THE LEADERSHIP DEVELOPMENT ON ENGINEERING STUDENTS: EVIDENCES FROM A BRAZILIAN CASE STUDY

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Abstract: *Academic articles on entrepreneurship leadership in engineering have grown over the last years. Papers have approached the leadership development from many points of view. Filion highlights in his entrepreneurial metamodel that leadership is a skill intrinsic to the entrepreneur and essential to the accomplishment of their vision. A research on a teamwork project of Innovative Idea in a semiannual Entrepreneurship course of a Brazilian university showed that the leadership skill was developed in 50% of the students that had participated in a survey applied in 9 classes between 2015 and 2016. From this previous result, the alternance of heading in the teams was introduced in a new class starting in the first semester of 2017. Thus, this study has the goal to analyze whether the alternance of heading in teams can influence the engineering students' leadership development. The research adopts the case study methodology. A statistical analysis was accomplished to verify the existence of significant differences of students' leadership development between the classes with and without alternance of heading in the teams. The results show that there is no significant difference of students' leadership development between the classes. The outcome contributes to expand the understanding of how the alternance of heading in engineering teams can foster students' leadership development.*

Keywords: *Leadership development. Engineering education. Entrepreneurship education. Filion's entrepreneurial metamodel.*

1 INTRODUCTION

There are many academic papers on entrepreneurship leadership in engineering that have been published over the past decade. These articles have researched, among other issues, the entrepreneurial skills development in engineering, particularly the leadership. The studies have presented programs of engineering leadership (GOLDING *et al.*, 2015; THOMAS; SWAMY, 2017), rhetoric of leadership development (IRISH, 2017), leadership measurement (AHN *et al.*, 2014), and impacts of engineering leadership for career success (PAUL; FALLS, 2015).

Nevertheless, there is a gap in the international academic literature on entrepreneurship engineering concerning the proposition, exploration and evaluation of tools to encourage the leadership development. In another direction, articles have not presented how integrated links among active learning, design thinking, and Bloom's Taxonomy can foster the engineering students' entrepreneurial skills development, as the leadership.

In this direction, this study focuses on engineering students' leadership development, by means of a tool called Entrepreneurship Dynamic Learning (EDLE tool). The EDLE tool has been used in engineering undergraduate courses of a Brazilian public university since 2015 in order to foster engineering students' entrepreneurial skills development, among them the leadership. Thus, it intends to explore engineering students' leadership development. Particularly, the study analyzes whether alternance of heading in engineering students' teams influences the students' leadership development in classes working under the EDLE tool dynamics.

The article is structured as follows. The second section focuses on the entrepreneurship education literature review, leadership development, active learning, design thinking, and Bloom's taxonomy, presenting the main elements which sediment the EDLE tool. The third section presents the EDLE tool and its previous implementation results, mainly those in relation to the leadership development. The fourth section outlines the methods and techniques. The results and discussion regarding the alternance of heading are introduced in the fifth section. Finally, the last section presents the conclusions.

2 LITERATURE REVIEW

2.1 Entrepreneurship education and engineering leadership

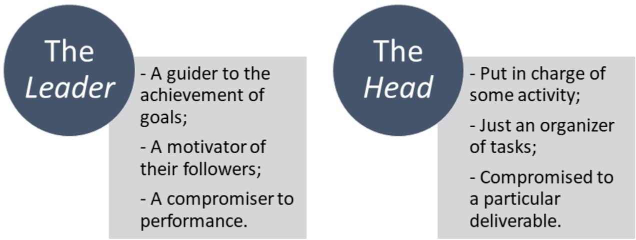
Entrepreneurship education assembles methods, strategies, and learning techniques that collaborate to the development of individuals' and society's entrepreneurial capacity (HASSARD, 1999; GIBB, 2002). Another definition states that entrepreneurship education contributes significantly for the identification of opportunities and problem solving in market situations of risk and uncertainty (GARAVAN; O'CINNEIDE, 1994). It is common for many authors that entrepreneurship education also provides skills and an entrepreneurial behavior that allow the professional to manage with challenges and tensions of post-modern society organizations (GARAVAN; O'CINNEIDE, 1994; HASSARD, 1999; GIBB, 2002; HUQ; GILBERT, 2016).

In Brazil, the National Confederation of Industry (CNI) has recently published reports claiming for the strengthening of Brazilian engineering education (CNI, 2015, 2018). According to the CNI (2015, 2018), Brazilian Schools of Engineering should educate their students to develop not only the traditional technical skills, but also the entrepreneurial skills, as entrepreneurship behavior, teamwork, innovative capacity, creativity, and leadership. These entrepreneurial skills are essential to make Brazilian engineers able to contribute for Brazil's socioeconomic development and competitiveness (CNI, 2015, 2018).

In this context, leadership is an entrepreneurial skill among those needed for professionals working in the globalization environment of post-modernity (FILION, 1999; GIBB, 2002). However, the international academic literature has shown that few Schools of Engineering have programs for the development of leadership on engineering students, despite of its importance for engineers' carriers (SEAT; PARSONS; POPPEN, 2001; KUMAR; HSIAO, 2007; GRAHAM; CRAWLEY; MENDELSOHN, 2009).

Filion (1993) proposes an entrepreneurial metamodel constituted of five entrepreneurial skills, namely: (1) *weltanschauung*; (2) vision; (3) leadership; (4) energy; and (5) networking. For Filion (1993), leadership an inseparable and indivisible skills from the entrepreneur's characteristics, as well as it is essential for the entrepreneur to accomplish their vision, their view of their product in the future. Leadership is an important skill for the entrepreneur to succeed in organizations and society (PAUL; FALLS, 2015). It is a process that a person guides followers in missions to achieve defined objectives (THOMAS; SWAMY, 2017). Yet, leadership competences on professionals, such as engineers, contribute for companies to perform better (GOLDING *et al.*, 2015). This study distinguishes the *leader* and the *head*. The leader's concept follows the previous-mentioned characteristics. On the other hand, the head is one put in charge to perform some task, and is responsible exactly for that task, and compromised with that specific deliverable. Not necessarily the head is also the leader in a teamwork project, for instance. Exhibit 1 delimitates the conceptualization of leader and head. This conceptualization helps the understanding of this paper goal, i.e., to analyze whether alternance of heading influences the engineering students' leadership development.

Exhibit 1 – The *leader* and the *head*



Source: the authors

2.2 Active learning, design thinking and Bloom's taxonomy

Active learning involves a set of participative activities that make the learning process to occurs from significant construction by students (MICHAEL, 2006). This means that active learning takes the student to involve, participate and conduct their own learning process (PRINCE, 2004; MICHAEL, 2006; LIMA; ANDERSSON; SAALMAN, 2016). Active learning encompasses in- and out-class activities, as projects, homework, teamwork, among others, enabling the student to think over what they are performing and their learning (ANTHONY, 1996; MICHAEL, 2006).

Michael (2006) highlights the five main elements of active learning, namely: (1) meaning constructions by students; (2) know-what and know-how are different learning processes; (3) knowledge transfer has to be positive; (4) learning in groups; and (5) facilitation of significant learning by means of explanation. Besides Michael's (2006) work, Anthony's (1996), Prince's (2004) and Andersson and Saalman's (2016) also show that active learning contributes to students' entrepreneurial skills development.

As active learning promotes students' involvement with real world and professional context problems, it is possible to establish a connection between the problem-solving process and design thinking. Design thinking is a design approach where design methods and techniques are focused on human needs and its adoption is expanded for business administration, medicine, engineering, etc. (JOHANSSON-SKÖLDBERG; WOODILLA; ÇENTINKAYA, 2013; SEIDEL; FIXSON, 2013). According to Brown (2008), design thinking refers to the manner that designers think, deal with problems and solve them, approaching by different perspectives. For Brown (2008), design thinking has three interrelated spaces which have the goal to foster innovation on the creative processes. These spaces are inspiration (circumstances that motivate a search for solutions), ideation (development and ideas prototyping that can be a solution), and implementation (ways of implementing the solution in the market).

Finally, it is pointed out the development of the entrepreneurial skills can be analyzed using the Blooms' taxonomy. The Bloom's taxonomy is a framework about what is expected for students to learn as a result of teaching (KRATHWOHL, 2002). Krathwohl (2002) affirms that this framework is hierarchized to form an organizational structure of knowledge in terms of the cognitive domains (KRATHWOHL, 2002). These domains are divided within two groups: lower order thinking activities (remember, understand, and apply); and higher order thinking activities (analyze, evaluate, and create). The lower- and higher- order thinking activities of the Bloom's taxonomy can help the professor to identify what is working in classroom and what is not, as well as to verify what has been fostered. Chart 1 presents the hierarchical structure of Bloom's taxonomy.

Chart 1 – Hierarchical structure of Bloom's taxonomy

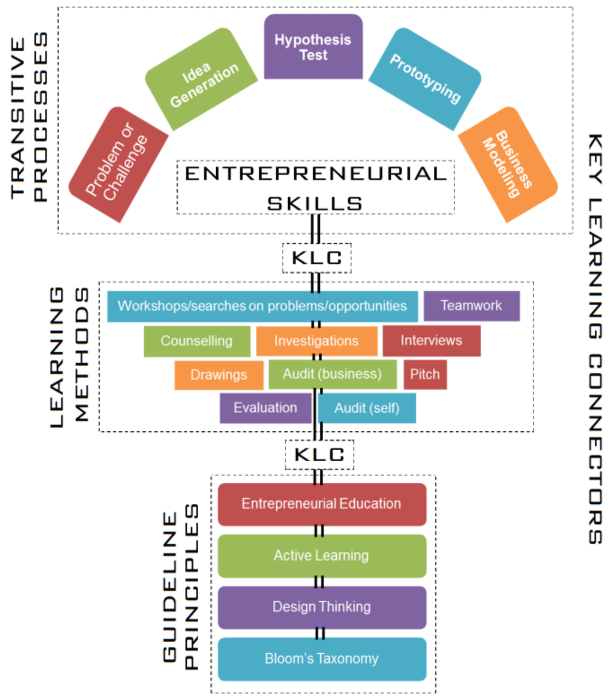
Hierarchy		Cognitive Domain	Description	Action Verbs
Lower Order Thinking Activities	1	Remember	Retrieving relevant knowledge from long-term memory	Recognizing, recalling
	2	Understand	Determining the meaning of instructional messages (oral, written and graphical communication)	Interpreting, exemplifying, classifying, summarizing, inferring, comparing explaining
	3	Apply	Carrying out or using a procedure in a given situation	Executing, implementing
Higher Order Thinking Activities	4	Analyze	Breaking material into its parts and detecting how they relate to each other and to the overall structure	Differentiating, organizing, attributing
	5	Evaluate	Making judgements based on criteria and standards	Checking, critiquing
	6	Create	Putting elements together to form a novel, coherent whole or making in original product	Generating, planning, producing

Source: adapted from Krathwohl (2002)

3 THE EDLE TOOL

The EDLE tool conceptual model is presented in Exhibit 2. It has four main elements to anchor the entrepreneurial skills development in engineering: guideline principles, transitive processes, learning methods, and key learning connectors. These elements were gathered from the literature analysis on entrepreneurship education, active learning, design thinking, and Bloom's taxonomy. EDLE has been used in a Brazilian public university since 2015.

Exhibit 2 – The EDLE tool conceptual model



Source: the authors

The EDLE tool scope is built around the four elements named above. The key learning connectors (KLC) establish internal linkages involving the four principles (entrepreneurship education, active learning, design thinking, and Bloom's taxonomy) that contributes to foster the entrepreneurial skills development. They also link externally the other three elements that integrate the proposed model (guideline principles, transitive processes, and learning methods). In our model, five KLCs have been proposed: KLCv (vision), KLCw (*weltanchaaung*), KLCl (leadership), KLCe (energy), and KLCn (networking).

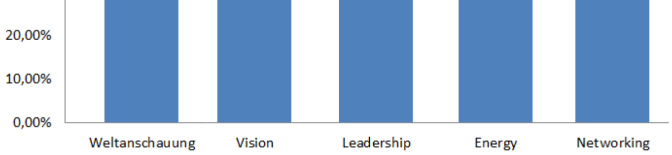
The guideline principles were identified in the international academic literature as driver elements for the entrepreneurial skills development in engineering. They are, respectively: entrepreneurship education, active learning, design thinking, and Bloom's taxonomy. The transitive processes are the steps that make it possible for the students to develop entrepreneurial skills in the course. In EDLE, there are five transitive learning processes: (1) Problem or challenge; (2) Idea generation; (3) Hypothesis testing; (4) Prototyping; and (5) Business modeling. Finally, the learning methods are composed of pitches (individual and group oral presentations), mentoring, evaluation, simulation, counselling, team activities, etc. throughout the transitive processes (Gibb 2002). Lastly, the learning methods help students to achieve the development of higher order thinking activities during the module, and, consequently, the entrepreneurial skills development.

3.1 Previous results of the EDLE tool implementation

The tool has been implemented in an Entrepreneurship course, taught in engineering undergraduate programs (Production, Materials, Energy, Control and Automation, Water, Mechanical, Environmental, among others) of a Brazilian public university. The course was taught in 9 classes between 2015 and 2016, with a total of 220 students. Particularly, the tool has been implemented in the Innovative Idea project, that integrates the course teaching plan.

In the end of the course, students were asked to answer a questionnaire based on Bloom's taxonomy and Filion's entrepreneurial metamodel. In the questionnaire, the students had to indicate the three among the five Filion's entrepreneurial skills that had had the most significant development under their perception. The questionnaire was applied in each of the 9 classes considered for the present research. Exhibit 3 presents the Filion's entrepreneurial skills development during the Entrepreneurship course throughout the classes (compiled).

Exhibit 3 – Engineering students' Filion's entrepreneurial skills development in the Innovative Idea project (without teams' alternance of heading)



Source: the authors.

As presented in Exhibit 3, about 50% of students indicated leadership as one of the three Filion's entrepreneurial skills with the most significant development. It was found that it could have had happened because in mostly only one team member had taken the heading of the team during the semester (i.e., the "natural" leader). Thus, from this outcome emerged the goal of the present study, to analyze whether alternance of heading in the teams could influence the students' leadership development.

In this way, in the first semester of 2017 the alternance of heading in teams was inserted in the teamwork within the Innovative Idea project of the Entrepreneurship course. In each class week one member of each team was nominated for the team heading position and should conduct the team activities during the week. In the end of the week, this head should handle a one-page report indicating which activities had been achieved. After the report handling, another team member was nominated for the team heading and had to conduct its activities in the next week, as well as handle the correspondent report. This dynamic was repeated with all team members and looped with all teams during the Innovative Idea project. From that, two hypotheses were formulated:

H0 (null hypothesis): alternance of heading in teams does not influence the engineering students' leadership development;
H1 (alternative hypothesis): alternance of heading in teams influences the engineering students' leadership development.

4 METHODS AND TECHNIQUES

The study is exploratory and quali- quantitative, adopting the case study methodology. Crowe *et al.* (2011) state that case studies approach in-depth and multifaced issues in a real-life setting, to make it possible to gather an understanding of them. Case study are useful to be used when there is a need to comprehend better and deeper phenomena in real life (CROWE *et al.*, 2011). Then, the undertake of the case study methodology helps the researcher to make considerations, assumptions, and expand interpretations of events to other of some context (CROWE *et al.*, 2011).

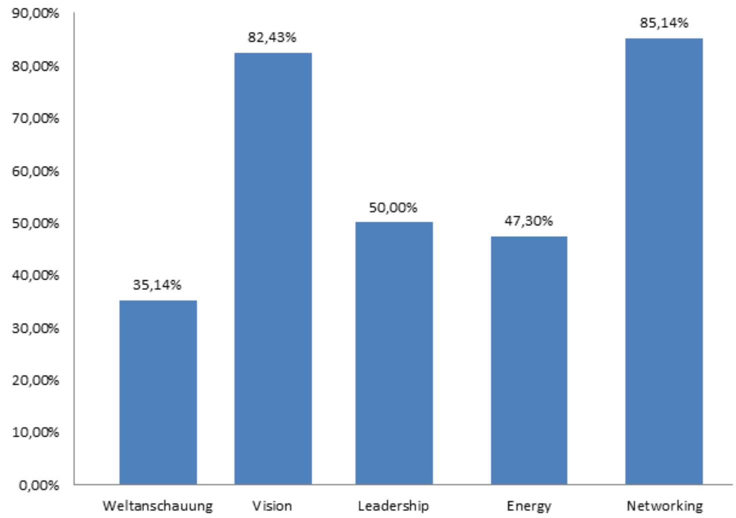
We gathered the methods and techniques of this study in ten steps. In the first step, the literature review on entrepreneurship education, active learning, design thinking, and Bloom's taxonomy was accomplished to subsidize the EDLE tool configuration. Then, from the previous results of the EDLE tool implementation regarding students' leadership development, the goal of this study was proposed. The international academic literature on engineering leadership was reviewed to guide the reflection on leadership development and hypothesis definition. The technique to be utilized (alternance of heading) and the unit analysis (engineering students' teams) were chosen in the fourth step. From that, the hypotheses were defined. In the sixth step occurred the implementation of alternance of heading in the teams during the Entrepreneurship course, taught in engineering undergraduate programs (Production, Materials, Energy, Control and Automation, Water, Mechanical, Environmental, among others) of a Brazilian public university. The alternance of heading was implemented in two classes in the first semester of 2017, with a total of 74 students.

The seventh step corresponded to data collection in the classrooms at the end of the semester, by means of a questionnaire on the Google Forms platform. In the questionnaire, students were asked to indicate the three among the five Filion's entrepreneurial skills that had had the most significant development under their perception. This dynamic was the same as presented in the section 3.1. In the next step, the proportions of students who had indicated leadership among the three Filion's entrepreneurial metamodel which had had the most significant development were detached, both for the courses with and without alternance of heading during the Innovative Idea project. The proportions were compared using a two-sample Poisson rates test to verify the existence of significant difference between them, and corresponded to the ninth step of the research, where the hypotheses were analyzed. Finally, the last step concerned the discussion and documentation of the results.

5 RESULTS AND DISCUSSION

Exhibit 4 presents the results of the students' Filion's five entrepreneurial skills development from the Innovative Idea project for the classes where the alternance of heading was inserted to analyze the hypotheses presented previously (classes taught in the first semester of 2017). As presented, the proportion of students who indicated leadership among the three Filion's entrepreneurial skills which had had the most significant development remained 50%.

Exhibit 4 – Engineering students' Filion's entrepreneurial skills development in the Innovative Idea project (with teams' alternance of heading)



Source: the authors.

The proportions of students who had indicated leadership among the three Filion's entrepreneurial metamodel which had had the most significant development were detached, both for the classes with and without alternance of heading during the Innovative Idea project. Then, both proportions were tested by a two-sample Poisson rates in order to verify the existence of significant difference between them, with a significance level of 5%. "Sample 1" corresponds to the proportion without alternance of heading during the Innovative Idea project, and "Sample 2" refers to the proportion for which the alternance of heading occurred. Both proportions are presented in Table 1, and Exhibit 5 presents the results of the two-sample Poisson rates test.

Table 1 – Leadership development proportions in the classes without (1) and with (2) alternance of heading

Sample	Leadership Development Proportion
1	0,509091
2	0,500000

Source: the authors.

Exhibit 5 – Results from the two-sample Poisson rates test

Test and CI for Two-Sample Poisson Rates

```
                Total          Rate of
Sample  Occurrences    N  Occurrence
1               112  220    0,509091
2                37   74    0,500000


Difference = rate(1) - rate(2)
Estimate for difference: 0,00909091
95% CI for difference: (-0,177578, 0,195759)
Test for difference = 0 (vs ≠ 0): Z = 0,10 P-Value = 0,924

Exact Test: P-Value = 1,000
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Source: the authors.

As it is possible to notice, the p-value obtained through the test was bigger than the significance level (1,000>0,050), and then the null hypothesis is accepted. Therefore, the results indicate that the leadership development proportions do not differ significantly between the classrooms. This outcome shows that teams' alternance of heading did not influence the students' leadership development in the classes.

6 CONCLUSIONS

This study focused on engineering students' leadership development, by means of the EDLE tool. From the previous results of students' Filion's leadership skill development through the EDLE implementation in an Entrepreneurship course of a Brazilian public university, it intended to analyze whether the alternance of heading in teams could influence the students' leadership development. Two hypotheses were formulated and statistically analyzed in order to achieve the established goal.

The results evidenced that the alternance of heading in engineering students' teams might not be able to influence (that should mean *increase the proportions of*) the students' leadership development, since the proportions remained the same. Nevertheless, as a preliminary result, this evidence must be continuously investigated in other classes, as well as it is necessary other investigations about the factors that might influence the leadership development on engineering students. The study also contributes for the international academic literature on engineering leadership and leadership development, adding knowledge and empirical evidences to these fields.

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O DESENVOLVIMENTO DA LIDERANÇA EM ESTUDANTES DE ENGENHARIA: EVIDÊNCIAS DE UM ESTUDO DE CASO NO BRASIL

Resumo: *Artigos acadêmicos sobre liderança empreendedora em engenharia cresceram nos últimos anos. Os trabalhos abordam o desenvolvimento da liderança sob vários pontos de vista. Filion destaca em seu metamodelo empreendedor que a liderança é uma habilidade intrínseca ao empreendedor e essencial para a realização de sua visão. Uma pesquisa sobre um programa de trabalho em equipe de Ideia Inovadora em uma disciplina semestral de Empreendedorismo de uma universidade brasileira mostrou que a habilidade de liderança foi desenvolvida em 50% dos alunos das 9 turmas que participaram do programa entre 2015 e 2016. A partir deste resultado, a alternância de liderança nas equipes foi introduzida em uma nova turma a partir do primeiro semestre de 2017. Assim, este estudo tem como objetivo* *analisar se a alternância de liderança em equipes pode influenciar no desenvolvimento da liderança dos alunos de engenharia. A pesquisa adota a metodologia do estudo de caso. Foi realizada uma análise estatística para verificar a existência de diferenças significativas no desenvolvimento de liderança dos alunos entre as turmas com e sem alternância de liderança nas equipes. Os resultados mostram que não há diferença significativa no desenvolvimento da liderança dos alunos entre as classes. O resultado contribui para ampliar a compreensão de como a alternância de liderança em equipes de engenharia pode promover o desenvolvimento da liderança nos alunos.*

Palavras-chave: *Desenvolvimento de liderança. Educação em engenharia. Educação empreendedora. Metamodelo empreendedor de Filion.*