Implementation of Delphi methodology for designing engineering syllabus according to the industry’s needs

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Construction and civil engineering are multidisciplinary professions where students are acquiring a career that is based on the durable knowledge; practical abilities and industry’s needs. Other studies, such as mathematics or physics are pure science based on theoretical knowledge. But a question persists: is the knowledge acquired by engineering student completely needed by the industry? Are engineering syllabus actualized and designed considering the industries’ needs emerged by the continuous change in the sector? It is very important that the industry receives well qualified and specialized engineers able to assume their responsibility and to carry out their job assignments. The industry should be involved in the determination of the main courses of an engineering syllabus. This paper presents the implementation of the Delphi method to investigate the industry’s needs regarding engineering education. This implementation doesn’t contradict with durable knowledge to be acquired by students, durable knowledge doesn’t mean being rigid and non-innovative. Engineering departments should adopt auto innovative process for its syllabus design. This methodology could be suitable for some engineering more than others. In construction and civil one, we believe that new graduate engineers should be qualified for the ultimate industry tendencies. This methodology enhances the dialogue between the industry and the syllabus designers. Through the Delphi, a documented and questionnaire oriented dialogue is achieved. The main deliverable of this implementation is to find an interactive tool to actualize and redesign an engineering syllabus, considering the industries’ needs while maintaining the curricular coherence and homogeneity. Each single department can apply this methodology independently from the whole school to actualize its own syllabus. The paper consists of: an introduction; a revision of the application of the Delphi method in the investigation of similar fields; the design of the Delphi method application process to carry out the investigation; and conclusions.

Keywords: Engineering curriculum, curriculum design, industry’s needs, Delphi method.

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1. Introduction
Engineering, as a profession, usually deals with a lot of challenges, such as the changeable and progressive industry, changeable client perspectives and expectations, uncertainty, initial data shortage, and variability of legal and normative situation from one place to another. This situation implies that the engineer should be able to face all of these situations; this, on one hand, is a university responsibility, on the other hand, is an industry’s expectation to receive well prepared engineers.

Recently, many studies have been carried out to determine the technical and personal abilities required of engineers by the modern industry [1], this means that the syllabus and curriculum should be in a continuous and auto innovative process to meet many criteria to be well designed. Some of the hints for a well designed curriculum are holistic and coherent; inclusive/accessible/student centred; one that fosters a deep approach to learning; encouraging independence in learning; based upon/has links to research/scholarship; and based on feedback, evaluation and review [2]. According to the Accreditation Board for Engineering and Technology (ABET) [3] engineering programs students must demonstrate that they have the ability to:

- Apply knowledge of mathematics, science and engineering.
- Design and conduct experiments, as well as analyze and interpret data.
- Design a system, component, or process to meet desired needs.
- Function on multi-disciplinary teams.
- Identify, formulate, and solve engineering problems.
- Understand professional and ethical responsibility.
- Communicate effectively.
- Understand the impact of engineering solutions in a global and societal context.
- Recognize the need for and the engagement in life-long learning.
- Know the contemporary issues.
- Use the techniques, skills and modern engineering tools necessary for engineering.

According to Rodrigues, R. [4]: new engineers should be able, according to the industry’s needs, to presume several activities such as:

- Confirm existence of an experiment or test to avoid duplication of effort.
- Locate recognized experts, consultants and organizations that can answer complex questions.
- Find trends in venture capital spending.
- Find revenue opportunities such as contracts from government sources.
- Locate technologies that are licensable.
- Identify new and emerging research frontiers which the company may be interested in pursuing, leading to new technical and financial success.
- Identify and monitor others working on technologies of interest to the company.

But still a very important factor to be considered, which is the involvement of the industry where the engineer is going to transmit the acquired knowledge, this can be done while maintaining the traditional curriculum design criteria. The industry’s needs is not sufficiently involved in the engineering syllabus and curriculum design process, this may due to the complexity of that involvement and the satisfaction with the traditional design criteria. A lot of studies have emphasized the importance of the industry’s needs in the syllabus design, Rodrigues, R. [4] studies the situation of the information acquisition and management needed by the industry. A survey to assess the needs of the industry from the newly graduated engineers was carried out by Lang et al
[5], in that study, it is argued that qualitative methodologies (surveys and structured interviews) can be used to capture and quantify industry expectations for entry level engineering employees, for that; a survey was carried out to assess how can the industry-university-government enhance the engineering education to initiate a continuing and evolving process to provide curriculum designers with important information from industry. Schott et al [1] debate the problem of the Australian engineering education system which depends the traditional mode and the “chalk and talk” pedagogy, they argue the importance of the development of a new mixed system which considers the industry’s needs. May be there no perfect method or procedure to be followed while designing an engineering curriculum, Dym et al [6] study the project-based learning, but they emphasize the importance of the involvement of the interest of the industry in the engineering education. The involvement of the industry is applicable to all engineering fields, Bagert et al [7] highlight the industry participation as a curriculum design support for the software engineering education.

2. Delphi method
Delphi method can be a powerful technique to justify research results. But also, it can be used as a tool for other applications, between them, the proposed one in this article; it can be implemented through its introduction in the investigation methodology, or as a research tool [8]. Delphi method can be characterized as a technique for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem [9].

The method, along its history until the present, has passed several stages of perfection and use. According to the Greek mythology, the oracle at Delphi was consulted to forecast the future and important actions such as waging wars [10]. The history of the Delphi method was classified in five stages by Landeta [11]: The first one is the genesis from 1948 to 1959. The second one is the novelty stage which was encompassed between 1963 and 1964 when the method was used for military objectives. The third stage is the popularity one between 1970 till 1979, where more than 489 articles were published about the method. The fourth stage is the method’s criticism and re-examination between the years of the 1974 till 1979. The last stage is the continuation one since early 1980s till the moment, where the method has been emerged in various fields, problems and methodologies. Generally, the Delphi method was put in practice by the RAND Corporation in the late 1950’s as a forecasting methodology for military purposes[12].

Several modifications and combinations were introduced to the Delphi methods. Hecht [13] presented a modified Delphi technique which depended on individual or small group interviews at the first round, then face-to-face interviews during later rounds of data organizing and reporting; this modified technique consists of several steps which are the need’s identification, ranking and relative importance assignation to each identified need, rank calculation of the identified need, feedback of rankings to campus administrators, planning of actions and reporting of developed plans to all administrators. A combination of the Delphi method with a quality control technique to propose a systematic and flexible model for group decision making in the presence of multiple objectives also was proposed by Khorramshaholgol [14]. An important modification was introduced to the Delphi method, such as the minimization or elimination of the sequential rounds in a way that improves drastically the method
efficiency [15]. The minimization of the non-response of the Delphi participants was achieved by a series of proposed options [16].

This article presents a proposal for the application of the Delphi method as a technique to identify the construction industry’s needs; the curriculum designing team transforms these needs into design criteria. The structure of the article consists of: an introduction to revise the incorporation and importance of the industry’s needs in the engineering curriculum design; a brief introduction to the Delphi method; proposed methodology; Delphi method application (process design, rounds and questionnaire elaboration); and finally the conclusions.

3. Proposed methodology
In this article, a methodology is proposed to capture the industry’s needs; hence they are to be applied as syllabus design criteria. It depends on an interactive process of two parts; the first one is the syllabus or curriculum designing team, who is responsible for the establishment of the design criteria; the other part is the industry represented by the employer which can be any company or firm that is interested in certain skills and formation of the engineer. The process is to be performed through a series of interactive questionnaires to be filled by the industry.

In several countries, including Spain, national projects are being carried out actually to enhance the knowledge transfer from the university to the company [17]. These projects correspond to one direction (university-company), they could be developed to form a process considering the feedback, where the company (industry) provides the university with its needs, with which the university (department or curriculum designing teams) can modify, update or redesign its curriculum.

![Figure 1: university-company knowledge transfer](image)

In this article, a Delphi methodology is proposed as a tool to carry out the previous feedback, figure 2 represent the whole process and enumerate the curriculum design criteria in each case.

![Figure 2: university-industry knowledge transfer process](image)
4. Delphi method application

The application of the Delphi is a process which should be designed in a way that serves to reach the objectives. Delphi method is used to justify certain aspects of a certain investigation issue, such as those economical, functional, future, etc.; traditionally, this justification could be done through statistics or not.

In the case of the present Delphi method application, the Delphi questionnaire is elaborated based on the first approximation to the industry’s needs. Some aspect of those needs should be investigated. The main aim of the method application is the study of the following aspects about the needs:

- **Importance for the industry**: the importance of each included factor in the classified information to identify the industry’s needs.
- **Innovativeness**: innovative aspect of the needs for the industry and for the university curriculum as well.

At the same time, the application of the method aims to gather the industry’s recommendations about the curriculum content, coherency, innovativeness, completeness, etc. The application methodology of the Delphi method is presented in figure 3.

![application methodology of the Delphi method](image)

**Figure 3: application methodology of the Delphi method**

4.1. Application process design

The application of the Delphi method should be carried out taking into account various factors. These factors are: the number of the proposed rounds; Delphi questionnaire design; expert panel size; and application time. The application process consists of several steps which lead to the method complete implementation. The considered steps are seven, and they are the following:

1. **Problem (issue) to be studied**: it is the problem to be solved by the Delphi method. In this paper, it corresponds to the identification of the industry’s needs. In this application, the problem will correspond to a single department or a single syllabus.

2. **Expert panel selection**: in this case, this panel corresponds to the members of the industry, or companies and employers, in the case of the construction industry, then it refers to constructing, consulting firms, public administration, etc. there is no study that advocates an exact number of experts forming the panel. Loo, R. [10] says that a panel of 15-30 experts is sufficient for a heterogeneous population, while 5-10 are enough for a homogenous population. The panel size is a function of: the complexity of the problem; expert’s availability; number of possible rounds; dealt issue importance; and expert interest. In the research, a panel of experts is organized for each project phase to be studied. The final panels are not decided yet, but in the pilot study, three experts participated.

3. **Document hand out**: explanatory material including the research objectives and methodology. This documentation aims to make the expert to understand the subject
of the Delphi questionnaire, and what the study pretends. Such documentation can be sent along with the Delphi questionnaire.

4th. Delphi questionnaires: in this step the questionnaires should be elaborated and sent to the expert panel. These questionnaires are designed taking into consideration the project phase, stage and Delphi round.

5th. Coordinating group: it is the group which organizes the whole Delphi application processes; its main tasks are to elaborate, send and receive the filled questionnaires, analyze and report the obtained results.

6th. Roundtable: it is optional; it can be done for each stage or for the whole Delphi implementation; it is a decision of the coordinating group. Results report is prepared at the end of the roundtable meeting with the experts.

7th. Final report: the results from the last two steps are presented; if the round table is not adopted, then the final report refers to the fifth step only.

Figure 4 shows the schematic flowchart which represents the Delphi method implementation process.

4.2. Proposed rounds
The number of Delphi rounds is very important, as well as the size of the elaborated Delphi questionnaires. Traditionally, the number of the rounds to be conducted depends on the convergence to the expert conscious. But, the questionnaires could be planned and designed in a way to reach a conscious after two rounds.

4.3. Delphi questionnaires elaboration:
The elaboration of the questionnaires for the interactive process is a tough task. It should involve the information containing clues of the industry’s needs to be captured, at the same time; it should consider the traditional curriculum design criteria. For that, the information related to the industry and its relation with the university curriculum should be analyzed, arranged and presented in a certain way that serves for the questionnaires elaboration.

Delphi questionnaires can be designed with open and closed questions, such a way that both statistical and no statistical analysis can be carried out. It is proposed that for each curriculum or syllabus, a single Delphi questionnaire to be developed.

5. Conclusions
1. The curriculum design process is a complicated and critical function; it should consider several criteria, such as the knowledge durability, curriculum coherency, competitiveness, etc. These are the traditional criteria applied in the curriculum design.
2. The rigidity and the innovation resistance are some of the problems that face the engineering curriculum.
3. Industry is the best reference for the curriculum designer; its needs can be emerged as design criteria. This will reflect the continuously changed demand’s preferences in the engineer profile.
4. The relation university-company is a single direction one, where it is argued that the knowledge is only transferred from the university to the industry, but this could be changed to a complete process, where the industry could feedback the university with valuable information to update, modify or redesign the engineering curriculum.
5. The main question is how can the industry feedback the university? And what type of information to be provided in this process? The way that the curriculum designer should adopt a methodology to capture and identify the industries needs which should be satisfied by the graduated engineers.

6. Delphi method is a well known investigation tool, in this article, it is proposed as a tool to be applied by the curriculum designers to identify the industry’s needs. The identified needs could be converted in curriculum design criteria.

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**Figure 4: application process of the Delphi method**
6. Acknowledgments
The research described in this paper was partially financed by the Spanish Ministry of International Affairs and J. A. Goméz Cerezo Foundation in Valencia-Spain. The authors want to thank both organizations for their support.

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