Thinking styles and engineering: proposals for strengthening the professional training of engineers through physics courses

C Gaete-Peralta¹, and J Huincahue²

¹ Departamento de Matemáticas y Física, Universidad Bernardo O'Higgins, Santiago de Chile, Chile
² Centro de Investigación de Estudios Avanzados del Maule, Universidad Católica del Maule, Talca, Chile

Email: claudio.gaete@ubo.cl, jhuincahue@ucm.cl

Abstract. One way to contribute to the strengthening of professional training processes in Engineering is through teaching and evaluation methods physics courses that promote those thinking styles that should be preferred by an engineer to solve tasks of their profession. Based on the above, the objective of this research was to identify those thinking styles that ideally a graduate of industrial civil engineering from a certain Chilean university should prefer to perform their profession tasks. Responding to this objective, it will be possible to generate educational proposals in physics courses for that career. For this, a qualitative methodology called thematic analysis was used. The data sources were semi-structured interviews with academics with enough experience in the career, besides the analysis of the institutional graduation profile. From a deductive perspective, according to the thinking styles, the ideal preferences for the legislative, judicial, global, hierarchical, liberal and external styles emerged as a result. Finally, a discussion was held on some teaching and evaluation methods that can be carried out in the physics courses of this career in order to promote these thinking styles.

1. Introduction

At present, several investigations reveal the competences, attitudes, skills and knowledge that must be part of an engineer in order to practice their profession, which grant references to higher educational institutions that teach engineering careers to strengthen their professional training processes. To mention some of them, it is possible to find research that considers that an engineer must be able to solve problems [1], be creative, innovative and entrepreneurial [2] and have knowledge related to technology and society [3], and from a more precise approach, the importance of physics courses in engineer training [4] and how such features can be promoted. from a more precise and directed conception, studies are displayed that account for different types of characteristics to be possessed in specific engineering, such as computer engineering [5], electrical engineering [6], or industrial civil engineering [7].

One way to contribute to the strengthening of professional training processes in engineering is through the implementation, in physics courses, of different evaluation and teaching methods that aim at the development of cognitive characteristics that are required, ideally, by an engineer to solve tasks of their profession. This type of characterization can be carried out through a study of ideal preferences for thinking styles [8] in engineering careers, which can be taught through different evaluation and teaching methods [9], for example, in Physics courses which are essential in the
training of an engineer [4]. In this way, the question that will guide this research will be the following: what are the thinking styles that an engineer should ideally prefer to develop typical tasks of his/her profession? To better address the research question, it was necessary to limit the study to a particular type of engineering, taught in a specific higher educational institution. In this case, the study was limited to a degree in industrial civil engineering at a Chillean university.

To answer the research question, we will begin by recognizing the patterns of meanings that emerge from the discourse of people who currently direct the career, and who, at the same time, are academics of the industrial civil engineering career, in addition to the analysis of the graduation profile. These patterns can be described by thematic analysis [10,11], which will be described in the methodology section. From an educational psychology approach, the patterns of meaning will allow us to know what preferences the career has in its training. Answering this research question will allow a discussion about some teaching and evaluation methods that can be carried out in the physics courses of this career with the purpose of promoting those thinking styles that a graduate of the industrial civil engineering career ideally should prefer to develop their profession specific tasks. Thus, the objective of this research is to identify those thinking styles that ideally a graduate of industrial civil engineering from a certain Chilean university should prefer to carry out tasks related to their profession.

The structure of this essay will be as follows: first, you will be aware of the methodological aspects that will allow you to address the research question (section 2). Next, section 3 will show a thematic analysis of the conceptions of two academics of the industrial civil engineering career of a Chilean university and of what is established in the graduation profile of this career, regarding the competencies, skills and knowledge that a graduate of industrial civil engineering from this university should ideally possess to practice their profession. Next, these conceptions will be categorized through the theory of thinking styles [8] to account for those styles that a graduate of industrial civil engineering should prefer to develop tasks of their profession. In section 4, there will be a discussion about some teaching and assessment methods that can be carried out in the physics courses of referred career to promote the thinking styles categorized in section 3. Finally, the conclusions of this investigation will be described.

2. Methodology
To answer the research question, thematic analysis [10,11] was used, since it is an exploratory, descriptive and interpretive methodological framework that allowed the identification of patterns of meanings (themes) that characterize the preferences of the career. The thematic analysis consists of six phases: (1) familiarization with the data, (2) generation of initial codes, (3) search for themes, (4) review of themes, (5) definition and naming of themes, and (6) production of the report. The first phase consisted of reading and studying all the information to propose a first understanding of the key concepts of both scenarios. In the second phase, a descriptive coding was carried out which made it possible to recognize certain codes of a more general nature, thus generating potential themes. In phase 3, a refinement of the coding process was carried out based on the search for patterns associated with thinking styles. Phase 4 brought together the analysis of all code associations between two researchers in parallel and then agreed on discordant codes. In this sense, phase 4 included a review of phases 1 and 2 to generate a first version of the thematic map which is a way of relating the themes with subcategories that are recognized in the data. Phase 5 focused mainly on the refinement of the thematic map where the definitions of themes were generated so that map faithfully represented the data, subject to a prevalence emanating from the theoretical framework. Finally, a synthesis of phase 6 is presented in this article. The way to report the analysis in this research will be similar to the one made it in [12].

The data collection consisted of generating limited and precise questions about the activities that a graduate of the civil industrial engineering career of that university will carry out, characterizing from the theoretical framework of the theory of mental self-government [8], certain preferences and attitudes that are required to be promoted within the courses that offer the training. The recorded and transcribed interviews were directed to active academics of the industrial civil engineering career who
VII International Conference Days of Applied Mathematics  
Journal of Physics: Conference Series 1702 (2020) 012020  
doi:10.1088/1742-6596/1702/1/012020

coincide with having managerial positions within the career. In addition, as a process of validation and interpretive surveillance, the analysis of the interview (initial phases) was triangulated with the institutional information about the graduation profile of the career, in order to strengthen the familiarization of the data.

3. Analysis and results

3.1. Analysis of empirical data

After carrying out the transcription of the information, the process of thematic analysis phases considering two experts in the theory of mental self-government began [8]. The coding process made it possible to recognize the characteristics of most of the thinking styles (Table 1). The Table 1 show the codes resulting from the analysis of the semi-structured interviews and the graduation profile of the industrial civil engineering career of a determined Chilean university. Subsequently, based on a frequent evaluation, the coding process was refined to decide the possible themes that capture the meaning of the thinking styles. In this phase of the thematic analysis, the graduation profile was used as a framework of interpretive validity against the responses of the interviewees, allowing contextualizing the meanings that emerge in their responses. In addition, in this phase the relevance of each style was recognized according to the explanations of competences and abilities, allowing to discard some thinking styles and to link and compile codes that share meanings related to the preference of styles. Finally, after continuously carrying out a process of refinement and adjustment of codes with the linking and naming of the subtopics according to the meanings of the thinking styles, a final refinement of the thematic map was generated, which is presented in Figure 1.

During the analysis, four more general codes were identified as the main topics to categorize the ideal characteristics that a graduate of the industrial civil engineering career of a certain Chilean university should possess: creativity, leadership and ability to work in teams. A thematic map that systematizes the meaning patterns of the interviewees and the profile graduation of a certain Chilean university is shown in Figure 1. This thematic map (Figure 1) will be explained below, in the following subsections.

Table 1. Codes resulting from the analysis of the semi-structured interviews.

| Source of information | Codes |
|-----------------------|-------|
| Dean                  | Creative; entrepreneur; leader of work teams; able to work in teams; outgoing professional; multidisciplinary; pragmatic; problem solver; innovative. |
| Director of that career | Creative; entrepreneur; innovative; business management; managerial skills; optimization of processes; teamwork; ethical; leader in his occupation, rudeness. |
| Graduate profile      | Innovative; process optimization; ethical; leader; project and process management; problem solver; critical professional; thoughtful professional; collaborative worker; negotiating skills; responsibility. |

Figure 1. Thematic map to describe the ideal characteristics that a graduate must have to develop their professional tasks.
3.1.1. Creativity. During both interviews the need to promote creativity arises. This is linked with the examples to the ways of addressing problems that arise in the exercise of the profession, which is also validated with the career graduation profile. The dean specifies this type of problem with the need to develop innovation: "creativity is linked to innovation … (the industrial civil engineer) has to be able to have a vision of things ... be visionary, see what things can be improved or fixed". At the same time, the career director pointed out in the interview that creativity is an ideal characteristic that a graduate of this career should have, mainly to carry out the creation of complex systems in the exercise of the profession: “the ideal would be to achieve the creation, but I think it is still a second derivative. The idea is to aim, in a vision of the future, the creation of complex systems”.

According to the graduation profile of the industrial civil engineering career of this university, creativity is manifested in the ability to solve typical problems of their profession, with a comprehensive and systemic approach, to deliver solutions that are innovative.

3.1.2. Ability to work in teams. For the dean the ability to work in teams is a property fundamental of an industrial civil engineer, since the problems that occur in their work field are mainly multidisciplinary in nature, being necessary to gather more information from multiple approaches for decision making:

✔ It is essential that the engineer work in teams, because the challenges in engineering are generally multidisciplinary ... then, you have to recognize that you have certain skills, but not others, so you have to learn to work with a team of whatever: multidisciplinary ... whatever you have next to you ... then if [the engineer] should work in teams (dean).

In addition, for the career director and triangulating the dean’s opinion an industrial civil engineer must have multidisciplinary knowledge to carry out management tasks in different areas of the industry: “[the industrial civil engineer] must have a certain domain in multidisciplinary areas. He must know management in different areas of the industry (career director)”. According to the graduation profile of this career, the ability to work collaboratively is a desired characteristic in a graduate of this career, since this will allow them to solve problems of the context in which they operate. All these components on the meaning of teamwork are latent and explicit in each of the speeches and documents.

3.1.3. Leadership. Leadership is linked to the practice of the industrial civil engineer, since the need for decision-making requires that he/she should be recognized as a leader in the teams where he/she performs. About, the engineer’s tasks allow him/her to focus his/her knowledge on a global sense for each area of work in which he/she participates (for example, construction, resistance of materials, economy). For the dean, leadership is a fundamental characteristic in an industrial civil engineer which will allow him/her to take on professional challenges:

✔ It is desirable that [the industrial civil engineer] be a leader, that he will be capable of leading a company “... it is desirable that engineers will be leaders, because it gives them a certain degree of independence to do their things. It is necessary for them to be leaders to be able to take on greater challenges (dean)”.

In the case of the career director, the leadership capacity of an industrial civil engineer is reflected when it refers to the fact that this type of professionals must be capable of making managerial decisions: “[the graduate requires] understanding the complete system of the company. From the productive, management and financial side ... that has a complete vision and can actively participate in senior management decisions in all areas” (career director). The graduate profile also refers to leadership capacity, since skills are expected to optimally direct and manage development projects and production processes.
In summary, and from the data analysis, the thematic map shows us significant patterns in the work of the future professional, whose results, being related to the forms of thinking [8,9], provide alternatives to promote such strategies in the physical courses.

4. Ideal preferences for thinking styles of an industrial civil engineer

Given the meanings that have emerged in the previous analysis, these were related to characteristics of the theoretical framework with the purpose of proposing which are the identified thinking styles. In [13], creativity is associated with the legislative, judicial, global, hierarchical and liberal styles, and the ability to work in teams is an aptitude that is commonly associated with the external style, according to what the theoretical framework points out. In the particular case of Leadership, it is not necessarily associated with a specific thinking style, but it is a skill that can be cultivated from multiple thinking preferences. However, it is common to locate leadership with external style preferences; in this sense, the leadership theme of the thematic map reinforces the relationship with the thinking styles already identified.

In this way, from the perspective of the theoretical framework, thinking styles that an industrial civil engineer from a certain Chilean university should ideally prefer to develop tasks of their profession, are the legislative, judicial, global, hierarchical, liberal and external styles.

According to the above, it should be noted that the teaching and evaluation methods carried out by teachers in their classes allow the promotion of different thinking styles [9]. In the particular case of the engineering career studied in this research, it is recommended that teachers who teach classes in that career use evaluation and teaching methods that allow the promotion of legislative, judicial, global, hierarchical, liberal and external thinking styles.

In the case of the external thinking style, it is possible to promote it through teaching and evaluation methods based on collaborative learning [9], which can be done through the use of technologies of the information [14]. One way to promote the Judicial thinking style is through teaching methods that allow the formulation and verification of hypotheses in physics courses (basic part of the scientific method), such as, for example, the use of teaching methods where students have to analyze the veracity of different statements about the causes of floating bodies [15]. One way to promote hierarchical, legislative, judicial and external thinking styles is through the use of portfolios as evaluation instruments [9]. In this sense, the use of electronic portfolios in the interactive Moodle platform, in physics courses, is an interesting evaluation method to promote such styles [16].

One way to promote the Liberal thinking style is by using teaching and assessment methods, in physics courses, that encourage students to solve problems in alternative and non-obvious ways [8].

Regarding the promotion of the global thinking style, it can be carried out through methods that allow students to make global statements but are not supported by specific evidence [8]. In physics courses, this could be done through teaching and assessment methods that encourage students to formulate hypotheses about various types of physical phenomena, but without having to verify their validity through experimentation.

These proposals are very interesting for the academics who teach physics courses in the civil industrial engineering career at the already studied Chilean university. They give opportunities to innovate the ways they teach the lessons based on theoretical framework which come from educational psychology with the purpose to promote those thinking styles that a graduate from this career should prefer to solve their profession tasks.

5. Conclusions

This research revealed those thinking styles that a graduate of the civil industrial engineering career of a certain Chilean university should ideally prefer to be able to solve tasks that are typical of their profession: legislative, judicial, global, hierarchical, liberal and external. It should be noted that the above does not imply that the rest of thinking styles should not be ideally preferred by a graduate of this career, it only means that this research did not find enough evidence to incorporate more of them. On the other hand, despite of the fact that the study to discover the thinking styles was carried out
considering particular aspects, such as the specificity of the engineering career and the institution that teaches it, the methodological aspects presented in this research are sufficiently flexible to replicate this study to any university career, regardless of the institution of higher education that has it.

Studies such as the one presented in this work, allow to strengthen the professional training processes of a certain career, since it gives, to the respective educational institutions, references on those thinking styles that must be promoted so that their graduates can develop their specific profession tasks. In the particular case of this research, the contribution to the educational community in physics is to discuss about some teaching and evaluation methods that allow promoting those thinking styles that, ideally, a graduate of the industrial civil engineering career of a certain Chilean university, should to prefer to develop tasks that will be part of their professional work.

It should be noted that a greater discussion about other teaching and evaluation methods that allow promoting certain thinking styles remains for the educational community in physics. In this sense, it is necessary to continue with the development of research from the perspective of thinking styles, to continue contributing to the strengthening of training processes in engineering, based on teaching and evaluation methods in physics courses.

References

[1] Boccardo R 2006 Creatividad en la Ingeniería del Diseño (Caracas: Equinoccio)
[2] García-González A, García-González M, Aguileo-Giraldo M 2019 Formando ingenieros emprendedores Revista Educación en ingeniería 14(27) 72-82
[3] De Graaff E, Ravesteijn W 2001 Training complete engineers: global enterprise and engineering education European Journal of Engineering Education 26(4) 419-427
[4] Garza Rivera R G 2001 El rol de la física en la formación del ingeniero Ingenierías 4(13) 48-54
[5] Huincahue J, Gaete-Peralta C, Garrido-Vélez V 2019 Thinking styles and computer engineering training: An empirical study International Journal of Cognitive Research in Science, Engineering and Education 7(1) 21-33
[6] Vásquez C, González C 2011 El desarrollo sustentable, la dependencia energética y las nuevas competencias del ingeniero electricista Publicaciones en Ciencias y Tecnología 5(1) 5-14
[7] Valle M, Cabrera P 2009 ¿Qué competencias debe poseer un ingeniero civil industrial? La percepción de los estudiantes Revista iberoamericana de Educación 50(4) 1-14
[8] Sternberg R 1997 Thinking Styles (New York: Cambridge University Press)
[9] Sternberg R, Zhang L 2005 Styles of thinking as a basis of differentiated instruction Theory into Practice 44(3) 245-253
[10] Braun V, Clarke V 2006 Using thematic analysis in psychology Qualitative Research in Psychology 3(2) 77–101
[11] Braun V, Clarke V, Hayfield N, Terry G 2019 Handbook of Research Methods in Health Social Sciences ed Lliamputtong P (Singapore: Springer)
[12] Frejd P, Bergsten C 2018 Professional modellers’ conceptions of the notion of mathematical modelling: ideas for education ZDM Mathematics Education 50(1-2) 117-127
[13] Zhang L, Sternberg R, Rayner S 2012 Handbook of Intellectual Styles: Preferences in Cognition, Learning, and Thinking ed Zhang L et al (New York: Springer)
[14] Lagos Figueroa J A 2017 El papel de la física en la formación profesional del ingeniero Technology, Education and Nature 1(1) 91-96
[15] Corona A, Slisko J, Meléndez J 2007 Haciendo ciencia en el aula: Los efectos en la habilidad de falsear diferentes hipótesis sobre la flotación y en las respuestas a la pregunta “¿ por qué flotan las cosas?” Latin American Journal of Physics Education 1(1) 44-50
[16] Fuentes B, Pérez A, Montoto, A, Dominguez, M, Calzadilla O 2007 La plataforma interactiva Moodle: Una oportunidad para la docencia universitaria de la Física Latin American Journal of Physics Education 1(1) 73-77