Engineering graduation profiles and thinking styles: educational proposals to strengthen the training of engineers

Claudio GAETE-PERALTA
Departamento de Matemáticas y Ciencias de la Ingeniería, Universidad Bernardo O´Higgins
Santiago, 8320000, Chile

Jaime HUINCAHUE
Centro de Investigación de Estudios Avanzados del Maule, Universidad Católica del Maule
Talca, 3480005, Chile

ABSTRACT

This research was framed in Sternberg's theory of Mental Self-Government and aimed to identify ideal preferences for thinking styles that graduates of Mining Civil Engineering career from different Chilean universities must possess to develop their professional work tasks. In order to fulfill this objective, the methodology used was qualitative and consisted of a semantic thematic analysis of the information obtained from the graduate profiles of Mining Civil Engineering from eight Chilean universities. As a result of the research, it was identified that the graduates of this career should ideally prefer the Legislative, Judicial, Global, Hierarchical, Liberal and External thinking styles. Based on the above, some teaching and evaluation methods that can be carried out in the professional training processes of this career were proposed, to promote those thinking styles.

Keywords: Thinking styles, Engineering, Thematic analysis, Graduate profile, Teaching and evaluation methods

1. INTRODUCTION

There are different investigations that account for the desirable competencies and skills in an engineer for the development of his profession tasks. To mention some of them, it is possible to find desirable competencies and skills in specific engineering, such as Industrial Civil Engineering [2], Electrical Engineering [3] or Computer Engineering [8, 20], among others.

Higher educational institutions that teach engineering careers seek to promote the competencies and skills that they consider desirable in an engineer, through various teaching and evaluation methods, such as the use of virtual reality [18], the implementation of game techniques, gamification practices in education and e-learning [1], or through the mobile internet of devices [9]. However, the development of desirable competencies and skills in an engineer can also be carried out from a cognitive perspective, through the construction of models that allow promoting those types of thinking required in this type of professionals, such as critical thinking [23] or logical and abstract thinking [15], among others. In that direction, there are researches that have been in charge of characterizing the desirable competencies and abilities in Engineering graduates, through the construction of thinking models that account for ideal preferences for thinking styles [21], that students of specific careers in higher education must possess in order to carry out their profession tasks, such as, for example, Industrial Civil Engineering [2] and Computer Engineering [8].

Thinking styles [21] have characteristics such as they can be learned -and therefore modified- by living with other people in the everyday environment [16] and being susceptible to change based on teaching and evaluation methods [10, 11]. Given these characteristics, the construction of thinking models such as those carried out in [2] and [8], provide references to higher educational institutions so that they can carry out discussions about teaching and evaluation methods that can be implemented in their professional training processes, to promote the suitable preferences for the thinking styles raised in that model.

Chile has a wide diversity of mineral resources and mining operations, which is why it increasingly requires professionals specialized in the mining area who can collaborate in the country's development in this area. In this way, and to contribute to the training of this type of professionals, Mining Civil Engineering career was chosen to carry out this research.

Based on the aforementioned, the objective of this research is to identify suitable preferences for thinking styles that graduates of the Mining Civil Engineering career from different Chilean universities must possess to develop tasks of their professional work. The above, in order to discuss about some teaching and evaluation methods that can be implemented within the professional training processes of this career to promote these suitable preferences for thinking styles.

The structure of this article will be as follows: first, the methodology that responds to the proposed research objective (section 2) will be disclosed.

Subsequently, in section 3, the thematic analysis carried out on the profiles of graduates of the different Chilean universities that teach the Mining Civil Engineering career will be shown. This allowed the construction of a thematic map that characterized the competences and skills that these universities expect in their graduates. Next, the information provided in the thematic map will be categorized through the theory of thinking styles. [21]In order to identify ideal thinking styles that a graduate of the Mining Civil Engineering career should prefer to develop his professional work tasks. In section 4, there will be a discussion about teaching and evaluation methods that allow promoting preferences for the thinking styles reported in section 3. Finally, in section 5, the conclusions of this research will be presented.

2. METHODOLOGY

Data Collection

The purpose of data collection was to know the competencies or abilities that graduates of the Mining Civil Engineering career must possess in order to perform their professional work tasks. The data collection was made from what was established in the graduate profiles of Mining Civil Engineering of eight Chilean universities: Universidad de Chile, Universidad de Concepción, Universidad de La Serena, Universidad de Talca, Universidad Técnica Federico Santa María, Pontificia Universidad Católica de Valparaíso, Universidad Arturo Prat and Universidad Católica del Norte. All this information is public and can be found on the website of each of these higher educational institutions. The choice of them was due to the fact that these universities are all the institutions that teach this career in Chile. At the same time, they have an agreement with the PACE program (Spanish acronym for *Programa de Acceso a la Educación Superior*), a program whose purpose is to support the professional training process of students starting higher education, through permanent accompaniment and supportive actions. The importance of these universities having an agreement with the PACE program lies in the fact that this research seeks alternatives that allow complementing the accompaniment and supportive actions carried out by each of these universities.

Data analysis

To analyze the data obtained from the graduation profiles, a thematic analysis was carried out. [31, 32] It was an exploratory, descriptive and interpretive approach that allowed the identification of themes for the construction of a thematic map that described the ideal characteristics that graduates of the Mining Civil Engineering career should have to develop their professional work tasks. Given the nature of the data, the analysis was directed by its semantic nature, in order to characterize the ideal preferences for thinking styles declared by the institutions in their graduation profiles. The thematic analysis consists of six phases: 1) familiarization with the data, 2) generation of initial codes, 3) searching for topics, 4) reviewing topics, 5) definition and naming of topics, and 6) writing of the report. The first phase consisted of familiarizing the data obtained from the graduation profiles of the Mining Civil Engineering career of each of the eight studied universities, to raise a first understanding about the ideal expected characteristics. In the second phase, a descriptive coding was carried out, which allowed us to recognize certain codes and potential themes that capture the essence of the ideal characteristics expected by the graduates. In phase 3, a refinement of the coding process was carried out. This was guided by the study of the competences and abilities expected in the graduates, after analyzing the underlying cognitive characteristics. Phase 4 brought together the analysis of all the code associations that were between two researchers in parallel in order to agree on discordant codes and highlight the eventual issues that manage to describe the ideal characteristics of a graduate of Mining Civil Engineering to develop their profession tasks. In this sense, phase 4 included a review of phases 1 and 2 to generate a first version of the thematic map. 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. Finally, a synthesis of phase 6 will be presented in this article.

Once the thematic map was constructed, the information obtained in that map was characterized from the Mental Self-Government theory [21], to identify preferences for thinking styles that, ideally, a graduate of the Mining Civil Engineering should prefer to perform tasks of their professional work.

Finally, it is important to note that this type of analysis has been used in research such as the one carried out in [2].

3. ANALYSIS AND RESULTS

Analysis of data obtained from graduation profiles

During the data analysis, it was possible to identify three themes that characterized the desirable competencies and abilities that were reflected in the graduation profiles of the eight universities studied: creativity, ability to work in teams, and scientific knowledge. Table 1 shows the codes obtained after analyzing the data obtained from the eight graduate profiles, which allowed the construction of a thematic map that systematized the competencies and abilities declared in the shown graduation profiles (Figure 1). This analysis, being triangulated with the thinking styles allowed rescuing the cognitive essence of such characteristics. Next, the topics that were part of the thematic map will be explained.

Have creativity. The design process is in itself creative [14] and to be able to optimize different types of processes in Engineering, creativity is necessary. Regarding this, five universities included desirable characteristics in their graduate profiles, such as the ability to optimize and design process in the mining area [17, 24, 26, 28, 29].

In [5] it is pointed out that it is desirable for engineers to have knowledge related to technology. Regarding this, a basis for achieving technological development is creativity [4]. In this direction, three of the studied universities included characteristics associated with the development of technologies in their graduation profiles [17, 26, 29].

On the other hand, the ability to solve problems, desirable in every engineer [19], is a characteristic associated with creativity [13]. In this direction, three universities included this ability in their graduation profiles, either explicitly or not [24, 26, 29].

Have the ability to work in teams. Teamwork is a fundamental characteristic in a Mining Civil Engineer to solve problems in the mining area. Specifically, it is desirable that graduates of this career possess the ability to lead multidisciplinary teams in the mining area, which was declared in the graduate profile of three of the universities studied [25, 28, 29].

Possess scientific knowledge. The use of scientific knowledge is very important to solve problems in the area of mining. Six universities included within their graduation profiles characteristics linked to possessing scientific knowledge, specifically in Basic sciences and in Engineering sciences [17, 24, 25, 26, 27, 29].

Table 1. Codes resulting from the analysis of the graduation profiles.

University	Codes
Universidad de Chile	Design and optimization of scientific-technological solutions in mining; management of operations and projects in mining; management of mining ventures; problem solving in mining.
Universidad de Concepción	Ability to face technological changes in mining; solid foundations in Basics science and Engineering.
Universidad de la Serena	Design and planning of mining operations; sustainability; ability to work in multidisciplinary teams; solid foundations in Basics science and Engineering.
Universidad de Talca	Application of knowledge of Basic sciences and Engineering; design and planning of mining processes; problem solving in mining; entrepreneurship; technology development; innovation.
Universidad Técnica Federico Santa María	Business in mining; operation of mining chores; entrepreneurship in mining; research in mining.
Pontificia Universidad Católica de Valparaíso	Problem solving in mining; use of technology in mining; knowledge in Basic science and Engineering; evaluation and optimization process in mining; process design in mining; planning and management of mining projects.
Universidad Arturo Prat	Knowledge in Basic sciences and Engineering; design and optimization process in mining; design and plan mining projects.
Universidad Católica del Norte	Knowledge of Basic sciences and Engineering; effective communication; leadership and proactivity; innovation, entrepreneurship; ability to work in multidisciplinary teams; planning and operation of mining operations; management of mining projects.

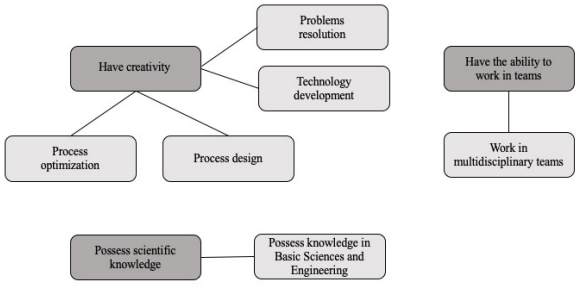

Figure 1. A thematic map to describe the ideal characteristics of a graduate of Mining Civil Engineering to develop his profession tasks.

Suitable preferences of thinking styles of graduates of Mining Civil Engineering.

In [12] creativity is associated with the Legislative, Judicial, Global, Hierarchical and Liberal thinking styles while the ability to work in teams is commonly associated with the External thinking style, as indicated by the Mental Self-Government theory [21]. Regarding scientific knowledge, it is not a characteristic that can be associated with a preference for any particular thinking style, although the rigor of basic sciences and Engineering provide perspectives that promote characteristics associated with the creation and execution of tasks, algorithms and techniques that are related to Legislative, Judicial and Hierarchical thinking styles.

In this way, from this theoretical perspective, the thinking styles that a Mining Civil Engineer should ideally prefer to carry out his profession tasks are *Legislative*, *Judicial*, *Global*, *Hierarchical*, *Liberal* and *External*.

4. DISCUSSIONS

The teaching and evaluation methods carried out by teachers in their lessons allow promoting different thinking styles [22]. Physics is a science that is studied in different subjects that are part of its curriculum in the case of the Mining Civil Engineering career, so it is possible to promote the Legislative, Judicial, Global, Hierarchical, Liberal and External thinking styles through different teaching and evaluation methods in physics courses, such as those proposed in [2].

One way to promote the Legislative, Judicial, Hierarchical thinking styles is through the use of portfolios as evaluation method [22]. This is explained, given the need to visualize and operationalize multiple work projects and in various areas of Mining Civil Engineering. In this sense, what has been done in [17] offers an interesting reference to build portfolios as an evaluation method for engineers in training, since it offers different alternatives to build portfolios that are extremely rich in diversity of evidence that allow the achievement of different competencies and desirable abilities in an engineer. It is possible to promote External thinking style through teaching methods that allow students to discuss in small groups [22], about the different solutions of a problem, challenging students to work in multidisciplinary teams where they are encouraged to lead and systematize tasks. The promotion of preferences for External thinking style can also be done through the use of collaborative learning as a teaching method [22]. In the latter case, what has

been done in [6] is an interesting reference to carry out this type of method, since its purpose is to develop teamwork competence in Engineering students.

Finally, one way to promote the Global thinking style is through teaching methods that seek to rescue main ideas in reading texts [22].

The teaching and evaluation methods proposed in this section are of great interest to academics who give lessons in the Mining Civil Engineering career at the Chilean universities studied in this research. These methodologies provide opportunities to promote those thinking styles that a graduate of this career should prefer to solve tasks that are specific to their profession.

5. CONCLUSIONS

The identification of preferences for thinking styles [21] has admitted those competencies and abilities desirable by different Chilean universities for their graduates of Mining Civil Engineering. This allows building a thinking model that provides elements so that higher educational institutions can design teaching and evaluation methods that aim to strengthen the professional training processes of this career.

The methodological aspects presented in this research make possible to replicate the construction of this type of model for other Engineering careers. Researchers' challenges concerned with the engineering education are to continue with the development of research, from the perspective of thinking styles, which allow strengthening what has been done in this research and, in this way, to continue contributing to the strengthening of professional training processes in Engineering.

Finally, a task for the educational community is to generate other teaching and evaluation methods that allow promoting the thinking styles proposed in this research.

6. REFERENCES

[1] A. Markopoulos, A. Fragkou, P. Kasidiaris and J. Davim, "Gamification in engineering education and professional training", **International Journal of Mechanical Engineering Education**, Vol. 43, No. 2, 2015, pp 118–131.

[2] C. Gaete-Peralta and J. Huincahue, "Thinking styles and engineering: proposals for strengthening the professional training of engineers through Physics courses", **Journal of Physics: Conference Series,** Vol. 1702, 2020.

[3] C. Vásquez and C. González, "El desarrollo sustentable, la dependencia energética y las nuevas competencias del ingeniero electricista", **Publicaciones en Ciencias y Tecnología,** Vol 5, No. 1, 2011, pp. 5-14.

[4] D. Ramírez, O. Castellanos and D. Rodríguez, "Divulgación y apropiación del conocimiento en Ingeniería: oportunidad ra la innovación", **Ingeniería e Innovación**, Vol. 31, 2011, pp 63-73.

[5] E. Van der Graaff and W. Ravesteijn, "Training complete engineers: global enterprise and engineering eductions", **European Journal of Engineering Education**, Vol. 26, No. 4, 2001, pp. 419-427.

[6] I. Herrero, C. García, E. González, L. Molina-Tanco, E. Pérez and C. Urdiales, "Aprendizaje colaborativo en el ámbito de la Ingeniería: Una experiencia de Iniciación al trabajo en grupo", **Revista de Docencia Universitaria**, Vol. 11, 2013, pp. 221-251.

[7] I. May-Cen and C. May-Cen,"El portafolio de evidencias delingeniero en formación: Una propuesta de amplio espectro", **Revista del Centro de graduados e investigación. Instituto Tecnológico de Mérida**, Vol. 33, No. 70, 2018, pp 54-59.

[8] J. Huincahue, C. Gaete-Peralta and V. Garrido-Véliz, "Thinking styles and computer engineering training: an empirical study". **International Journal of Cognitive Research in Science, Engineering and Education,** Vol. 7, No.1, 2019, pp 21-33.

[9] L. Lei, Q. Dai, M. Wang, Q. Liu and M. Xiao, "The research and implementation of engineering training system based on mobile internet of things**"**, **IEEE International Conference on Consumer Electronics-China (ICCE-China)**, 2016.

[10] L. Zhang, **The malleability of Intellectual Styles**, New York: Cambridge University Press, 2013.

[11] L. Zhang and R. Sternberg, **The Nature of Intellectual Styles**, New Jersey: Lawrence Erlbaumm Associates, 2006.

[12] L. Zhang, R. Sternberg and S. Rayner **Handbook of Intellectual Styles: Preferences in Cognition, Learning, and Thinking,** ed L. Zhang et al, New York: Springer, 2012.

[13] M. Callejo, "Creatividad matemática y resolcución de problemas", **Sigma**, Vol. 22, 2003, pp. 25-34.

[14] M. Guerrero, B. Hernandis and A. Begoña, "Estudio comparativo de las acciones a considerar en el proceso de diseño conceptual desde la ingeniería y el diseño de productos", **Ingeniare. Revista chilena de ingeniería**, Vol. 22, No. 3, 2014, pp 398-411.

[15]M. Serna and J. Polo, "Lógica y abstracción en la formación de ingenieros: una relación necesaria", **Ingeniería Investigación y Tecnología**, Vol. XV, No. 2, 2014, pp: 299-310.

[16]M. Valadez and D. Zarabozo, "Estilos de pensamiento y elección profesional en tres universidades mexicanas", **Actualidades Investigativas en Educación**, Vol. 17, No. 3, 2017, pp 1-22.

[17]Pontificia Universidad Católica de Valparaíso. **Ingeniería Civil de Minas**. Retrieved December 27, 2020, from https://www.pucv.cl/pucv/pregrado/ingenieria-civil-de-minas/2015-06-11/172344.html

[18]P. Wang, P. Wu, J. Wang, H. Chi, and X. Wang, (2018). "A Critical Review of the Use of Virtual Reality in Construction Engineering Education and Training", **International Journal of Environmental Research and Public Health**, Vol. 15, No. 6, 2018.

[19] R. Boccardo, **Creatividad en la Ingeniería del Diseño**, Caracas: Equinoccio, 2006.

[20] R. Parra, "Competencias profesionales del ingeniero agrónomo", **Agronomía Colombiana**, Vol. 21, 2003, pp 7-16.

[21] R. Sternberg, **Thinking Styles**, New York: Cambridge University Press, 1997.

[22] R. Sternberg and L. Zhang, "Styles of Thinking as a Basis of Differentiated Instruction", **Theory into Practice**, Vol. 44, No. 3, 2005, pp 245-253.

[23] R. Vásquez, "¿Qué ingenieros necesita México?", **Innovación Educativa**, Vol. 12, 2012, pp 125-135.

[24] Universidad Arturo Prat. **Ingeniería Civil de Minas.** Retrieved December 27, 2020, from: https://www.admisionunap.cl/detalle-carrera?carrera=20

[25] Universidad Católica del Norte. **Ingeniería Civil de Minas**. Retrieved December 27, 2020, from: https://www.ucn.cl/carrera/ingenieria-civil-de-minas/?tipo=admision

[26] Universidad de Chile. **Ingeniería Civil de Minas**. Retrieved December 27, 2020, from: https://www.uchile.cl/carreras/4977/ingenieria-civil-de-minas

[27] Universidad de Concepción. **Ingeniería Civil de Minas**. Retrieved December 27, 2020, from: https://fi.udec.cl/pregrado/ingenieria-civil-de-minas/

[28] Universidad de La Serena. **Ingeniería Civil de Minas**. Retrieved December 27, 2020, from: http://www.userena.cl/boton-carreras/item/ingenieria-civil-de-minas.html

[29] Universidad de Talca. (2020). **Ingeniería Civil de Minas**. Retrieved December 27, 2020, from: http://www.ingenieria.utalca.cl/Repositorio/vvt8mTELq8CbzWPfnq0Loj0LWVtuOK/Perfil%20de%20Egreso.pdf

[30] Universidad Técnica Federico Santa María. **Perfil de egreso.** Retrieved December 27, 2020, from: http://metalurgia.usm.cl/futuros-alumnos/ingenieria-civil-minas/perfil-de-egreso/

[31] V. Braun and V. Clarke, "Using thematic analysis in psychology", **Qualitative Research in Psychology**, Vol. 3, 2006, pp. 77– 101.

[32] V. Braun, V. Clarke, Hayfield N. and G. Terry, **Thematic Analysis**, in: P. Liamputtong (eds) Handbook of Research Methods in Health Social Sciences. Singapore: Springer, 2019.