Proceedings of International Structural Engineering and Construction
Holistic Overview of Structural Design and Construction
Edited by Vacanas, Y., Danezis, C., Singh, A., and Yazdani, S.

ISSN: 2644-108X

KNOWLEDGE AREAS FOR TRAINING JUNIOR CIVIL ENGINEERS IN OPERATIONS AND CONSTRUCTION MANAGEMENT TASKS

SMADAR SHILONY[1], YEHIEL ROSENFELD[2], EITAN GOLDSCHMIDT[1], and SHRAGA SHOVAL[3]

[1]*Dept of Civil Engineering, Ariel University, Ariel, Israel*
[2]*Faculty of Civil and Environmental Engineering, Technion- Israel Institute of Technology, Haifa, Israel*
[3]*Dept of Industrial Engineering and Management, Ariel University, Ariel, Israel*

After leaving university with a bachelor's degree in civil engineering, many graduates join construction companies in key roles such as operations engineer or project manager. Junior engineers often acquire the knowledge they need through mentorship by experienced engineers. Their knowledge is acquired on-the-job, according to the requirements of whatever projects are underway when they begin their employment. This study introduces the required areas of knowledge, with the goal of integrating junior engineers efficiently and effectively into the construction industry. The study found that the knowledge acquired by a graduate with a bachelor's degree in civil engineering does not match the knowledge required for engineers working in management and operations roles. In addition, the process of learning and filling in knowledge gaps often takes place on-the-job, or immediately before beginning a new project, without any external monitoring of the content or quality of the knowledge acquired. Although the various topics were defined by the engineers as important to their work, the findings indicate that both experienced engineers and young engineers need to fill in their knowledge gaps in critical various fields. This study highlights the need to build a comprehensive, standardized training program for all young engineers entering the workforce in construction management in order to fill in the knowledge gap and provide them with the tools to integrate properly in construction companies.

Keywords: Civil engineers education, Professional training, Training junior engineers, Operations engineer knowledge, Practical knowledge, Level of knowledge.

1 INTRODUCTION AND LITERATURE REVIEW

Training civil engineers in construction management and their integration into the workforce are critical issues for junior engineers and for construction companies. Many young engineers, who enter the workforce after obtaining their academic degrees, take up key positions in the construction industry as operations engineers and project managers for projects of varying sizes, without the necessary knowledge to carry out their various responsibilities, and several years of training are required before they can become independent in their jobs. In this study, civil engineers, as the target population for professional training, were individually approached in order to obtain a unique and subjective perspective, and to document the topics that need to be learned, strengthened, emphasized, and expanded in the training of young engineers.

In various countries around the world, a graduate engineer's transition from the university to professional life can be difficult and complex process (O'Donnell *et al.* 2008). The universities do not always teach students the required professional skills to carry out their roles (Thompson and Surgeoner 2014). To become an expert engineer in the construction industry, one must first work as an assistant engineer (Simon 2015). The concern is that if the knowledge gap is not bridged, there will not be enough skilled engineers in the field (Naidoo 2016).

Although academic institutions are making efforts to bridge the gaps between academic studies and industry expectations, an effective solution has yet to be found. Various teaching approaches have been recommended. One of the recommended approaches is that the curriculum should be linked to the various capabilities and skills required for civil engineers in the 21st century (Mostafavi *et al.* 2016). Academic departments of civil engineering are required to demonstrate close relationships with industry (Mills 2011). Courses' content must balance the university's academic needs, the student's needs, the lecturer's expertise, and the employer's needs (Hawkins and Chang 2016).

Various Accreditation requirements have been enhanced by cooperative, part-time, and summer work experiences. The perceptions suggest that both undergraduate and graduate students with civil engineering experience believe that their understanding has been greatly enhanced (Koehn 2004), and therefore, it was suggested that summer practical training be a requirement for all undergraduate civil and construction-engineering students (King and Duan 2010). Analyzing the results of the approach called a "service learning project", showed that such learning projects can help develop basic, technical, and professional skills (Mostafavi *et al.* 2016). A practical learning approach in which civil engineering undergraduates participated in planning and executing a project was found to be effective (Er 2017). It was found that the use of modern, active teaching methods like business games and interdisciplinary projects, develop professional abilities (Maximova *et al.* 2017). Comparing curricula that combines academic studies with industry to the old "classic" program, shows that the new program contributes to more comprehensive quality on the practical side (Fok 2007, Zhang *et al.* 2013).

The challenges of transmitting knowledge and skills is crucial for the industry of the future (Naidoo 2016). Industrial mentoring is the most effective tool for engineers' professional development (Thompson and Surgeoner 2014). There are various initiatives in the industry, in different countries, to find ways to overcome the lack of knowledge of young engineers. Engineering is a complex subject, and many people retire with great amounts of knowledge that they have acquired but have not passed on to young people (Naidoo 2016). Mentoring programs for engineers was set up in coordination with industry. The programs intended to meet the needs of employers. The programs have achieved good results in training engineers (O'Donnell *et al.* 2008, McGettingan and O'Neill 2009, Simon 2015, Bai and Song 2016).

2 OBJECTIVES AND RESEARCH METHODS

The objective of the study presented here is to investigate and define the essential issues related to the required knowledge, their relative importance, the recommended method and timeframe required for training young engineer in construction management and supervision jobs. The study involved 67 civil engineers with varying degrees of experience, working in construction management and operations in Israeli construction firms. A questionnaire, that covered 10 basic knowledge areas in construction management, was delivered to the participants in the survey. For each knowledge area, the participants were asked questions, a total of 34, related to their day-to-day operational work in which they need to demonstrate knowledge and expertise. The list of knowledge areas and subjects appear in Table 1.

Table 1. List of sections and topics in the questionnaire.

Knowledge area	Subject number	Subject in each topic: Examination the knowledge and skill
Principles of planning site organization	1	Managing site organization
Measurements and marking	2	Data from the surveyor
Planning earthworks	3	Organization during implementation of earthworks
Schedules	4,5,6	Preparing Gantt charts/timetables, biweekly and monthly timetables
Equipment for operations	7	Planning and assembling cranes
	8	Planning building casts
	9	Planning forms for ceilings/walls
Management and operations	10	Planning and executing frame
	11	Planning independent excavation including inclines, drainage, tools
	12	Planning and assembling scaffolding: console, suspension, free standing
	13	Planning and executing finishing work
Construction	14	Reading construction plans
	15	Carrying out quantity checks for the foundation
	16	Carrying out quantity checks for the frame
	17	Work with concrete: vibrating, curing, timeframe for removing forms and braces
	18	Level of knowledge with different types of concrete and their uses
Construction systems	19	Reading and analyzing a water diagram
	20,21,22 ,23,24, 25	Reading and analyzing plans in different systems: sewage, wastewater, drainage and rainwater, firefighting, public electrical and low-voltage, ventilation, smoke removal, air conditioning
Use of knowledge base and systems	26	Calculating quantities and ordering steel reinforcement bars
	27	Content of the contracts relevant to your job
Knowledge of standards	28, 29, 30,31,32 ,33	Standards: 1045 (thermal insulation of buildings), 2378 (walls faced with natural stone), 466 (The Constitution of the Concrete: General Principles), 118 (concrete requirements, function, production), 904 formwork (braces for concrete) and "Home Front Command" Standard
	34	The general specification for construction work (the blue book)

3 RESULTS OF THE STUDY

The findings were analyzed by the following sections: level of knowledge; degree of importance; comparison between level of knowledge and degree of importance; acquisition of the knowledge on the job in comparison with learning at the university; the recommended method of learning (self-teaching or mentoring); and the recommended amount of time required for training. In addition, the engineers were divided in two ways: the first is by the amount of work experience and the second by their major for their bachelor's degree in civil engineering. In the division by work experience, two categories were defined: "young engineers", which included experience of up to four years, and "experienced engineers", which included more than four years of experience. 43 engineers (64%) are defined as "young engineers", and the remaining 24 are "experienced engineers" (36%). In the division by undergraduate major, 21 majored in construction management (31.3%) and 46 majored in structural planning (68.7%).

3.1 Level of Knowledge (LK) Vs. Degree of Importance (DI)

The respondents were asked to rank the Level of Knowledge (LK) and the Degree of importance (DI) of each topic. The ranking ranges from 1 to 5, where 1 is the lowest value and 5 is the highest. The average Level of Knowledge (LK) among all 67 engineers is 3.42. The study shows, with regard to the LK, that in four topics: #14, #18, #17, and #26, there is a significant larger positive difference (0.5-1) from the overall average. The larger negative difference from the average (0.5-1) is found in six topics: #7 and five standards (#28, #29, #31, #32, #33). The study shows that the average LK of the experienced engineers is 3.94, compared with 3.15 for the young engineers. Standard deviation among experienced engineers ranges from 0.28 to 1.70 (a difference of 1.42), while among young engineers it ranges from 0.94 to 1.59 (a difference of 0.65). This difference indicates that among the experienced engineers, the LK varies more among different topics. The study found that, the largest differences in LK of experienced and young engineers are in the following topics: #21, #24, #27, #16, and #12.

The average DI among all 67 engineers is 4.16. Comparing experienced engineers with young engineers shows that the young engineers assigned the topics an average rank of 4.01, while the experienced engineers' average rank was 4.44. That is, the experienced engineers ranked the various topics higher in importance than the young engineers did. The results are shown in Table 2.

Table 2. Comparison between knowledge level and degree of importance divided into categories.

	Planning Majors	**Management Majors**	**Young Engineers**	**Experienced Engineers**	**All Engineers**
Knowledge Level (KL)	3.45	3.39	3.15	3.94	3.42
Degree of Importance (DI)	4.20	4.09	4.01	4.44	4.16

3.2 Coordinated Degree of Importance (CDI)

Comparing LK and DI shows a negative difference for all the questions. That is, the engineers are declaring that all the topics have a higher degree of importance than their knowledge of those topics or, in other words, there is a lack of adequate knowledge in all the topics. To find and rank topics which are problematic, it was decided to examined the difference between LK and DI multiplied by DI. This value is called "Coordinated Degree of Importance" (CDI) as shown in Eq. (1). As the absolute value of CDI increases, it indicates that the topic has a higher gap of knowledge. According to the data, it was found that all CDI values are negative. A negative value indicates a lack of knowledge in the given topic despite the fact that it is important.

$$CDI = (LK - DI) * DI \tag{1}$$

where: CDI – Coordinated degree of importance, DI – Degree of importance, LK – Knowledge level

The average value of CDI is -3.08. Subject #7 shows -7.19, the highest value of CDI by a significant amount, and subject #12 also has a high CDI value relative to the other questions, -5.07. Values between -4 and -5 appear in topics #4, #8, #10, #32, and #33.

3.3 Acquiring Knowledge on the Job vs. University Studies

In order to evaluate whether engineers enter the field with knowledge that meets the requirements of their jobs, the respondents were asked, for each of the 34 topics, if they learned it in the framework of their undergraduate degrees at their universities. It was found that, on average, 85.7% of the engineers did not learn the various subjects as part of their undergraduate degrees at their universities.

3.4 Summary of the Topics by CDI Related to Timeframe and Form of Learning

In summary, a comparison was made, comparing the CDI with the recommended learning timeframe and the preferred form of learning (mentoring or self-teaching) that summarized all the parameters for each topic. The breakdown shown in Table 3.

Table 3. CDI as related to recommended learning methods and timeframes.

Topics ranked as more important											
Above-average learning time				**Average learning time (3.10)**				**Below-average learning time**			
Mentoring Topic no.	CDI	Self-teaching Topic no.	CDI	Mentoring Topic no.	CDI	Self-teaching Topic no.	CDI	Mentoring Topic no.	CDI	Self-teaching Topic no.	CDI
7	7.19	3	3.65	2	3.58	14	1.86			27	3.22
10	4.23	1	2.30							5	3.00
13	3.62									26	1.34
										17,18	1.07

Topics ranked as less important											
Above-average learning time				**Average learning time (3.10)**				**Below-average learning time**			
Mentoring Topic no.	CDI	Self-teaching Topic no.	CDI	Mentoring Topic no.	CDI	Self-teaching Topic no.	CDI	Mentoring Topic no.	CDI	Self-teaching Topic no.	CDI
12	5.07	11	3.12	15	3.98	33	4.82	8	4.27	32	4.39
4	4.10	16	2.82			24	2.68			29	3.93
9	3.65	34	2.80			21	2.12			28	3.44
6	3.33	22	2.57			23	1.58			31	3.42
		30,20	1.50			25	1.15			19	1.67

4 CONCLUSIONS

At present, in many countries there is no organized, structured learning process for civil engineers to fill in the gaps in their knowledge. The knowledge acquired at different construction companies is not standardized, and there is no auditing of content, quality, or knowledge level of operations engineers and project managers once they complete their undergraduate academic degrees. Construction companies at present do not allot the resources needed to train young engineers in an organized way. The study indicates that both experienced engineers and young engineers need to fill in their knowledge gaps, and that the engineers' recommended timeframe for learning the various topics is between half a year and a year. This study highlights the need to build a comprehensive, standardized training program for all young engineers entering the workforce in construction management in order to fill in the knowledge gap, and provide them with the tools to integrate properly in the construction companies.

References

Bai, J., and Song, Y., *Research and Practice On the Training Mode of the Core Competence About the Application-Oriented Electrical Information Engineering Undergraduate*, SHS Web of Conferences, EDP Sciences, 24(02016), 1-6, 2016.

Simon, A., *Take a Different Approach to Training the Civil Engineers of Tomorrow.* Construction News, London, 2015. Retrieved from https://www.constructionnews.co.uk/agenda/opinion/expert/take-a-different-approach-to-training-the-civil-engineers-of-tomorrow-05-01-2015/ on May 25, 2019.

Er, M., *Construction Project Management: An Experiential Learning Case Study*, International Journal of Engineering and Technology, 9(5), 378-382, 2017.

Fok, W. H., *The Engineering Graduate Training Scheme of the Hong Kong Institution of Engineers-Fulfilling The Purpose of Training Civil Engineering Graduates to Become Professional Civil Engineers*, International Journal of Technology and Engineering Education, 23(5), 981-989, 2007.

Hawkins, H. G., and Chang, K., *Employers' Perspectives on Needs for Critical Skills and Knowledge in the Transportation Field*, Institute of Transportation Engineers, ITE Journal, 86(6),34-37, Jun, 2016.

King, W. S., and Duan, L., *Practical Summer Training in Civil and Construction Engineering for Cultivation of Professional Ability*, Journal of Professional Issues in Engineering Education and Practice, 136(4),233-238, October, 2010.

Koehn, E. E., *Enhancing Civil Engineering Education and ABET Criteria Through Practical Experience*, Journal of Professional Issues in Engineering Education and Practice, 130(2), 77-83, April, 2004.

Maksimova, S., Kutrunova, Z., Maksimov, L., and Voronov, A., *Experience in The Use of Modern Educational Technologies in Teaching Professional Disciplines of Training Direction "Civil Engineering"*, MATEC Web of Conferences, EDP Sciences, 106, 1-9, 2017.

McGettingan, E., and O'Neill, D., *From Apprentice to Construction Manager and Beyond: Developing A Talent Pipeline*, Education+Training, 51(3), 220-231, 2009.

Mills, P. J., *Civil Engineering Degrees: Fit for The Future?,* Proceedings of the Institution of Civil Engineers, 164(4), 221-228, December, 2011.

Mostafavi, A., Huff, J. L., Abraham, D. L., Oakes, W. C., and Zoltowski, C. B., *Integrating Service, Learning and Professional Practice: Toward The Vision for Civil Engineering in 2025*, Journal of Professional Issues in Engineering Education and Practice, 142(3), B4013001-1-10, July, 2016.

Naidoo, D., *Guiding Our Young Engineers,* Civil Engineering, 24(6), 11-15, July, 2016.

O'Donnell, H., Karallis, T., Sandelands, E., Cassin, J., and O'Neill, D., *Case Study: Developing Graduate Engineers at Kentz Engineers and Constructors*, Education+ Training, 50(5), 439-452, June, 2008.

Thompson, P., and Surgeoner, D., *Bridging The Gap: University to Professional Qualifications*, Proc. of the Institution of Civil Engineers-Management, Procurement and Law, 167(4), 189-200, August, 2014.

Zhang, Q., Yuan, J. N., and Gaoc, C., *Connotation Construction of Training Process Promoting Excellent Engineers Training Quality*, Applied Mechanics and Materials, Trans Tech Publications, 263-266:3457-3461, 2013.