A STATISTICAL ANALYSIS OF ENGINEERING STUDENTS' ENTREPRENEURIAL SKILLS DEVELOPMENT IN BRAZIL

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Abstract: *Academic papers on entrepreneurship education in engineering have been growing over the last decades and have presented analyses about students' entrepreneurship development from many points of view. The Entrepreneurial Metamodel proposed by Filion presents the five entrepreneurial skills inseparable and necessary for entrepreneurs (vision, weltanschauung, leadership, energy, and networking). These skills are essential for engineers and leaders working under the entrepreneurship paradigm. Nevertheless, there are few studies proposing, implementing, and evaluating tools aimed to foster the entrepreneurial skills development on engineering students, leaving an open gap on the international academic literature. This study addresses this gap and has the goal to explore, validate and evaluate by a statistical analysis the implementation of a tool named Entrepreneurship Dynamic Learning (EDLE). The EDLE tool intends to foster the Filion's Entrepreneurial Metamodel skills development on engineering students. The study is exploratory and adopts multiple case study methodology. As from the EDLE tool implementation in an Entrepreneurship course offered to engineering undergraduate programs at a Brazilian public university, students from 12 different classrooms between 2015 and 2017 indicated the main three Filion's Entrepreneurial Metamodel skills (among the five ones) which had the most significant development in the course. After that, the possible differences about Filion's Entrepreneurial Metamodel skills development among the classrooms were evaluated using a statistical software. The results indicate that the EDLE tool fostered the Filion's Entrepreneurial Metamodel skills development on engineering students over the classes, validating its implementation, and have practical implications.*

Keywords: *EDLE tool. Filion's entrepreneurial metamodel. Entrepreneurship education. Engineering education. Bloom's taxonomy.*

1 INTRODUCTION

The growth of academic papers on entrepreneurship education in engineering all over the world in the last decades have shown how it has been gaining the attention of researchers in academia. Those papers have presented methods and techniques of entrepreneurship learning (NICHOLS; ARMSTRONG, 2003; KASSEAN *et al.*, 2015), its importance and impacts (MORRIS *et al.*, 2013; ANTONITES; NONYANE-MATHEBULA, 2012; MARESCH *et al.*, 2016), and entrepreneurial skills (FILION, 1993; GIBB, 2002; ABDULWAHED; HASNA, 2017).

However, the international academic literature on entrepreneurship education has not proposed tools to foster the entrepreneurial skills development on engineering students.

Similarly, papers on entrepreneurship education in engineering have not been analyzing how the integrated insertion of entrepreneurship education, active learning, design thinking, and Bloom's Taxonomy in classrooms can foster the entrepreneurial skills development in engineering. These gaps raise some questions, as: (1) what are the tools that can foster the entrepreneurial skills development in engineering? (2) what are the impacts of these tools on engineering students' entrepreneurial skills development?

Thus, this study is addressed to the previous-mentioned gaps and has the goal to explore, validate, and evaluate from a statistical point of view the implementation of a tool named Entrepreneurship Dynamic Learning (EDLE). The EDLE tool is a learning framework proposed by and used in engineering classrooms of a Brazilian public university, in order to foster the entrepreneurial skills development. The EDLE tool is also anchored in four guideline principles: entrepreneurship education, active learning, design thinking, and Bloom's taxonomy.

The EDLE tool validation and evaluation is accomplished considering the engineering students' Filion's entrepreneurial skills development. The EDLE Tool was implemented in 12 engineering classrooms between 2015 and 2017, with a total of 294 students. Control charts for individual samples were used to compare the differences about Filion's entrepreneurial skills development among the classrooms.

The article is structured as follows. The next section presents the literature review on entrepreneurial skills and the Filion's ones, as well as the EDLE Tool conceptual model. The third section outlines the methods and techniques. The fourth section introduces the statistical results and discussion of EDLE Tool implementation. Finally, the last section presents the practical implications and final considerations.

2 LITERATURE REVIEW

2.1 Entrepreneurial skills and Filion's entrepreneurial metamodel

International academic papers on entrepreneurship state that it collaborates for the entrepreneurial skills development on students, leaders, and professionals dealing with the challenges of organizations (GARAVAN; O′CINNEIDE, 1994; GIBB, 2002; HUQ; GILBERT, 2017)). Entrepreneurship education gathers learning methods and techniques that encourage the entrepreneurial capacity on individuals and society (HASSARD, 1999; GIBB, 2002). Entrepreneurship education also contributes to problem-solving, opportunity identification, and it helps professionals to work under uncertainty and risk situations in companies (GARAVAN; O′CINNEIDE, 1994).

One of the authors presenting entrepreneurial skills needed by professionals working in companies, Filion (1993) presents his entrepreneurial metamodel constituted of five entrepreneurial skills, namely: (1) *weltanschauung*; (2) vision; (3) leadership; (4) energy; and (5) networking. Filion's (1993) entrepreneurial metamodel states that professionals develop their *weltanschauung*, formulate and accomplish their vision, through their leadership, energy, and networking. These entrepreneurial skills are inseparable from the entrepreneur's behavior and were identified from a study with business' leaders around the world (FILION, 1993).

The notion of what the vision refers to is the idea that the entrepreneur needs clarity and precision about the desired position of what they intend to achieve in terms of goals and objectives in the future, in products, services, processes, or technologies, for instance (FILION, 1993). The vision is understood from three categories: emergent, central, and complementary. Chart 1 presents the vision development process, according to Filion (1993).

Chart 1 – Development process of the vision

Vision Category	Step	Content	Requirement
Emergent	Embryo	Product, service, or concept ideas	Imagination
Emergent	Development	Market, product, and concept viability studies	Reflection
Central	From	Company idea	Evaluation
Complementary	Target	Goals to be achieved	Concentration

Source: adapted from Filion (1993)

In his work, Filion (1993) states that the reality perception through *weltanschauung* enables the vision formulation, having as a support the networking. Leadership is another essential component for the entrepreneur to implement the vision, having as a raw material the networking and the energy allocated to the activities (FILION, 1993). The entrepreneurial skill paradigm is essential for leaders and engineers of postmodernity to succeed in organizations and society (FILION, 1993; GIBB, 2002).

2.2 The EDLE Tool

The Entrepreneurial Dynamic Learning Tool (EDLE Tool) is a learning tool proposed by and used in classrooms of a Brazilian public university, located in the State of Minas Gerais. In order to understand the learning dynamic supported by EDLE Tool, it is necessary to review the concepts of active learning, design thinking, and Bloom's taxonomy. These three concepts, together with entrepreneurship education (presented above), are the EDLE tool guideline principles.

Active learning is a learning approach that brings the student to accomplish their learning through meaning construction (MICHAEL, 2006). This meaning construction is involved by a set of activities and projects that take the student to conduct their own learning process (PRINCE, 2004; MICHAEL, 2006; LIMA; ANDERSSON; SAALMAN, 2017). 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's (2006), Anthony's (1996), Prince's (2004), and Lima, Andersson e Saalman's (2017) works show that active learning contributes to the entrepreneurial skills development on students.

To the present research it was taken in account that the involvement with real world problems that active learning promotes on students, as well as its links to companies' problems, make it possible to connect the active learning approach to the design thinking one. Design thinking is an 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; ÇETINKAYA, 2013; SEIDEL; FIXSON, 2013).

Brown (2008) argues that design thinking has three learning innovation spaces, namely: (1) inspiration (circumstances that motivate a search for solutions); (2) ideation (development and ideas prototyping that can be a solution); and (3) implementation (ways of implementing the solution in the market). These spaces seek to foster innovation and the creative process. According to Brown (2008), the innovation spaces are also interconnected and the creative process may go forward and back through them many times.

The last guideline principle embedded in the EDLE Tool is the Bloom's Taxonomy. The Taxonomy is a framework about what is expected for students to learn as a result of teaching (KRATHWOHL, 2002). Krathwohl (2002) emphasizes that this framework is hierarchized in order to form an organizational structure of knowledge in terms of cognitive domains

(KRATHWOHL, 2002). These domains are divided into 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 a classroom and what is not, as well as to verify what has been fostered. It is pointed out that the development of the entrepreneurial skills can be analyzed using the Blooms' taxonomy. Chart 2 presents the hierarchical structure of Bloom's taxonomy.

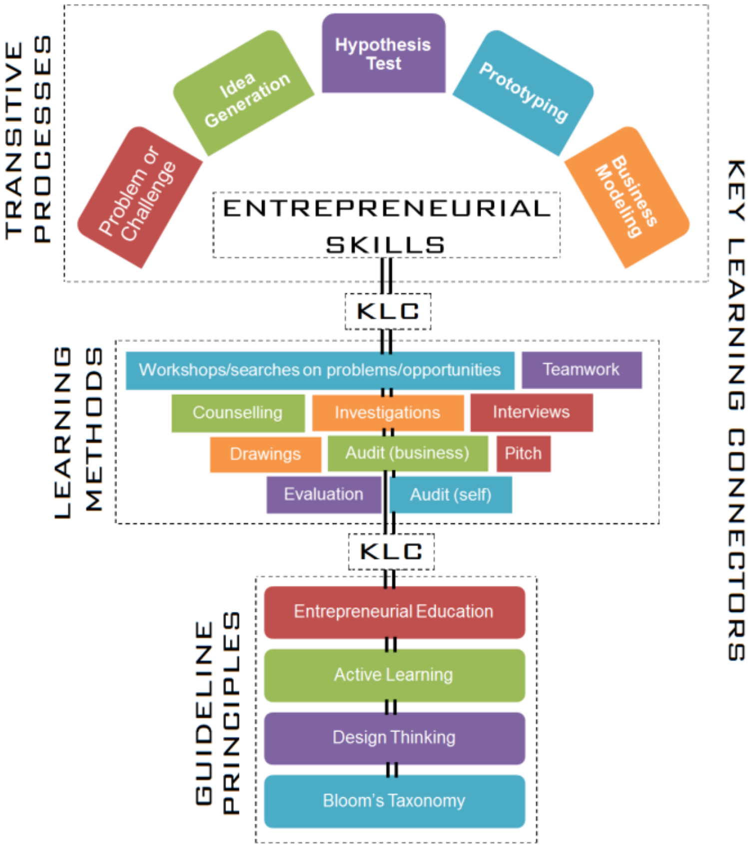
Chart 2 – Hierarchical structure of Bloom's taxonomy

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)

In this way, the EDLE Tool adopts these four guidelines principles (entrepreneurship education, active learning, design thinking, and Bloom's taxonomy) in a structured way that aids to foster the entrepreneurial skills development on engineering students. Besides the guideline principles, the EDLE Tool is also anchored by three other elements, namely: transitive processes, learning methods, and key learning connectors. Exhibit 1 presents the EDLE Tool conceptual model.

Exhibit 1 – The EDLE tool conceptual model



Source: the authors

The EDLE tool scope is built around its four main elements. The key learning connectors (KLC) establish internal linkages involving the four principles (entrepreneurship education, active learning, design thinking, and Bloom's taxonomy) that contribute 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 (weltanschaaung) KLCl (leadership), KLCe (energy), and KLCn (networking).

The transitive processes are the steps that make it possible the students' entrepreneurial skills development over 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 involve various dynamic activities, as pitches (individual and group oral presentations), mentoring, evaluation, simulation, counselling, team activities, etc. throughout the transitive processes. Finally, the learning methods help students to achieve the development of higher order thinking activities during the module, and, consequently, the entrepreneurial skills development.

3 METHODS AND TECHNIQUES

The study is exploratory and quanti-qualitative, adopting the multiple case study methodology. According to Gustafsson (2017), a case study is a research about a specific unit, to make assumptions that can be generalized to other various units. Multiple case studies are adopted to understand the parities and differences about the units, and it gives the possibility to undertake analyses within and across them, to contrast the results and clarify whether the results are valuable or not (GUSTAFSSON, 2017).

This study was accomplished in 7 steps. In the first step, the literature review on entrepreneurship education, active learning, design thinking, and Bloom's taxonomy was accomplished to explore the EDLE tool proposition. Motivated by the previous-mentioned gap and the literature on entrepreneurship engineering education, a focus was directed to the entrepreneurial skills and their development on engineering students. The second step concerned the implementation of the EDLE tool in the Innovative Idea project of an Entrepreneurship course, taught in engineering undergraduate programs of a Brazilian public university. The course totalized 294 students in 12 classes between 2015 and 2017.

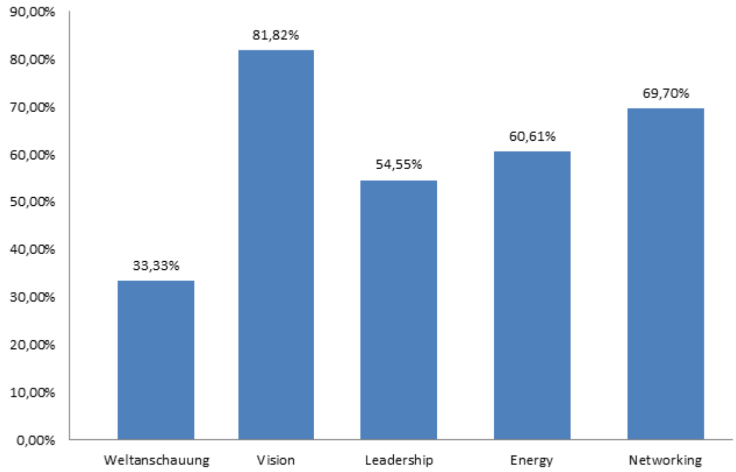
The fourth step consisted of data collection in the classrooms, in order to analyze the students' perceptions regarding the EDLE tool implementation, in the end of the Innovative Idea project, that integrates the course teaching plan. By means of a questionnaire on Google Forms platform, the engineering students were asked to respond a questionnaire based on Bloom's taxonomy and Filion's entrepreneurial metamodel. Regarding the Filion's entrepreneurial metamodel, students had to indicate the three among the five entrepreneurial skills which had had the most significant development under their perception. This dynamic was repeated for each of the 12 classes.

Next, the responses from the classes for each of the five Filion's entrepreneurial kills were compared using control charts for individual samples in Minitab, the statistical software chosen for the data analysis. The control chart for individuals represents graphically the individual observations (i.e., the classrooms' responses) and makes it possible to identify variations among the observations. In our study, significant variations larger than 3 standard deviations (up or down) could indicate a misunderstanding of the way we expected the EDLE tool to operate in classrooms and, consequently, the level of students' entrepreneurial skills development. The sixth step consisted of the analysis and interpretation of the results obtained from the statistical software. Finally, in the last step the conclusions and practical implication of the study were documented.

4 RESULTS AND DISCUSSION

As presented in methods and techniques (section 3), students from each of the 12 classes had to indicate the three among the five entrepreneurial skills which had had the most significant development under their perception. From each class it was possible to plot a graph of the students' proportions regarding the Filion's entrepreneurial skills development. Exhibit 2 presents the results obtained for the class number 7, where 33 students answered the questionnaire (results for each class available under request).

Exhibit 2 – Engineering students' Filion's entrepreneurial skills development in the class no.7



Source: the authors

Exhibits 3 to 7 show the results from the control charts for individual samples of the students' proportions regarding the Filion's entrepreneurial skills development among the 12 analyzed classrooms. In Exhibit 3, the X-axis refers to the classes (1 to 12), while the Y-axis refers to the proportions of students who indicated *weltanschaaung* among the three Filion's entrepreneurial skills that had had the most significant development in the course. In the same way, the Y-axes of the Exhibits 4 to 7 present the proportions for the skills of vision, leadership, energy, and networking, respectively. Each exhibit also presents its upper control limit (UCL) and lower control limit (LCL), provided by Minitab. The charts also present the upper bound (UB) and the lower bound (LB) as 100% and 0%, respectively. A reference line of the UB is shown in all exhibits (i.e., the maximum proportion that could be achieved).

Exhibit 3 – Individual control chart for *weltanschauung*

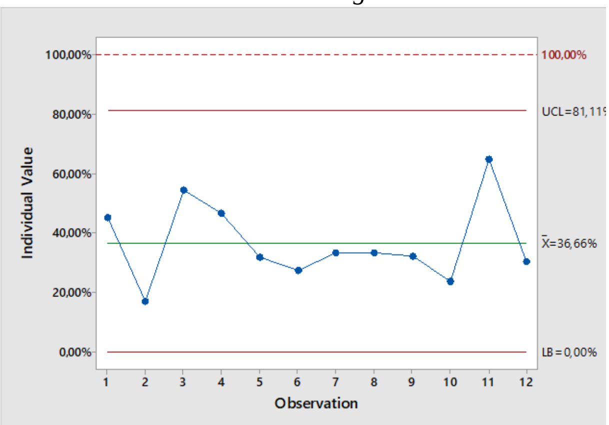


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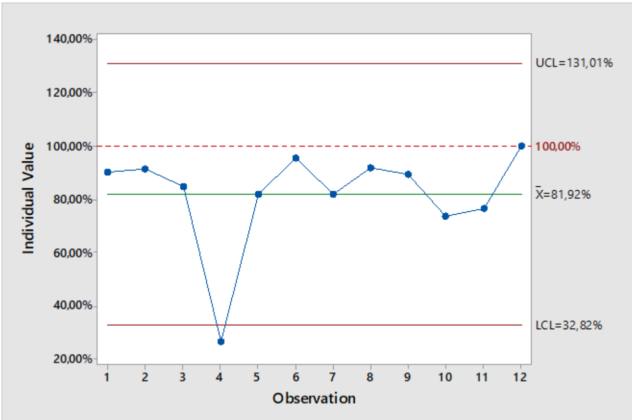
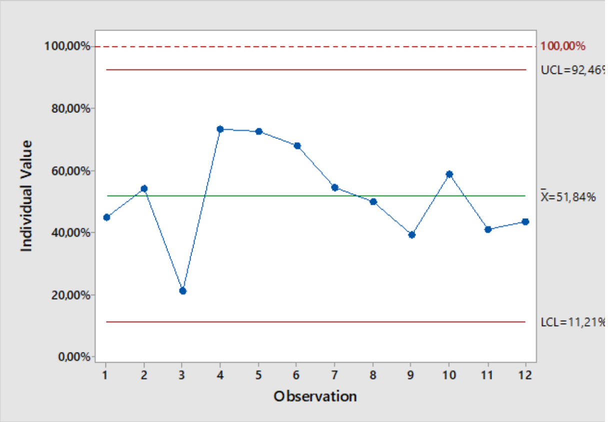
Exhibit 4 – Individual control chart for vision



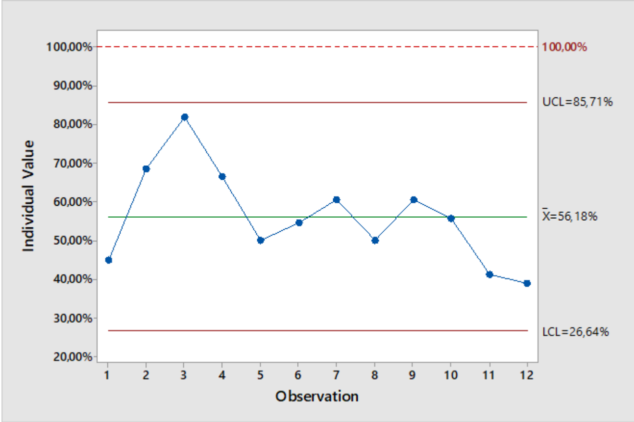
Source: the authors

Exhibit 5 – Individual control chart for leadership



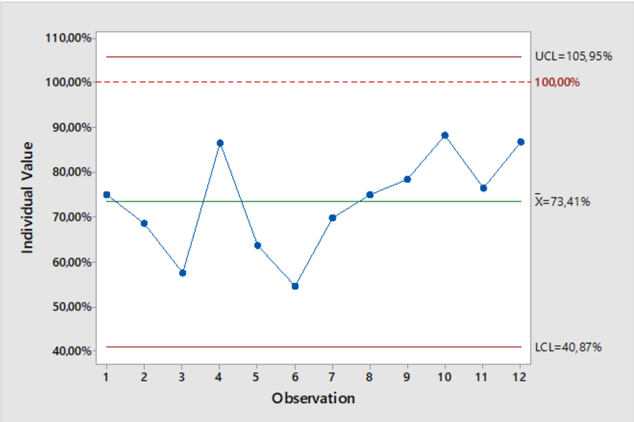
Source: the authors

Exhibit 6 – Individual control chart for energy



Source: the authors

Exhibit 7 – Individual control chart for networking



Source: the authors

The statistical results obtained from the control charts indicate that the engineering students' Filion's entrepreneurial skills development throughout the 12 classes did not differ significantly. Actually, only the Exhibit 4 presents a point out of the LCL. It is important to remark that the Filion's entrepreneurial skills development in these classes was achieved with the implementation of the EDLE tool, a learning framework proposed by and used in classrooms of a Brazilian public university to foster the development of entrepreneurial skills on engineering students, among them the Filion's ones.

Therefore, the empirical results evidence that the EDLE tool fosters the Filion's entrepreneurial skills development on engineering students. These outcomes from EDLE implementation fulfil the previous-mentioned gaps in the international academic literature, regarding the existence of few studies proposing, implementing, and evaluating tools aimed to foster the entrepreneurial skills development. It also achieves the goal of exploring, validating, and evaluating the EDLE tool implementation from a statistical point of view.

5 FINAL CONSIDERATIONS

This study addressed the gaps concerning the existence and impacts of tools aimed to foster the entrepreneurial skills development on engineering students. It had the goal to explore, validate, and evaluate from a statistical point of view the implementation of the EDLE tool, a learning framework proposed by and used in engineering classrooms of a Brazilian public university. The results showed that the EDLE tool fostered the Filion's entrepreneurial skills development consistently throughout 12 classes of engineering students between 2015 and 2017, supported by a statistical analysis.

The study has some practical implications. Both Brazilian and international engineering schools can use the EDLE tool in their engineering undergraduate programs to foster entrepreneurial skills development. Professors and scholars of entrepreneurship education can also introduce the EDLE tool dynamics inside their classes and research in order to analyze its results in different contexts. Finally, in the macrolevel, government agencies and independent organizations can use the example of the EDLE tool as start point to the updating and strengthening of the engineering education, mainly in developing countries, such as Brazil.

REFERENCES

ABDULWAHED, M.; HASNA, M. O. Engineering and Technology for Innovation- and Knowledge-Based Economies (iKBEs), Book Objectives, and Overview. *In*: **Engineering and Technology Talent for Innovation and Knowledge-Based Economies**. Cham: Springer International Publishing, 2017. p. 1–8.

ANTHONY, G. Active learning in a constructivist framework. **Educational Studies in Mathematics**, v. 31, n. 4, p. 349–369, dez. 1996.

ANTONITES, A. J.; NONYANE-MATHEBULA. Engineers as entrepreneurs: entrepreneurial orientation of engineers in South Africa. **South African Journal of Industrial Engineering**, v. 23, n. 1, p. 1–17, 2012.

BROWN, T. Design Thinking. **Harvard Business Review**, p. 85–92, 2008.

FILION, L. J. Visão e relações: elementos para um metamodelo empreendedor. **Revista de Administração de Empresas**, v. 33, n. 6, p. 50–61, dez. 1993.

GARAVAN, T. N.; O′CINNEIDE, B. Entrepreneurship Education and Training Programmes: **Journal of European Industrial Training**, v. 18, n. 8, p. 3–12, 12 set. 1994.

GIBB, A. In pursuit of a new "enterprise" and "entrepreneurship" paradigm for learning: creative destruction, new values, new ways of doing things and new combinations of knowledge. **International Journal of Management Reviews**, v. 4, n. 3, p. 233–269, 1 set. 2002.

GUSTAFSSON, J. Single case studies vs. multiple case studies: a comparative study. 2017. Available in: <http://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf>. Accessed in: 10 apr. 2018.

HASSARD, J. Postmodernism, philosophy and management: concepts and controversies. **International Journal of Management Reviews**, v. 1, n. 2, p. 171–195, 1 jun. 1999.

HUQ, A.; GILBERT, D. All the world's a stage: transforming entrepreneurship education through design thinking. **Education + Training**, v. 59, n. 2, p. 155–170, 13 fev. 2017.

JOHANSSON-SKÖLDBERG, U.; WOODILLA, J.; ÇETINKAYA, M. Design Thinking: Past, Present and Possible Futures. **Creativity and Innovation Management**, v. 22, n. 2, p. 121–146, 1 jun. 2013.

KASSEAN, H. *et al.* Entrepreneurship education: a need for reflection, real-world experience and action. **International Journal of Entrepreneurial Behavior & Research**, v. 21, n. 5, p. 690–708, 3 ago. 2015.

KRATHWOHL, D. R. A Revision of Bloom's Taxonomy: An Overview. **Theory Into Practice**, v. 41, n. 4, p. 212–218, nov. 2002.

LIMA, R. M.; ANDERSSON, P. H.; SAALMAN, E. Active Learning in Engineering Education: a (re)introduction. **European Journal of Engineering Education**, v. 42, n. 1, p. 1–4, 2 jan. 2017.

MARESCH, D. *et al.* The impact of entrepreneurship education on the entrepreneurial intention of students in science and engineering versus business studies university programs. **Technological Forecasting and Social Change**, v. 104, p. 172–179, 1 mar. 2016.

MICHAEL, J. Where's the evidence that active learning works? **Advances in Physiology Education**, v. 30, n. 4, p. 159–167, dez. 2006.

MORRIS, M. H. *et al.* A Competency-Based Perspective on Entrepreneurship Education: Conceptual and Empirical Insights. **Journal of Small Business Management**, v. 51, n. 3, p. 352–369, 1 jul. 2013.

NICHOLS, S. P.; ARMSTRONG, N. E. Engineering entrepreneurship: does entrepreneurship have a role in engineering education? **IEEE Antennas and Propagation Magazine**, v. 45, n. 1, p. 134–138, fev. 2003.

PRINCE, M. Does Active Learning Work? A Review of the Research. **Journal of Engineering Education**, v. 93, n. 3, p. 223–231, 1 jul. 2004.

SEIDEL, V. P.; FIXSON, S. K. Adopting Design Thinking in Novice Multidisciplinary Teams: The Application and Limits of Design Methods and Reflexive Practices. **Journal of Product Innovation Management**, v. 30, p. 19–33, 1 dez. 2013.

UMA ANÁLISE ESTATÍSTICA DO DESENVOLVIMENTO DE HABILIDADES EMPREENDEDORAS EM ESTUDANTES DE ENGENHARIA NO BRASIL

Resumo: *Os artigos acadêmicos sobre educação empreendedora em engenharia têm crescido nas últimas décadas e apresentado análises sobre o desenvolvimento do empreendedorismo dos estudantes sob vários pontos de vista. O metamodelo empreendedor proposto por Filion apresenta as cinco habilidades empreendedoras inseparáveis e necessárias para os empreendedores (visão, weltanschauung, liderança, energia e relações). Essas habilidades são essenciais para engenheiros e líderes que trabalham sob o paradigma do empreendedorismo. Entretanto, existem poucos estudos propondo, implementando e avaliando ferramentas que visam promover o desenvolvimento de habilidades empreendedoras em estudantes de engenharia, deixando uma lacuna aberta na literatura acadêmica internacional. Este estudo aborda essa lacuna e tem como objetivo explorar, validar e avaliar, por meio de uma análise estatística, a implementação de uma ferramenta denominada Aprendizagem Dinâmica Empreendedora (EDLE). A ferramenta EDLE pretende promover o desenvolvimento de habilidades empreendedoras de Filion nos estudantes de engenharia. O estudo é exploratório e adota metodologia de estudo de casos múltiplos. A partir da implementação da ferramenta EDLE em uma disciplina de Empreendedorismo oferecida a cursos de graduação em engenharia de uma universidade pública brasileira, alunos de 12 diferentes turmas entre 2015 e 2017 indicaram as três principais habilidades empreendedoras de Filion (entre as cinco) que tiveram o desenvolvimento mais significativo no curso. Em seguida, as possíveis diferenças sobre o desenvolvimento dessas habilidades entre as turmas foram avaliadas usando um software estatístico. Os resultados indicam que a ferramenta EDLE promoveu o desenvolvimento das habilidades empreendedoras de Filion nos estudantes de engenharia, validando sua implementação e possuem implicações práticas.*

Palavras-chave: *Ferramenta EDLE. Metamodelo empreendedor de Filion. Educação empreendedora. Educação em engenharia. Taxonomia de Bloom.*