From the Pyramids via Modern CE to Automation & Robotics: Progress or Regress?

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Abstract –

Construction management courses are currently mostly based on frontal lectures, homework and exams – where the exams comprise of questions similar to the ones that the professor showed in the lectures & later the student is asked to solve at home. In practice, construction engineers are required to be able to quickly resolve unstructured complex problems, under conditions of uncertainty, by finding, collecting and integrating information from different sources and providing creative solutions. We propose that a learning-centered approach to the education of the construction management student, in which s/he is confronted with the need to find solutions for such complex problems, and to identify the relevant data, will better prepare the future engineer for the profession. Moreover, the students have to be exposed to the fact that there is more than one correct solution and none of the solutions is perfect. Ethical dilemmas in particular may require construction managers to resolve problems for which they cannot rely on simple formulas. An elective course in construction management, which has been developed over the past four years, in which these principles have been incorporated, will be described.

Keywords –

Construction management; Education; Learning-centered approach; Problem solving; Ethics.

1 Introduction

Most of today's students will still be professionally active in the 2060-70s (!). Hence, the curriculum and teaching methods of the previous century, which still prevails, will not be sufficient to provide the engineers of the future with the appropriate skills. Very early in their career they will find their education irrelevant. In fact, we already hear from young engineers and their employers that this is the situation.

With this in mind, we believe that the main objective of academic studies is not merely to provide technological and engineering knowledge. Instead, they should focus on EDUCATING students and developing their CREATIVE THINKING and their analytical skills. However, Construction Engineering & Management (CEM) studies currently focus mostly on a very particular type of quantitative analysis, which does not prepare the student well enough for the actual challenges of the profession.

The framework within which CEM students are educated has changed very little over the past decades. CEM courses are still mostly based on the use of frontal lectures, homework and exams. Moreover, in most of those courses the data required to solve assignments is given to the students in advance. Not only that, but the assignment normally has ONE "correct solution". As a result, many of those courses seem similar to students, and their content becomes merely a series of technical assignments. Such assignments are generally solved through well-structured procedures, as described in generic terms in Figure 1. This paradigm does not encourage creative thinking at all. In fact, it often even inhibits thinking altogether. With such an approach it is no wonder that many construction engineers and their employers ask questions, such as the ones quoted above.

The need to engage students and encourage learning and creative thinking has been recognized by some when it comes to engineering design courses, including civil engineering (e.g. Stouffer et al. [7]). We argue that the need for such an approach is just as clear when it comes to educating CEM students, as it is for gearing Civil Engineering students toward a career as design professionals who will concentrate on the engineering design work.

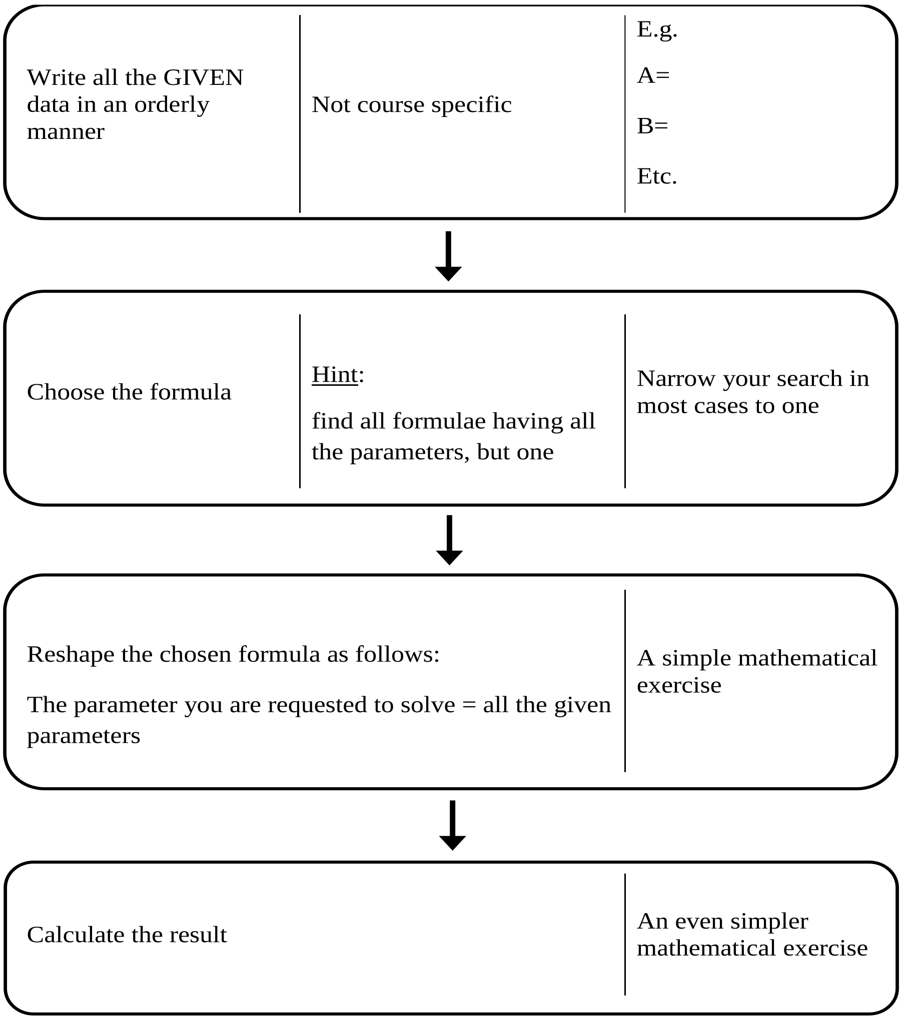

Figure 1. A typical procedure to solve assignments and exams in CEM

Construction engineers will concentrate in their professional career on project management aspects such as construction procedures, methods, and people management, which may appear to some to be more technical than creative design processes. In practice, however, construction engineers are required to be able to quickly resolve complex unstructured problems, under conditions of uncertainty and in "no time", by collecting and integrating information from different sources and providing creative solutions.

A clear example of a situation in which construction managers have to resolve a complex problem for which no simple formula exists, is when they face ethical dilemmas. Such dilemmas may occur when an engineer needs to quickly solve a complex problem while adhering to the project schedule– the customary solution for which may conflict with engineering ethics. The complexity is amplified because such dilemmas not only do not have easy solution, but in many cases, if not the majority of them, they are not even RECOGNIZED by the engineer. This is possibly why construction engineers focus more on the technical issues, and in turn, the civil engineering schools align with current practices of the industry instead of serving as the beacon, indicating what the practice SHOULD be.

Many of the colossal accidents in Israel, if not all, were caused because of such a situation. Areas in construction management in which such a situation may occur range from accounting practices to onsite worker safety, as well as others. A limiting paradigm, which can address only specific technical problems, will obviously not prepare the student to deal with such issues.

We, therefore, propose that a learning centered approach to the EDUCATION of the CEM student, in which they are confronted with the need to find not only solutions for such complex problems, but also to select the data from databases containing partial, excess and often conflicting data, will better prepare them for their profession.

Consequently, the objective of this paper is to discuss the prevailing paradigm in CEM education, and to present an alternative model, which seeks to engage the students and encourage them to think creatively in order to provide solutions to the types of problems that they are likely to encounter in their professional careers. This model was implemented in a course that has been developed by the first author over the past four years.

2 Enabling Student Learning

A number of educational methods that stimulate student learning have previously been proposed. These include: interdisciplinary focus, collaborative learning and active experiential learning, and more [6].

Kolb and Fry [3] have argued in this context that experiential learning entails a cyclic process containing four different steps:

1. Concrete experience.
2. Reflective observation.
3. Abstract conceptualization.
4. Active experimentation.

This integrated process begins with here-and-now experience (1), followed by the collection of data about that experience (2). The data regarding the immediate concrete experience is then analyzed in order to form abstract concepts and generalizations concerning the experience that is studied (3). Finally, the implications of these concepts are tested in new situations through active experimentation (4), leading to a modification of behavior and choice of new experiences when returning to the first step of the cycle. Immediate concrete experience is thus the basis for observation and reflection that lead to a theory from which new implications for actions can be deduced.

Two common strategies that have been used to engage students and encourage learning and creative thinking are problem-based learning and group learning.

Problem-based learning uses real-world problems to encourage critical thinking and problem-solving skills (e.g. [1,5]). The main difference between problem-based learning and other types of active, student-centered learning processes is in that it introduces concepts to students by challenging them with problems related to their future profession. It thus reverses the conventional model, by using problems before the content has been introduced, in order to initiate learning. Problem-based learning also focuses on problems that are open-ended, unstructured and do not have only one “correct” answer.

Group learning is a term used for exercises in which students learn to work together in small groups on a task, which usually mimics a real-life project [4]. Students carry out realistic tasks, without direct supervision, in order to acquire through experience knowledge and skills. The aim of these exercises is to give students a chance to experience group dynamics, to learn project and time management, prioritizing and to enhance their inter-personal skills. It is clear that construction engineering graduates will need high levels of such teaming and communication skills to be successful in their work places.

3 A Practical Implementation

An elective course in CEM has been developed by the first author over the past four years, in which the above mentioned principles and methods of a learning centered approach have been incorporated. The objectives were to create a course in which the students are actively engaged, and are required to think creatively in order to tackle real-world problems. These objectives were determined for the course despite the fact that its domain was construction management, rather than structural engineering design in which such an approach has more often been implemented.

The course involved the four steps of experiential learning that were defined by Kolb and Fry [3]. These are reflective observation, abstract conceptualization, active experimentation and concrete experience:

1. Reflective observation was attained by holding class discussions based on topics that were presented in lectures. Students were expected to reflect upon those topics, and to take an active part in the discussions. The outcome of those discussions was usually not a single authoritative conclusion regarding the topic discussed. Instead, students were encouraged to form their own individual opinion, even if it differed from that of the lecturer.
2. Abstract conceptualization was attained by assigning the students an academic paper to read, to interview an industry expert on the same topic, and finally to compare the findings obtained from both sources. This required the students to confront differing opinions, from an academic and from a professional point of view, on a single topic. Despite these differences, the students were expected to form concepts and generalizations of their own concerning the topic investigated. The students presented their findings in a short presentation (a very important by-product on its own).
3. Active experimentation was carried out by iteratively preparing a bid for a tender, based on data that they collected themselves from different sources (e.g. the statistical analysis of data, interviews with industry experts, an analysis of plans, etc.). The students were required to follow the entire process of preparing a tender

for the execution of a real-life BOT project, based on a real call that had been issued at the time. The process started with an analysis of the existing planning conditions, proposing alternative programmatic solutions, carrying out feasibility studies, and investigating financial and contractual aspects. A key to this process was the fact that it had to be carried out through a number of iterations, as previous decisions were revisited based on additional information that was gathered.

4. Concrete experiences were gained through the simulation of team work and multi-team exercises. The students were required to carry out all the exercises in teams in the classroom, in a studio environment. The preparation of the tenders was competitive, with only one team eventually winning the bid. In some exercises, a multi-team experiment was conducted, in which different teams were required to negotiate with each other and to reach a consensus.

The attitude of the students often changed considerably during the course. Bernold [2] has observed that in practice, most people are not equally proficient in all four of the abilities that are part of Kolb and Fry's framework [3]. Similar to the findings in Bernold [2], it was clear from informal exchanges with the students participating in the course, that they were initially not all equally comfortable with the different components of the course. In particular, all students found it challenging to deal iteratively with an open, ill-structured problem. This was for them the first time they experienced dealing with such a problem in their studies, having previously had to solve mostly well-defined assignments, as described in Figure 1, for which all the information required to solve the assignments was given to the students in advance. Many expressed concerns on this when given the assignments. However, whereas Bernold [2] reports findings according to which most Civil Engineering students do not consider active learning as being effective, the overall opinion of the students, once they had participated in the course, was very positive.

Anonymous on-line survey was conducted, the results of which showed a general satisfaction with the course. When asked to rate on a 5-point Likert scale whether they had acquired new knowledge, tools and an understanding of the subject that provided them with new analytical abilities, the average response was 4.6, with a standard deviation of 0.6 (where 1 indicated "very little" and 5 "very much"). When asked whether they had felt that they needed to invest a significant effort in the course, the average response was 4.3, with a standard deviation of 0.8. But when asked whether they had encountered difficulties completing the course the average response was 2.8, with a standard deviation of 1.2.

4 Conclusions

Whereas the experience in this particular course was positive, it does raise the question of how the proposed approach can be expanded to other courses, or even to the entire curriculum. In particular, this course was an elective course, in which relatively small groups of students (on average 15-30 students) participated, in the fourth year of their studies. It could therefore be a challenge to apply a similar learning-centered approach in courses with larger groups of students, and at an earlier stage of their studies. Nevertheless, we believe that this is vital in order to make CEM studies an experience that will be more valuable and relevant for students.

One possible solution for working with a larger number of students, which has already been partly explored in the existing course, is to use multiple-team exercises, in which multiple teams of students work on a single project, with each team responsible for a specific part of the project. Such exercises simulate the more complex real-life work environment, in which large engineering projects are often executed by multiple teams. Such projects require not only the coordination of the work of individual team members, but also some form of organizational structure that ensures the coordination of the work of different teams. Multiple-team exercises are therefore also an opportunity to allow students to become familiar with different project management structures and roles.

Another possible solution in order to engage students more actively in courses at earlier stages of their studies is the use of IT solutions. Technologies such as online learning platforms can be used during lectures, even in introductory courses, in order to ask the students to answer questions during the lecture, display their answers to the class immediately afterwards, and promote discussions. The introduction of such innovations in the classroom can be an inherent part of the effort to bring about a paradigm change in CEM education.

The second author is currently leading the development and establishment of a new Civil Engineering Department in ORT Braude College of Engineering. The proposed departmental curriculum, submitted to the Council for Higher Education, is based on principles such as the one described above. We will be reporting the progress in this area in the next paper.

Lately we conducted a very limited pilot study, in which the students had to do two things:

1. IDENTIFY a dilemma in given scenario which we described to them.
2. Evaluate the optional solutions in a structured manner.

This pilot study will be described and demonstrated in the presentation.

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