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## LEADING ENGINEERS TO THE FUTURE: AN ARTIFICIAL INTELLIGENCE APPROACH FOR ENGINEERING CREATIVITY SUPPORT

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**Abstract.** Creativity, innovation and engineering are deeply related fields in current market context. It is common task among engineers to create alternatives and design solutions, both in academy and organizations. Engineers of the future will be requested to manage and innovate using their technical expertise, aspects that are still undermined in many engineering courses. Such responsibility will require a high degree of creativity, aiming to develop innovative solutions to solve problems. Newly graduated engineers are prepared for the technical engineering tasks that require their expertise, but may lack the creativity background to innovate. To evaluate such factors, a study with undergraduate students and newly graduated engineers was conducted to investigate current skills on creativity and innovation. Results pointed out the latent necessity for deepening on the subject, especially considering current engineering curriculum structure. As an alternative towards more creative engineers, this paper presents an Artificial Intelligence prototype developed to support the selection and application of creativity techniques. Widely used methods in organizations for new product development, the techniques are able to catalyze the creative process, reaching solutions faster when adequately used. Such expertise was represented in the prototype, which is able to identify the design scenario, select adequate creativity techniques, explain the reasoning process and instruct about the use of each technique. As a complementary approach, the system may be able to better prepare creative engineers without overburdening the education process, offering crucial information on how to innovate and be prepared to the market.

**Keywords:** Creativity, Engineering education, Artificial intelligence, Product development

### 1. INTRODUCTION

Engineering practices are commonly associated with problem solving and development of solutions (Belski *et al.*, 2016). Many professions have changed with the advent of information age and the fourth industrial revolution, requiring gradually more from the professionals the ability to solve problems (Steiner, 2011). The primal education purpose is to develop students' potentials and offer adequate knowledge for them to permeate and succeed on social environment (Wagner, 2008), meaning that professional development should be guided by changes in society. This new scenario demands from universities sensibility and adaptability, molding their educational methods to better fit the changing reality (Belski *et al.*, 2016). The engineer's tasks have surpassed the technical and scientific repertoire, requiring from engineering curricula to adequately develop students' problem-solving skills, such as creative thinking (Steiner, 2011).

The new demands from engineering profession highlights the increasing importance of creativity (Runco *et al.*, 2017). Current market requires the ability to innovate at high paces, and creative skills are being increasingly valued by employers due to its impact on the organization competitiveness (CNI, 2015; MEI, 2016; Runco *et al.*, 2017). Unfortunately, students commonly display lesser creativity potential inside universities than in outside environments (Runco *et al.*, 2017). This might indicate that our universities environments are somehow hindering creative behavior, or that such matter is not being sufficiently addressed on engineering curricula.

Creativity can be described as the ability to generate novel and useful ideas (Amabile, 1997; Gabriel *et al.*, 2016). The perpetuated vision of artistic free creation has been replaced on companies by the notion that the creation process should be efficient and not demand excessive time. This becomes clear when considering competitiveness factors that require quick generation of good ideas to perpetuate the innovation process. Therefore, innovation can be seen as a

continuous process of implementing such creative solutions into feasible, viable and desirable products to the market (Tidd and Bessant, 2009; Brown, 2010).

Given the market need for more creative engineers and the changes on the engineering profession attributions, the underlying questions remain: are our universities' curricula adequate to the changing perspective of engineering? Do our students perceive creativity and innovation as relevant in the engineering profession? This work focused on understanding the perceptions of engineering students and graduates on the importance of creativity and innovation to the engineering practice. This was achieved through a virtual questionnaire distributed to the engineering community of Federal University of Santa Catarina (UFSC). The results served as a basis to argue if current engineering curricula are compatible with the aspirations from market and students. The discussion was also based on the differences on curricula from worldwide universities credited as the best in mechanical engineering (QS, 2017; Times, 2017) to the best Brazilian mechanical engineering universities (Folha, 2017). As a result, we propose a solution to overcome possible deficiencies on Brazilian curricula on creativity and innovation without overburdening the curricula, through an artificial intelligence system for creativity techniques learning and problem-solving skills enhancement.

## 2. ENGINEERING EDUCATION

To form the next generations of engineers demands intensive knowledge and preparation for professors and universities. The educational process by itself is complex, but to be able to predict future demands of professions in constant change is a great challenge. Given the current market dynamics, professions are constantly being forced to change to better fit current reality, and engineering has transformed deeply over the last decade (Belski *et al.*, 2016).

Universities adopt different practices to achieve desired student competences. On engineering, professors may use different perspectives to teach, such as Project Based Learning, Method, Group Works, and Guided-Problem Solving, each with particular applications and learning effectiveness (Steiner, 2011). Regardless of the methodology, the major university focus has changed from sole technical repertoire into active learning, where students learn from theory and practice along the undergraduate course (Steiner, 2011; Rodríguez *et al.*, 2015). Traditional engineering education curricula, that prime for values such as functionality and profit (Rugarcia *et al.*, 2000), are being replaced by a balance between technical knowledge and problem-solving skills, which are more compatible to the education of future engineers (Hamzah *et al.*, 2012).

The ability to solve problems is correlated to creation capabilities, which provide a basis to apply the technical knowledge in developing solutions. Creative problem-solving skills are important not only to ideate and generate solutions, but to adequately frame the problem and evaluate conceptions (Chen *et al.*, 2015). In fact, creativity itself is an ability that requires adequate expertise, as well as adequate cognition and motivation that potentiate creative thinking (Amabile, 1997). Technical knowledge is, therefore, of great importance to problem-solving, but its use is deeply impacted by adequate mindsets that are developed through experience. Such applied expertise aid the development of "tool-kits", which might include design heuristics, methodologies and appropriate creativity techniques.

Regardless of the problem at hand, every project requires notions of creativity and innovation on theoretical and practical levels. Problem-solving is an interdisciplinary activity that requires multiple perspectives to achieve adequate solutions (Tran *et al.*, 2017). Students immersed on technical engineering education learn by absorbing knowledge from professors and repeating such patterns in controlled situations, which are mostly presented as well-planned problems (Rugarcia *et al.*, 2000). This generates a dualist point-of-view, in which answers are either right or wrong and problems can be solved solely by applying engineering expertise (Hamzah *et al.*, 2012). However, when subjected to real engineering problems, students face multidisciplinary problems with high levels of uncertainty (Hamzah *et al.*, 2012). Thus, despite the years of engineering training and learning, novice engineers face the reality that they have yet to learn how to solve broad and systemic problems (Steiner, 2011).

### 2.1 Best engineering schools in the world

Engineering universities are becoming aware of such incompatibilities, and some curricula of engineering education have changed over the last decade to a more problem-solving perspective. While some schools remain inertial, most highly praised engineering courses seem to be applying creativity, innovation and active learning methods to guide students. By analyzing the considered best mechanical engineering schools in the world, some aspects of their successful practices may be highlighted. QS's "World University Rankings 2017" (QS, 2017) and Times Higher Education's (THE) "World University Ranking 2016-2017" (Times, 2017) were used in the analysis, selecting the 3-best mechanical engineering courses in each and cross-examining both rankings. Given the different indicators used by each ranking, 5 universities were elected to examination, whose curricula were analyzed regarding the insertion of direct problem-solving teaching. The analysis was based on provided mechanical engineering curriculum and discipline syllabus on each of the universities webpage, screening for any subject that intersected with active problem-solving, creativity, innovation, design or entrepreneurship.

First on the QS ranking and fourth on THE, Massachusetts Institute of Technology (MIT) (MIT, 2017) is one of the most renowned universities for engineering. The mechanical engineering course focuses on problem-solving, design

and communication skills to prepare future generations of creative thinkers. To graduate as bachelor, 189 units are required beyond the 17 General Institute Requirements. From creation and design perspective, 3 subjects (36 units) are included in the core of the curriculum: “Design and Manufacturing I”, “Design and Manufacturing II”, and “The Product Engineering Process” (equivalent to “Engineering Systems Design” and “Engineering Systems Development”). Electives add up to 72 units (24 restricted to the program and 48 unrestricted), of which the student might choose: “Elements of Mechanical Design” and “Management in Engineering” as restricted, and “Engineering Innovation and Design”, “Product Design and Development”, “Development of Mechanical Products”, among many others as unrestricted. Other technical subjects also include projects related to the acquired knowledge. Of the total requirements to declare, a student is able to direct up to 57% of the course to disciplines fundamentally related to problem-solving, creativity and innovation.

Second on both THE and QS rankings, Stanford University (University, 2017) stands with one of the best employability levels and market trust. Mechanical Engineering curriculum is built around 5 themes, including a design program and a transversal emphasis on human-centered design and sustainability. From the 116 units required for declaration, including 48 basic disciplines from math and science, there are 4 mandatory subjects (16 units) regarding design and problem-solving abilities: “Visual Thinking”, “Mechanical System Design”, “Mechanical Engineering Design” (equivalent to “Consumer Analytical Product Design”) and “Design and Manufacturing”. Remaining 6 minimum electives’ units include “Perspectives in Assistive Technology” and “Integrating Context with Engineering”. Overall, 19% of the course can be focused on design. Several other related subjects are offered by the Mechanical Engineering Graduate Program.

Third on QS and fourth on THE ranking, Cambridge University (Cambridge, 2017) is the best placed European school of mechanical engineering. Different from United States universities that allow a great freedom for students to choose a major over time, Cambridge curriculum starts with two years of pure engineering subjects. On the third-year students may choose between Engineering and Manufacturing Engineering Tripos, acquiring a bachelor’s degree on one year or a master’s degree on two. During university life students have contact with disciplines and projects such as “Lego Mindstorms Project”, “Product Design Project”, “Multidisciplinary Design”, “Machine Design”, “Design Methods”, “Design Case Studies”, and “Bicycle Design”. Given the limited access to the content of the course and subjects, no further information could be obtained. With similar structure, Oxford University (Oxford, 2017) is the third place on THE ranking and ninth on QS. During the three or four-year course on Brooks, students have contact with elements such as “Design & Practice I”, “Design & Practice II”, “Engineering Project”, “Design of Machines”, “Engineering in Society”, “Group Design Project” and “Engineering Practical Work”.

First place on THE ranking and seventeenth on QS, California Institute of Technology (Caltech) (Caltech, 2017) offers along its four-year course subjects of “Design and Fabrication”, “Engineering Design Laboratory”, “Introduction to Multidisciplinary Systems Engineering”, “Management of Technology”, “Design for Freedom from Disability”. Out of 233 required units for declaring, students might direct 35% of the under-graduation course to problem-solving related themes.

This analysis showcases the relevance of problem-solving subjects and that considered best engineering schools have shifted to encompass such aspects into the curriculum. These universities give freedom for students to mold the course depending on interests, with a high level of electives. This allows students with interest on design to fulfill a great part of subjects related to the theme, but also granting that students with more interest in technical areas to learn the basics in obligatory subjects.

## 2.2 Best engineering schools in Brazil

To compare to the above-mentioned international curricula, four Brazilian universities’ mechanical engineering curricula were evaluated, according to “*Ranking Universitário Folha*” (RUF) 2017 (Folha, 2017). At the best of our knowledge and regarding information available on the internet, the curricula were analyzed in search for subjects related to design, innovation, creativity or problem-solving skills development. Best pointed mechanical engineering course is Campinas University (UNICAMP) (UNICAMP, 2017), which integrates only one subject related to design, innovation and creativity as an elective: “*Projeto de Sistemas Mecânicos*” (Mechanical System Design). Design does not integrate the seven specializations areas, and no information was found about active learning methods.

Second ranked university is University of São Paulo (USP) (USP, 2017), whose mechanical engineering bachelor course has five possible emphasis, one of which on Design. From the Design emphasis curriculum, 8% of the subjects are related to applied or theoretical design and problem-solving, including “*Teoria e Metodologia do Projeto*” (Design Theory and Methodology), “*Laboratórios de Engenharia de Projeto*” (Design Engineering Laboratory), “*Projeto de Máquinas I / II / IV*” (Machine Design I / II / IV), “*Gestão e Organização*” (Management and Organization), among other electives.

Third on the ranking Federal University of Minas Gerais (UFMG) (UFMG, 2017) has a curricular concentration area on Design and Manufacturing and includes “*Introdução ao Projeto*” (Mechanical Design) and “*Organização Industrial*” (Industrial Organization) among the obligatory subjects. Electives include “*Projetos Mecânicos Industriais*” (Industrial Mechanical Design), “*Processo Criativo e Empreendedorismo*” (Creative process and

Entrepreneurship), and “*Projetos Mecânicos I / II*” (Mechanical Design I / II). Of the total load, 7% can be directed to design, creativity and innovation themes, including the electives.

Forth school is Federal University of Santa Catarina (UFSC) (UFSC, 2017) includes four subjects related to problem-solving skills development: “*Metodologia de Projeto em Engenharia Mecânica*” (Design Methodology in Mechanical Engineering), “*Projeto Integrado em Engenharia Mecânica*” (Integrated Design in Mechanical Engineering), “*Laboratório em Manufatura e Metrologia*” (Manufacturing and Metrology Laboratory) and “*Organização Industrial*” (Industrial Organization). Two other elective subjects might also be directed to correlated themes, totalizing 10% of the course.

By comparing the curricula from the best mechanical engineering schools on international and Brazilian scenarios, a discrepancy can be marked. The shift from technical to problem-solving paradigm that can be seen on the top worldwide schools is still timid on Brazil, the closest university being UFSC. This shift naturally does not guarantee that the addition of such themes contributes to the formation of good engineers, but the difference in focus might reveal an unconformity between what is being taught in Brazilian universities and the actual market needs. To unveil that hypothesis, a study was conducted with students and bachelor engineers, aiming to evaluate their perceptions on innovation and creativity, and compare such information to reports about engineering education in Brazil developed by non-academic institutions.

### 3. EXPECTANCIES FOR ENGINEERS

#### 3.1 Market scenario

Particularly, Brazilian innovation ranking has been stable on recent reports from the Global Innovation Index, fluctuating from 70<sup>th</sup> place on 2015 to 69<sup>th</sup> in 2016 and 2017. However, Brazilian innovation efficiency, meaning innovation outputs (what a country produces as result of innovation activities within the economy) divided by innovation inputs (elements of the national economy that enables innovative activities), has declined (Cornell University *et al.*, 2017). This means that Brazil’s investments on innovation are not being translated into the economy, and are unable to avoid a worsening in the scenario. In fact, 62% of Brazilian business leaders consider Brazilian innovation degree low or very low (CNI, 2015).

This situation is impacted by several factors, including business environment, political and economic factors, and the educational model currently used in Brazil. The discrepancy between what is taught in engineering and actual market expectancies is an important factor. For instance, worldwide practicing engineers use creativity techniques in day-to-day work, such as simple Brainstorming sessions, TRIZ, Mind Mapping and Brainwriting (Belski *et al.*, 2016). This practice is not imbued in Brazilian mechanical engineering courses, which focus on more technical aspects. Engineers are expected to solve problems, lead teams and manage projects (MEI, 2016), but most end up learning such skills on practice after graduation (Belski *et al.*, 2016).

#### 3.2 Students perception on Creativity and innovation

Given the market and university positioning on engineering education, the third aspect to be analyzed is the perception of undergraduate students and newly graduated engineers on the importance of such themes as necessary for their professions. To evaluate the perceptions of such group, a questionnaire was developed on the first semester of 2017 and virtually sent to engineering courses through direct contact with professors and on social networks. Given the broadness of social media and the dissemination among professors from universities, we estimate that over a 1000 students and newly graduated engineers had contact with the questionnaire. Despite the wide range, only 68 answers were retrieved, with responses from several engineering courses. Respondents ranged from first semester students (which entered on the first semester of 2017) to new engineers that begun their courses on the second semester of 2007, encompassing 16 engineers and 52 undergraduate students.

Answers were grouped into three groups to allow statistical analysis. The division was based on the mechanical engineering curriculum from Federal University of Santa Catarina, from which a great number of responses were retrieved. This curriculum presents the first design-related subject on the 4<sup>th</sup> semester, the first 2 years are considered to have basic physics and mathematical subjects that support latter engineering subjects. In majority, such subjects are offered from 5<sup>th</sup> to 8<sup>th</sup> semesters, while from 9<sup>th</sup> onward the student already begins the end-course project and contact with the market. Therefore, responses were divided according to students’ entrée and expected ongoing semester, being group A (total of 27 responses) composed by 1<sup>st</sup> to 4<sup>th</sup> semester students, group B (15 responses) from 5<sup>th</sup> to 8<sup>th</sup> semester students, and group C (26 responses) by entrées from 9<sup>th</sup> semester onwards, with or without complete bachelor’s degree.

Besides course, completion of degree, entrée year and semester, the questionnaire inquired in a 5-point Likert scale (1 completely disagree and 5 completely agree) the student’s perception on the statements: “I consider myself a creative person”; “innovating is a fundamental role of engineers”; “being creative is an essential ability for engineers”; and “creativity is necessarily a prerequisite for innovation”. Furthermore, respondents were asked to comment their opinion on the role of creativity and innovation inside engineering practice. Data was qualitatively interpreted using mean

values and standard deviation. Quantitative analysis included Kruskal-Wallis test to evaluate statistically significant differences among all groups (significance level  $\alpha = 0,05$ ), and Wilcoxon rank sum test (Mann Whitney test) for unpaired data to evaluate statistically significant differences between paired groups (Steiner, 2011). Wilcoxon rank sum test significance level was corrected using Holm-Bonferroni procedure (Harpe, 2015).

Figure 1 and Table 1 present results regarding the first statement: “**I consider myself creative**”. In both qualitative and quantitative analysis, the results demonstrate no significant difference among the groups, meaning that the engineering course has no impact on the perception of the student’s creative potential. Kruskal-Wallis test indicates no significant statistical difference among the three groups, and no difference was found in comparisons two by two using Wilcoxon rank sum test ( $p$ -values between 0,643 and 0,768). Overall, students’ perception mean value remained between neutral and agree, with a small tendency to agree.

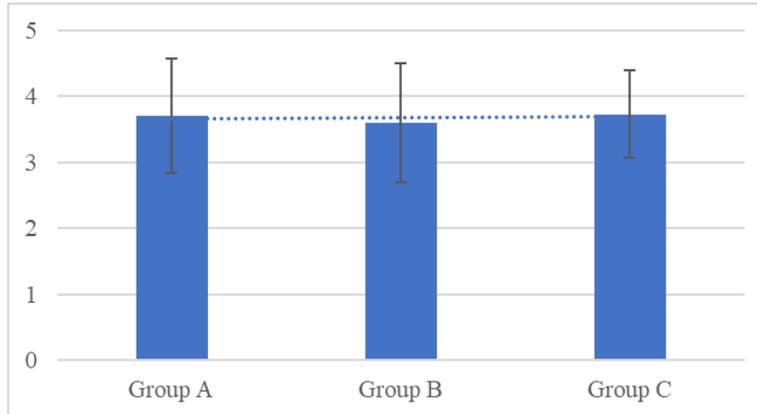


Figure 1. Answers for statement “I consider myself creative” by entrée semester.

Table 1. Mean, standard deviation and Kruskal-Wallis p-value for statement “I consider myself creative”.

	Total	Group A	Group B	Group C	K-W ( $p$ )
Mean	3,69	3,73	3,60	3,70	0,891
SD	0,80	0,67	0,91	0,87	

Second statement “**to Innovate is fundamental to engineers**” results are presented on Fig. 2 and Tab. 2. Qualitative analysis indicates a decrease on the perception of importance of innovation for engineering practice in the middle of the course, but with a slight raise with the beginning of the engineering career. In fact, qualitative analysis among all three groups is borderline conclusive (Kruskal-Wallis test  $p = 0,050$  for significance level  $\alpha_1 = 0,05$ ), and significant difference was confirmed between group A and group B using Wilcoxon rank sum test ( $p = 0,0248$ , lower than corrected significance level  $\alpha_2 = 0,025$ ). No significant difference was found between other comparisons ( $p = 0,020$  with corrected  $\alpha_1 = 0,0167$  for group A and group C comparison, and  $p = 0,851$  with corrected  $\alpha_3 = 0,05$  for group B and group C comparison). On average, students’ perception mean value remained between agree and strongly agree, with a small tendency to agree.

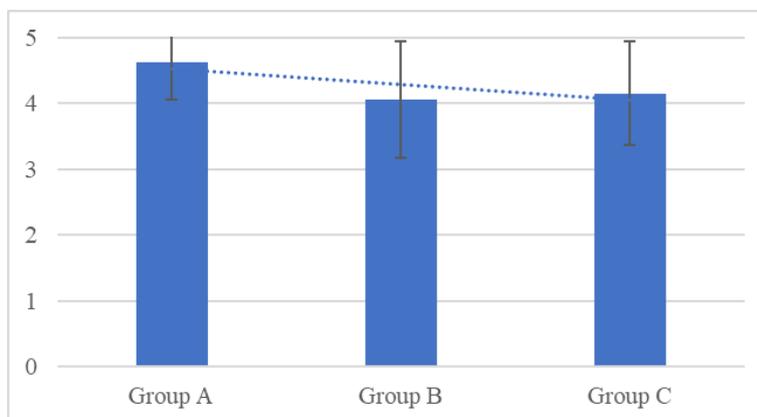


Figure 2. Answers for statement “to Innovate is fundamental to engineers” by entrée semester.

Table 2. Mean, standard deviation and Kruskal-Wallis p-value for statement “to Innovate is fundamental to engineers”.

	Total	Group A	Group B	Group C	K-W ( $p^*$ )
Mean	4,32	4,63	4,07	4,15	0,050
SD	0,76	0,56	0,88	0,78	

Third statement “**creativity is fundamental to engineers**” responses are presented on Fig. 3 and Tab. 3. Consonant to the previous statement answers, qualitative analysis indicates a decrease on the perception of importance of creativity for engineering practice on in the middle of the course, which is maintained in the beginning of the engineering career. Qualitative analysis is inconclusive on significant difference on two by two Wilcoxon rank sum tests ( $p$ -value ranged from 0,072 to 0,821). On average, students’ perception mean value remained in between neutral and agree, with a small tendency to agree.

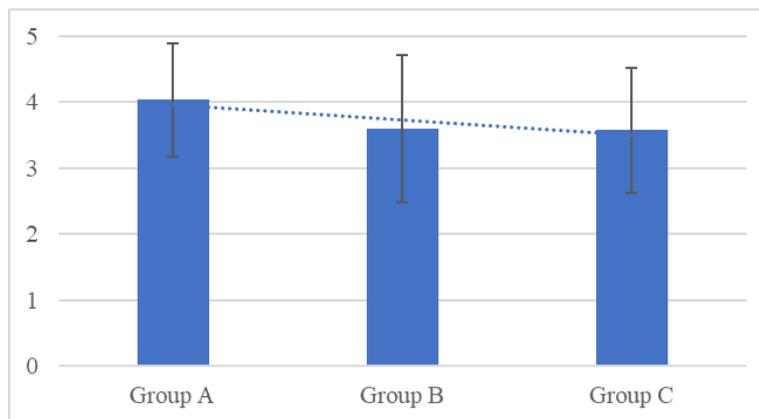


Figure 3. Answers for statement “creativity is fundamental to engineers” by entrée semester.

Table 3. Mean, standard deviation and Kruskal-Wallis p-value for statement “creativity is fundamental to engineers”.

	Total	Group A	Group B	Group C	K-W ( $p^*$ )
Mean	3,76	4,04	3,60	3,58	0,212
SD	0,96	0,85	1,12	0,95	

Figure 4 and Table 4 present responses regarding fourth statement “**creativity is necessarily a prerequisite to innovation**”. Even with a slight increase in the middle of the undergraduate course, both qualitative and qualitative analysis indicates a no difference on the perception of the relationship between creativity and innovation. Qualitative analysis shows no significant difference on two by two Kruskal-Wallis tests ( $p$ -value between 0,380 and 0,671). On average, students’ perception mean value remained in between neutral and agree, with a slight tendency to neutral.

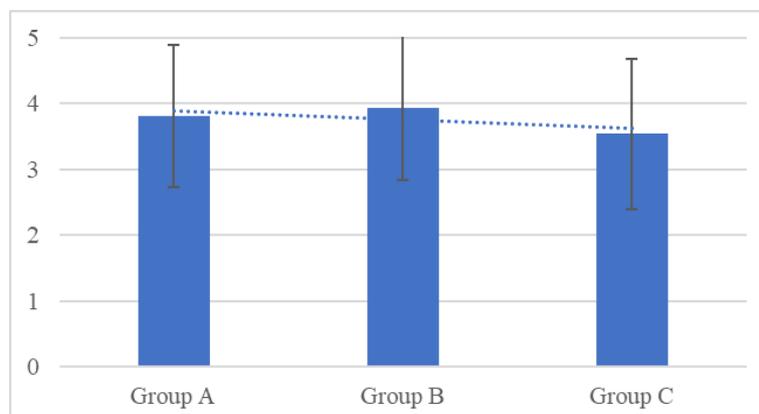


Figure 4. Answers for statement “creativity is necessarily a prerequisite to innovation” by entrée semester.

Table 4. Mean, standard deviation and Kruskal-Wallis p-value for statement “creativity is necessarily a prerequisite to innovation”.

	Total	Group A	Group B	Group C	K-W ( $p^*$ )
Mean	3,73	3,81	3,93	3,54	0,489
SD	1,10	1,08	1,10	1,14	

Relevant remarks pointed out by respondents when asked about the role of creativity and innovation on engineering include: a) the perception of engineers never working alone; b) these subjects are not well explored during undergraduate course; c) such themes might be able to “open the minds” of future graduates; d) both themes are required for competitiveness; e) creativity and innovation have deep bonds to engineering, and might help developing better solutions along the engineering career; f) students have less contact with such themes throughout the courses.

#### 4. DISCUSSION

Engineering profession has changes on latter decades (Hamzah *et al.*, 2012), especially with the implementation of global internet and powerful computing systems able to automate several technical engineering assignments (Belski *et al.*, 2016). With the incoming of fourth industrial revolution, artificial intelligence solutions will intensify such changes, and the competences of a future engineer are likely to be very different than current practices. Presently, engineers are expected to balance technical knowledge with several problem-solving skills, such as dealing with extreme uncertainty, being part and managing multidisciplinary teams, communicating and exchanging knowledge with several other experts on different areas, among others.

Traditional teaching methods on engineering has been reported to be ineffective on developing such problem-solving and creativity skills (Belski *et al.*, 2016). Engineers under such curricula, even when including punctual humanities and design subjects, are likely to outsource responsibility for socially harming, unethical or immoral decisions that they made (Hamzah *et al.*, 2012). Such engineers suffer a great impact when entering real organizational scenarios, to which they are oftentimes unprepared for.

New requisites on engineering profession are demanding from universities changes on the education paradigms, including expertise in leadership, teamwork, entrepreneurship, ability to deal with uncertainties and to communicate efficiently (MEI, 2014). Moreover, recommendations include pedagogies oriented to problem-solving and creativity stimulus, flexibilization of engineering courses given the early overspecialization present on most curricula, and a bigger interaction between university and market to promote projects that allow undergraduates and graduates to have market experiences (MEI, 2016). Organizations are in search for engineers with innovative profiles capable of create and communicate proactively, with knowledge on entrepreneurship, systemic view, management abilities, among others (CNI, 2015).

When observing the curricula from considered best mechanical engineering schools worldwide, a clear remodeling of the traditional engineering methods can be seen. Technical aspects are still relevant and presented to students, but they are permeated by several problem-solving challenges, including the development of team-work abilities, creativity skills and innovation. The Project-Based Learning paradigm is also used as an integrative option, in which students begin to realize engineering subjects as a whole, and not as separate and isolated bodies of knowledge. Contact with integrative design and a proportional raise on design notion as obligatory and elective disciplines have proven to develop better prepared engineers to actual engineering practices, given the high market acceptance of graduated engineers from these universities.

Such changes are still timid in Brazilian universities, which are slowly integrating design and innovation disciplines to their curriculum. While most universities neglected such subjects over a decade ago, the best ranked engineering courses have integrated obligatory and elective design disciplines, which focus on developing problem-solving skills. This movement seems to be spreading through a raise on students’ perception for such themes, and the need for them to search for such relevant knowledge outside the traditional engineering courses. As a matter of fact, even entrée students seem to perceive the importance of creativity and innovation for engineering practice, though the traditional curricula might affect negatively on such perceptions.

Answers retrieved through the virtual questionnaire hint to a change of perception on engineering profession. The aim was to perceive if students and newly graduated engineers have consonant opinions with market expectancies and the new paradigm for engineering education seen in the best mechanical engineering universities in the world. Results might be biased given the low number of respondents in relation to the whole reached public. Respondents might already present preferences to themes such as creativity and engineering, given the questionnaire distribution form being able to attract their attention. From an estimated total of over 1000 students and engineers who received the questionnaire, only 68 responded.

Overall, entrée students remark the important role of creativity and innovation to engineering practice. The decrease seen in such perception over the semesters might indicate that either engineering tasks on the Brazilian market still has a wide place for technical engineers, or the engineering courses are trimming such problem-solving abilities and

educating engineers that will require a recycling in the beginning of the career. This second assumption seems to have more support, given the differences on practices employed by novice and expert engineers (Hamzah *et al.*, 2012; Belski *et al.*, 2016). Among the competences indicated by experienced engineers, creativity techniques are extensively employed to aid problem-solving, and are used on a day-to-day basis by most professionals (Belski *et al.*, 2016).

Assuming that future engineers will be required to have high problem-solving skills, other aspect to be noted is that students and newly graduated engineers seem to have no development on creativity. This fact is endorsed by the also equal perception of the relationship between creativity and innovation. Recent developments show the intricate connection between creativity skills and innovation potential (Starkey *et al.*, 2016; Crilly and Cardoso, 2017), but engineering students are apparently not being taught these topics. In fact, the statement “creativity is necessarily a prerequisite to innovation” presented the highest standard deviation, which implies on a lack of information for students. By not having adequate creativity teaching, students are unable to adequately develop their problem-solving skills (Steiner, 2011), and leave undergraduate education without an important ability.

The inclusion of such themes on current engineering education might be costly given the already extensive course workload. Therefore, alternatives for teaching such themes are imperative to provide sufficient competences to students without overburdening the educational system. Artificial intelligence might be an ally to such endeavor, offering knowledge to students on alternative ways. The use of an artificial intelligence software to aid the selection and learning of creativity techniques may help the development of such creativity skills. The techniques are templates based on previous successful endeavors for solution finding, and hundreds of different approaches were developed over the years, each with different applications and potentialities (Forster and Brocco, 2008). When adequately used, creativity techniques ease the ideation process (understanding the problem, ideating and evaluating solutions) and teams are able to come up with more and better solutions in less time (Bertoncelli *et al.*, 2016).

The knowledge-based system (KBS) for creativity techniques selection (Botega and Silva, 2015) has shown potential to be an adequate alternative to fulfill such role. By using such system on design-related activities, students can learn about different creativity techniques that might prove to be useful on later professional environments. The techniques would also incite students to understand the creation process and develop problem-solving abilities. By using of 9 initial questions, the software is able to correlate 504 design scenarios and present to the user one or more appropriate creativity techniques selected from a database with 24 implemented ones.

The KBS was validated with students and experts on engineering and creativity (Botega, 2016). Validation pointed the relevance of the system for both professional and educational purposes. Even among validators, the average known techniques were 12 out of 24 in the system knowledge-base, highlighting the relevance of such system to both learn about new techniques and how to use them. Among the situations of use, validators indicated its use for design groups, such as in engineering design learning activities, especially considering creativity blocks. Expert validators also endorsed the adequacy and use of the presented techniques, as the most selected techniques were considered adequate by them to the presented validation scenario. Given the broadness of the system and the ease of implementing new techniques, we consider that the insertion of such alternative on engineering schools will benefit the education of engineers to the future.

## 5. CONCLUSIONS

Engineering is a changing profession, and the requirements for future engineers are likely to be different than current profession assignments. Teaching engineers with this perspective is a challenge for universities, but is imperative for students to learn and develop competences that are in fact useful for future engineering practices. Developing pedagogies solely based on the current scenario or delaying necessary changes is to train students in soon to be obsolete practices, and the curricula should reflect the rapid changing in the engineering profession.

Engineers, traditionally assigned with functional developments and technical solutions, are being gradually integrated in problem-solving contexts. Such new perspective requires the ability to find solutions, deal with uncertainty, communicate with several areas and be creative. These requirements are essential to organizations and are latent on aspiring engineers, who may have their expectancies frustrated with pure technical courses. Entering engineering students perceive the importance of problem-solving, creativity and innovation for their future professions, but seem to be having no teaching on such themes during their courses in Brazil. The discrepancy between international and Brazilian curricula may be an indicative of the need for change. International universities have adapted their curricula to balance technical and problem-solving aspects. Brazilian universities are beginning such transition, but some alternatives may be able to catalyze such process without overburdening the already extensive curricula.

Artificial intelligence has radically changed engineering profession on the fourth industrial revolution, and will also be an ally on teaching future engineers. The work presents a KBS prototype as a contribution to help the difficult task of educating future generations. By adding creativity techniques through an artificial intelligence software, students will be able to access extensive knowledge constantly without requiring the inclusion of new subjects or the necessity of extensive studies. The software does not replace the professor role, but may aid on transmitting knowledge and awakening the students' interest on the importance of creativity and innovation to problem-solving and to their future engineering professions.

Work limitations include the restricted number of responses, which hampered a more profound analysis that qualitatively guarantee statistical difference. The responses were also uneven, with several respondents for some semesters and few for others, which also interfered on a more deepened analysis semester-by-semester. Questionnaires were applied mostly at Federal University of Santa Catarina and surroundings, with the results more representative to this demographic population. A wider application of the questionnaire might reveal other facets of the Brazilian educational system. The analysis of the universities was based on international and national rankings, and subjects from each university were evaluated based on available online information.

## 6. ACKNOWLEDGEMENTS

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