Constraint	High	Average	Low	Unsure or None	*Composite Score	**Std. Dev.
Engineering Codes and Standards	56.3	31.3	6.3	6.3	3.4	.86
Economic Factors	18.8	50.0	25.0	6.3	2.9	.81
Environmental Effects	18.8	18.8	62.5	0.0	2.6	.79
Sustainability	18.8	12.5	62.5	6.3	2.4	.86
Manufacturability (Constructability)	25.0	50.0	25.0	0.0	3.0	.71
Ethical Considerations	43.8	43.8	6.3	6.3	3.3	.83
Health and Safety Issues	25.0	18.8	50.0	6.3	2.6	.93
Social Ramifications	25.0	12.5	43.8	18.8	2.4	1.06
Political Factors	18.8	6.3	50.0	25.0	2.2	1.01
Legal Issues	18.8	12.5	56.3	12.5	2.4	.93

*Composite score based upon 4.0 = High; 3.0 = Average; 2.0 = Low; 1.0 = Unsure.
**Standard Deviation

Specifically, the findings suggest that many of the design constraints have been incorporated into the curriculum at a reasonable level. For example, Table 1 shows that over 40% of the undergraduate students believe that 2 areas are being treated at a high level. They include:

- Engineering Codes and Standards; and
- Ethical Considerations.

In addition, the following 3 constraints are perceived to be considered at the 25% level in the high category:

- Manufacturablity (Constructability);
- Health and Safety Issues; and
- Social Ramifications.

The 5 constraints listed above are perceived by undergraduate students to be covered at a relatively high level. They include many of the traditional technical aspects of engineering in addition to areas such as constructability and safety which are of prime interest to those in construction. Nevertheless, as shown in Table 1, 5 design constraints are rated with a score below 25% in the high category. This indicates that additional attention and departmental/university resources may be necessary in these areas. However, approximately 40% of the undergraduates responding to the survey are required to enroll in at least one additional semester to complete their degree requirements. This includes taking, in many cases, the major senior design experience, concrete and foundation design, project management

systems, as well as a possible elective course. It is not unreasonable, therefore, to assume that many undergraduate

Table 2. Graduate Students' Perceptions of Present Level of Design Considerations or Constraints

	Level of Graduate Student Design Constraints, As a Percentage of Respondents					
Design Consideration or Constraint	High	Average	Low	Unsure or None	*Composite Score	**Std. Dev.
Engineering Codes and Standards	54.5	40.9	4.5	0.0	3.5	.58
Economic Factors	50.0	50.0	0.0	0.0	3.5	.50
Environmental Effects	40.9	50.0	9.1	0.0	3.3	.63
Sustainability	22.7	63.6	4.5	9.1	3.0	.80
Manufacturability (Constructability)	36.4	59.1	4.5	0.0	3.3	.55
Ethical Considerations	13.6	63.6	22.7	0.0	2.9	.60
Health and Safety Issues	40.9	50.0	9.1	0.0	3.3	.63
Social Ramifications	4.5	68.2	22.7	4.5	2.7	.62
Political Factors	13.6	45.5	22.7	18.2	2.5	.94
Legal Issues	13.6	50.0	22.7	13.6	2.6	.88

*Composite score based upon 4.0 = High; 3.0 = Average; 2.0 = Low; 1.0 = Unsure.
**Standard Deviations

students have not been exposed to the various design considerations and constraints at a high level of intensity. Therefore, the ratings most likely reflect the incomplete background of some respondents.

Graduate Student Perceptions of ABET Recommended Design Constraints

The perceptions of graduate students enrolled in a construction related course are shown in Table 2. Here, over 40% of the respondents indicate that 4 constraints are covered at a high level. They include:

- Engineering Codes and Standards;
- Economic Factors;
- Environmental Effects; and
- Health and Safety Issues.

In addition, Manufacturabilty (Constructability) received a score of 36.4% in the high category. Graduate students perceive that the aforementioned 5 areas are covered at a relatively high level. Nevertheless, 5 constraints are rated with a score below 25%. Three of these are also rated at a low level by undergraduates. They include: Sustainability, Political Factors, and Legal Issues. These results indicate that graduate and undergraduate students appear to agree that some non-technical design constraints should, perhaps, not be considered at a high level in the design sequence.

Table 3. Design Constraints with Undergraduate Composite Scores ≥ 3.0

	Level of Design Constraints, As a Composite Score*	
Design Consideration or Constraint	Undergraduate	Graduate
Engineering Codes and Standards	3.4	3.5
Manufacturability (Constructability)	3.0	3.3
Ethical Considerations	3.3	2.9

*Composite score based upon 4.0 = High; 3.0 = Average; 2.0 = Low; 1.0 = Unsure.

Table 4. Design Constraints with Composite Scores ≤ 2.7

	Level of Design Constraints, As a Composite Score*	
Design Consideration or Constraint	Undergraduate	Graduate
Social Ramifications	2.4	2.7
Political Factors	2.2	2.5
Legal Issues	2.4	2.6

*Composite score based upon 4.0 = High; 3.0 = Average; 2.0 = Low; 1.0 = Unsure.

Table 5. Comparison of Design Constraints with Differences in Composite Scores ≥ .6

	Level of Design Constraints, As a Composite Score*	
Design Consideration or Constraint	Undergraduate	Graduate
Economic Factors	2.9	3.5
Environmental Effects	2.6	3.3
Sustainability	2.4	3.0
Health and Safety Issues	2.6	3.3

*Composite score based upon 4.0 = High; 3.0 = Average; 2.0 = Low; 1.0 = Unsure.

Comparison of ABET Design Constraints

Table 3 compares the perceptions of undergraduate and graduate students. As shown, both groups have rated 3 design constraints with a relatively high composite score. This indicates that these areas are believed by undergraduate and graduate students to be reasonably well incorporated into the curriculum. The constraints include: Engineering Codes and Standards, Manufacturability (Constructability), and Ethical Considerations. These include, in part, the traditional technical aspect of engineering education in addition to the concept of

Constructability.

A comparison of low composite scores was also accomplished. As shown in Table 4, both undergraduates and graduates rate 3 constraints with a composite score $\leq$ 2.7. This may indicate that greater attention should, perhaps, be given by the department to areas such as social ramifications, political factors and legal issues as related to the design/construction process.

Table 5 compares the perceptions of undergraduate and graduate students of various constraints. It is restricted to those items with differences in composite scores $\geq$ .6. As illustrated, graduate students, many of whom have considerable industrial and construction experience, tend to rate some design constraints such as health and safety issues higher than undergraduates. However, as mentioned previously, approximately 40% of the undergraduates responding to the survey must take at least 1 - 4 additional courses to complete their degree requirements. This includes the major senior design experience. Differences in ratings, therefore, are to be expected.

Summary and Conclusions

This paper reviews a number of recent recommendations involving engineering education. In addition, it presents the results of an investigation of the perceptions of a group of undergraduate and graduate engineering students, enrolled in construction related courses, concerning the level at which various design considerations and constraints have been incorporated into the curriculum. Data for the study was obtained from a questionnaire which was completed by students enrolled in various civil engineering degree programs. The findings of the investigation could be utilized, for comparative purposes, by other institutions and departments that may wish to study their curriculum.

In particular, the results suggest that both undergraduate and graduate students believe that 3 design constraints have been incorporated into the program at a relatively high level. They include: Engineering Codes and Standards; Manufacturability (Constructability); and Ethical Considerations. These include, in part, the traditional technical aspect of engineering education in addition to the concept of Constructability. In contrast to the above, the following 3 areas have been rated at a lower level: Social Ramifications, Political Factors, and Legal Issues. It was found that graduate students, many of whom have considerable industrial and construction experience, tend to rate, overall, the consideration of design constraints at a higher composite score compared to undergraduates. This is not unexpected since 40% of the undergraduate respondents will be required to complete at least one additional semester to complete their course of study. This includes taking, for many students, the major senior design experience as well as concrete design, project management systems, and foundation design. The ratings, therefore, most likely reflect the incomplete academic background of some undergraduates.

Generally, the findings suggest that students appear to perceive that most design constraints have been incorporated into the civil engineering program at a reasonable level. The constraints chosen are those that are required by ABET as criteria that must be satisfied for a program to be accredited. They are listed in the professional component section of the “Engineering Criteria 2000" report which was adopted by ABET. It is hoped that consideration of the foregoing

concepts by educators will provide engineering students with the skills required for a successful career involving the design and management of engineering and construction projects.

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Biographical Data

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