Ideal preferences for thinking styles in Engineering graduates: educational proposals to assurance graduation profiles through mathematics courses

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

ABSTRACT

Framed in Sternberg's theory of Mental Self-Government, this research had two objectives. The first one was to describe the competencies and abilities declared in a cross-cutting perspective in graduation profiles of engineering programs of a specific Chilean university. The second objective was to categorize the previous description using ideal preferences for thinking styles. To achieve the objectives, the methodology used was qualitative and it consisted of a thematic analysis, combined with documentary analysis techniques, to the data obtained from the graduate profiles of six engineering programs taught at the already stated university. The results of this research were two; the first one was the construction of a thematic map that described competencies and abilities encompassed in the graduation profiles of engineering programs; while the second result was the categorization of that description employing ideal preferences for the Legislative, Executive, Judicial, Global, Hierarchical and Liberal thinking styles. Based on the foregoing, a discussion about teaching and evaluation methods in Mathematics subjects, which allow promoting preferences for the thinking styles already mentioned, was held.

Keywords: Thinking styles, Engineering, Graduation profiles, Teaching and evaluation methods, Mathematics.

1. INTRODUCTION

Different investigations have focused their objectives on designing teaching and evaluation methods that allow contributing to the strengthening of engineering training processes. In order to mention some of them, one can find methods used in engineering courses such as Project-based Learning [16], the use of Software Engineering Teaching Method and Theory [23], the use of virtual reality [24], implementation of gamification and e-learning techniques [2], the assessment of knowledge in Statistics [10] and the evaluation of soft skills [22], among many others. However, and in accordance with [9] the teaching and assessment methods used in subjects that are part of engineering careers, they do not usually contribute to the development of competencies and abilities declared in their graduation profiles. In this direction, some investigations [6, 7, 15] have established a line of research, in Educational Psychology, committed to the construction of models that characterize, through ideal preferences for thinking styles [26], those competencies and abilities that are desirable by higher education institutions for their graduates of engineering careers. In this case, this study is framed within this line of research with the purpose of providing higher education institutions with theoretical references to strengthen their professional training processes in engineering.

Thinking styles [26] have the characteristic of being able to be learned and modified through teaching and evaluation methods [17, 18, 27]. In this way, the construction of models such as those carried out by [6,7, 15] provide theoretical references for higher education institutions, that teach engineering careers, to design teaching and evaluation methods that can be implemented in different subjects of engineering, to promote those competencies and abilities declared in their graduation profiles.

In Chile, Mathematics subjects are traditionally taught in the common engineering career plan. In this way, teaching and evaluation methods carried out in this type of subject can contribute to the development of competencies and skills that are included in the graduation profiles of engineering careers. Based on the foregoing, the objectives of this research are two: 1) Describe the competencies and abilities declared in a cross-cutting perspective in the graduation profiles of engineering programs of a specific Chilean university, and 2) Categorize the description employing ideal preferences for thinking styles. These objectives are stated in order to carry out a discussion of some teaching and evaluation methods, which can be implemented in Mathematics subjects in engineering programs, which allow promoting preferences of the thinking styles already mentioned.

The structure of this article is as follows: Section 2 includes the methodological aspects that will allow responding to the proposed objectives. Hereinafter, in section 3, the analysis of the data obtained from the graduation profiles of six engineering careers from a specific Chilean university will be carried out. That analysis allowed the construction of a thematic map that described the competencies and abilities stated in all the graduation profiles of these engineering programs. Subsequently, the description given by the thematic map was categorized using the Mental Self-Government theory [26] for the identification of ideal preferences for thinking styles of graduates of engineering careers of this university. In section 4 there is a discussion about some teaching and evaluation methods that can be implemented in Mathematics subjects to promote preferences for thinking styles stated in section 3. Finally, in section 5 the conclusions of this research are presented.

2. METHODOLOGY

The competencies and abilities that are declared in the graduation profiles of engineering degrees depend, among other factors, on the institution of higher education that offers these degrees. Thus, in order to respond to the stated objectives, it was necessary to limit this study to a particular Chilean university that offers different engineering degrees.

Context
The institution of higher education that was studied in this research was Universidad Bernardo O'Higgins (UBO), located in Santiago, Chile. At present, UBO teaches six careers in the Engineering area that are Civil Industrial Engineering [29], Computer Engineering [33], Commercial Engineering [31], Surveying Engineering and Cartography [32], Civil Engineering in Environment and Sustainability [30] and Virtual Reality and Design of Digital Games Engineering [34]. The choice of this university was due to the fact that, currently, Mathematics is a subject that is taught in the common plan of these programs.

Data Collection
The purpose of the data collection was to describe the competencies and abilities included in all the graduation profiles of the engineering careers of UBO. The data collected were obtained from the graduation profiles of the different engineering programs taught at this university [29, 30, 31, 32, 33, 34]. It should be noted that graduation profiles for each of these careers are public data that can be found on the university's website. The time period of data collection was four months.

Data analysis
To analyze the collected data, taken from the graduation profiles studied, a thematic analysis was used [35, 36]. The main reason is that this is an exploratory, descriptive and interpretive approach that allowed identifying themes that contributed to the construction of a thematic map, that described the competencies and skills included in the graduation profiles of engineering programs. In addition, and in order to better analyze the information underlying each of the graduation profiles, the thematic analysis was combined with documentary analysis techniques [14]. This combined analysis was carried out with experts in Engineering and Education, who had the role of research assistants. The Thematic Analysis consists of six stages: 1) familiarization with the data, 2) generating initial codes, 3) search for topics, 4) review of topics, 5) definition and naming of topics and 6) production of the report. The first stage consisted of reading all the collected data from the graduation profiles, a process that allowed us to propose a first understanding of those competencies and abilities encompassed in the graduation profiles of UBO engineering programs. In the second stage, descriptive coding was carried to recognize certain codes of a more general nature, which allowed generating potential themes. It is important to note that "codes identify a feature of the data (semantic content or latent) that appears interesting to the analyst, and refer to 'the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon" [35, p. 88]. In this sense, codes differ from themes, as the latter are often broader [35].

In stage 3, a refinement of the encoding process was performed. Stage 4 brought together the analyses of all the code associations made by the experts, who worked in groups and parallel, and later agree on discordant codes. In this sense, stage 4 included a review of stages 1 and 2, allowing the generation of a first version of the thematic map. Stage 5 focused mainly on a refinement of the thematic map, where the definitions of themes were generated so that the map would faithfully represent the data. Finally, stage 6 consisted of the construction of a thematic map that described the competencies and abilities included in the graduation profiles of the Engineering careers at UBO. It should be noted that two groups of the experts mentioned above carried out the first three stages of the thematic analysis separately, who later discussed their results and focused on recognizing similarities and discrepancies obtained during the coding and topic search process, which allowed to generate the thematic map. In other words, the data triangulation method [20] was considered for the analysis of the data obtained, which allowed minimizing the bias of a single analysis, increasing the quality and validity of the information found [28].

Once the thematic map was constructed, the information obtained in the aforementioned map was characterized through the theory of Mental Self-Government [26], through identification of ideal preferences for thinking styles of graduates of engineering at UBO.

Finally, it is important to state here that this type of analysis has been carried out in investigations such as those made in [6, 7].

3. ANALYSIS AND RESULTS

Analysis of data obtained from graduation profiles
During the data analysis, three themes were identified that made it possible to describe the competencies and abilities mentioned in all the graduate profiles of engineering programs at UBO. They include (i) having creativity, (ii) having teamwork skills and (iii) having technological knowledge. Table 1 shows the codes obtained after analyzing the data taken from the six graduation profiles, allowing the construction of the thematic map (Figure 1). The topics that were part of this map will be explained hereunder.

Having creativity. In [11] it is pointed out that engineers should have knowledge related to technology, which is related to creativity, since this is a basis for achieving technological development [8]. With this, two engineering programs stated in their graduation profiles characteristics associated with the ability to develop technologies [33, 34].

The ability to solve problems, desirable in any engineer [25], is a trait that is also associated with creativity [21]. With this, all the studied engineering programs declared this ability as a desirable characteristic in their graduation profiles [29, 30, 31, 32, 33, 34] that constitutes an important characteristic that all engineering graduates from UBO must have.

Creativity is also considered as a basis for innovation [1]. Moreover, five engineering careers stated characteristics associated with innovation in their graduation profiles [29, 30, 31, 32, 33].

Having teamwork skills. UBO is a higher education institution that wants engineering graduates who possess characteristics such as leadership and the ability to work in multidisciplinary teams. This objective was declared in all graduation profiles of their engineering programs [29, 30, 31 , 32, 33, 34].

Having technological knowledge. For UBO, the use of technology is a fundamental trait, declared in all graduation profiles [29, 30, 31, 32, 33, 34].

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

Career	Codes
Industrial Civil Engineering	Project and process optimization; problem-solving; innovation; sustainability; use of technologies; leadership; collaborative work, negotiating skills.
Computer Engineering	Problem-solving; innovation; teamwork; use and development of technologies; sustainability; leadership; teamwork, multidisciplinarity; negotiating skills.
Commercial Engineering	Creativity; ability to manage companies and businesses; use of technologies; innovation; entrepreneurship; collaborative work; multidisciplinarity; problem-solving; leadership.
Surveying Engineering and Cartography	Theoretical-technical knowledge in geomatics; planning and project evaluation; sustainability; use of technologies; innovation; Problem-solving; leadership; collaborative work.
Civil Engineering in Environment and Sustainability	Process design and planning; innovation; sustainability entrepreneurship; use of technologies; entrepreneurship; work in multidisciplinary teams; problem-solving; leadership.
Virtual Reality and Design of Digital Games Engineering	Problem-solving; development and use of technologies; leadership; collaborative work; multidisciplinarity.

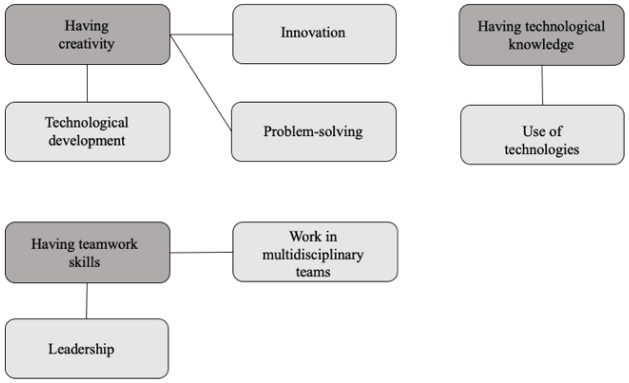

Figure 1. A thematic map describing the transversal competencies and abilities included in graduation profiles of engineering programs at UBO. Themes appear in dark gray.

Ideal preferences for thinking styles of engineering graduates from UBO.

Regarding the issues that appear on the thematic map in Figure 1, it can be noted that creativity is a characteristic associated with the Legislative, Judicial, Global, Hierarchical and Liberal thinking styles [19], while teamwork skills are associated with the External thinking style, as the theory of Mental Self-Government states [26]. On the other hand, having technological knowledge is not a characteristic that can be directly connected with the preference for some thinking style. However, the use of technologies requires certain traits such as the execution of algorithms and techniques, among others, which can be associated with the Executive thinking style.

In this way, ideal preferences for *Legislative*, *Executive*, *Judicial*, *Global*, *Hierarchical*, *Liberal* and *External* thinking styles are identified in engineering graduates from UBO.

4. DISCUSSIONS

One way to promote preferences for certain thinking styles is through teaching and evaluation methods [17, 18, 27]. In this way, to promote Legislative and Judicial thinking styles is required the use of portfolios as an evaluation method [27]. Concerning this, the research carried out by [12] demonstrates that the use of portfolios can significantly influence the achievement of the engineering graduation profile. [13] provide a reference that can serve as a basis for building, in Mathematics courses, portfolios that offer a great diversity of evidence to allow the development of different desirable characteristics in an engineer.

One way to promote an External thinking style is through teaching methods that allow students to discuss in small groups [27]. This can be done, for example, through teaching methods that incorporate mathematical modeling, so that engineering students can build mathematical knowledge through group discussions. A reference for the design of mathematical modeling situations can be found in Gaete [3, 4, 5], where, through group discussions, engineering students can build this type of knowledge in Mathematics subjects.

Finally, in [27] it is possible to find various proposals for teaching and evaluation methods that can be adapted and implemented, in Mathematics courses, to promote preferences

for Legislative, Executive, Judicial, Global, Hierarchical, Liberal and External thinking styles in engineering students at UBO.

5. CONCLUSIONS

This research seeks to provide, from a cognitive perspective, a guiding framework for higher education institutions to train quality engineers who can successfully insert themselves into society. The identification of ideal preferences for thinking styles provides theoretical references for higher education institutions to design, in Mathematics subjects, teaching and evaluation methods that enable the promotion of preferences of the already stated styles and, consequently allow promoting competencies and skills encompassed in the graduation profiles of engineering programs at UBO.

A pending task for the educational community is to seek mechanisms to design and implement teaching and evaluation methods, different from those proposed in this research, that allow promoting preferences for Legislative, Executive, Judicial, Global, Hierarchical, Liberal and External thinking styles. In general terms, a pending task for the educational community is to continue with the creation of thinking models such as those carried out in this research, in order to provide theoretical references that contribute to the strengthening of the professional training processes of the different careers taught in higher education institutions.

What has been done in this research provides methodological bases for future research that replicate the construction of models to identify suitable preferences for thinking styles characterizing the competencies and abilities declared in graduation profiles from different careers in higher education. A pending task for researchers in education is to provide opportunities to improve the methodological aspects used in this research to carry out the construction of this type of models.

Models that characterize preferences for thinking styles creates an opportunity for researchers in Education to design and implement teaching and evaluation methods that allow promoting preferences for certain thinking styles, which can be supported, for example, through the use of diverse information technologies. In this sense, the construction of this type of teaching and evaluation methods provides an excellent opportunity to generate a bridge between Mathematics Education and information technologies, making use of information systems or technologies that are developed with originality and innovation and that allow accompanying the teaching and evaluation processes in Mathematics courses. For example, in [37] it is pointed out that the use of information technologies in mathematics subjects enables the dynamic handling of mathematical objects, interactively passing through different representation registers: contextual, numerical, algebraic, analytical and visual, which can be explored consistently and directly manipulated, and how many times is necessary, a situation that is difficult to achieve with traditional educational resources.

6. REFERENCES

[1] A. Carrillo, F. Caballero and R. Roque, "Formación en creatividad e innovación estudiando las percepciones y prácticas de los jóvenes emprendedores locales", Revista Iberoamericana de Contaduría, Economía y Administración, Vol. 8, No. 15, pp 1-28.

[2] 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.

[3] C. Gaete-Peralta, **Acumulación de grados-días y categoría de modelación: un diseño de situación de aula para la construcción de la integral definida**, in D. Soto and H. Silva (eds), Situaciones de Modelación Educativa. Santiago: Editorial USACH, in press.

[4] C. Gaete Peralta, "Estudio socioepistemológico de la integral definida a través de la categoría de modelación, un modelo de anidación de prácticas y un marco de referencia de los usos de la medida", Tesis doctoral, Pontificia Universidad Católica de Valparaíso, Chile, 2019.

[5] C. Gaete-Peralta, "La categoría de modelación y el concepto de integral definida: una mirada socioepistemológica", **Revista UCMaule**, No. 58, 2020, pp. 83-105.

[6] C. Gaete-Peralta and J. Huincahue, "Engineering graduation profiles and thinking styles: educational proposals to strengthen the training of engineers ", **Proceedings of The 12th International Conference on Society and Information Technologies (ICSIT 2021),** Vol. II, 2021.

[7] 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.

[8] 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.

[9] D. Vélez and M. Soto, "La función docente y la planificación para el logro del perfil de egreso en Ingeniería Química", **Revista Científica Estudios e Investigaciones**, Vol. 7, No. 1, 2018, pp 24-37.

[10] E. Ayuga-Téllez, C. González-García, M. Grande-Ortiz and E. Martínez-Falero, "Diseño de un cuestionario para evaluar conocimientos básicos de estadística de estudiantes del último curso de ingeniería", **Formación universitaria**, Vol. 5, No. 1, 2012, pp 21-32.

[11] 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.

[12] H. Rivera, "El portafolio de evaluación de aprendizajes y el logro del perfil de egreso de los estudiantes en la carrera profesional de Ingeniería Electrónica de la Universidad Privada de Tacna", Tesis de Magíster, Universidad Privada de Tacna, Perú, 2020.

[13] 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.

[14] I. Rojas, "Elementos para el diseño de técnicas de investigación: Una propuesta de definiciones y procedimientos en la investigación científica", **Tiempo de Educar**, Vol. 12, No. 24, pp. 277-297.

[15] 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.

[16] J. Mesa, J. Álvarez, J. Villanueva and F. de Cos, "Actualización de Métodos de Enseñanza-Aprendizaje en Asignaturas de Dirección de Proyectos de Ingeniería". **Formación universitaria,** Vol. 1, No. 4, 2008, pp 23-28.
[17] L. Zhang, **The malleability of Intellectual Styles**, New York: Cambridge University Press, 2013.
[18] L. Zhang and R. Sternberg, **The Nature of Intellectual Styles**, New Jersey: Lawrence Erlbaumm Associates, 2006.
[19] 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.
[20] M. Arias, "La triangulación metodológica: sus principios, alcances y limitaciones", **Investigación y educación en enfermería**, Vol. 18, No. 1, 2000, pp 13-26.
[21] M. Callejo, "Creatividad matemática y resolución de problemas", **Sigma**, Vol. 22, 2003, pp. 25-34.
[22] M. Gómez, B. Manrique and G. Gasca, "Propuesta de evaluación de habilidades blandas en ingeniería de software a través de proyectos universidad – empresa", **Revista Educación en Ingeniería**, Vol 10, No. 19, 2015, pp. 131-140.
[23] M. Gómez-Álvarez, C. Zapata and H. Astudillo, "SETMAT (Software Engineering Teaching Method and Theory): una teoría para la enseñanza de Ingeniería de Software", **Revista Ibérica de Sistemas e Tecnologias de Informação** , No. 19, 2019, pp. 721-734
[24] P. Wang, P. Wu, J. Wang, H. Chi, and X. Wang, "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.
[25] R. Boccardo, **Creatividad en la Ingeniería del Diseño**, Caracas: Equinoccio, 2006.
[26] R. Sternberg, **Thinking Styles**, New York: Cambridge University Press, 1997.
[27] 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.
[28] S. Gavira and J. Osuna, "La Triangulación de Datos como Estrategia en Investigación Educativa", **Revista de Medios y Educación**, Vol. 47, pp 73-88.
[29] Universidad Bernardo O´Higgins, Industrial Civil Engineering, Retrieved April 28, 2021, from: https://www.ubo.cl/facultades/facultad-de-ingenieria-ciencia-y-tecnologia/ingenieria-civil-industrial/
[30] Universidad Bernardo O´Higgins, Civil Engineering in Environment and Sustainability, Retrieved April 28, 2021, from: https://www.ubo.cl/facultades/facultad-de-ingenieria-ciencia-y-tecnologia/ingenieria-civil-medio-ambiente-sustentabilidad/
[31] Universidad Bernardo O´Higgins, Commercial Engineering, Retrieved April 28, 2021, from: https://www.ubo.cl/facultades/facultad-de-ingenieria-ciencia-y-tecnologia/ingenieria-comercial
[32] Universidad Bernardo O´Higgins, Surveying Engineering and Cartography, Retrieved April 28, 2021, from: https://www.ubo.cl/facultades/facultad-de-ingenieria-ciencia-y-tecnologia/ingenieria-en-geomensura-y-cartografia/
[33] Universidad Bernardo O´Higgins, Computer Engineering, Retrieved April 28, 2021, from: https://www.ubo.cl/facultades/facultad-de-ingenieria-ciencia-y-tecnologia/ingenieria-en-informatica/
[34] Universidad Bernardo O´Higgins, Virtual Reality and Design of Digital Games Engineering, Retrieved April 28, 2021, from: https://www.ubo.cl/facultades/facultad-de-ingenieria-ciencia-y-tecnologia/ingenieria-realidad-virtual-diseno-juegos-digitales/
[35] V. Braun and V. Clarke, "Using thematic analysis in psychology", **Qualitative Research in Psychology**, Vol. 3, 2006, pp. 77– 101.
[36] 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.
[37] V. Riveros, X. Arrieta, M. Bejas, "Las Tecnologías de la Información y la Comunicación en el quehacer educativo del aula de clase" , **Omnia**, Vol. 17, No. 1, pp. 34-51.