# The Views of Engineering Students on Creativity


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**Abstract** Creativity plays a growing role in education, from elementary school to higher education. Nowadays, both employers and universities develop research and are committed to the development of the twenty-first-century interpersonal, applied skills—creativity included—foreseen as fundamental to all professionals, engineers added. Generally, engineering degrees focus on the content of their scientific areas. In some higher education degrees, creativity still plays a small role. In order to reinforce the importance of creativity in the engineering degrees in a Portuguese northeastern university, it was pertinent to study the conceptions of engineering students about creativity. This study presents the conceptions of creativity of the first-year students of higher education, in the engineering area in two school years. The answers of 128 first-year students from two academic years (61 from 2014/15

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and 67 from 2016/17) and four different degrees to the open question—"What is creativity?" were analyzed. It was a mixed study, qualitative to deepen students' conceptions and quantitative to study some proportions differences and variables crossing. The results show low personal involvement even in the use of the first person plural in either school year, although the students' most used sentence was "for me." In both academic years, students' definitions mentioned more the creation of the implicit category in the content analysis. The words "new" and "way" were common to all the word clouds produced, and creativity and innovation appear somehow connected. In general, proportion differences were not statistically significant and degree crossed with categories showed no dependency.

**Keywords** Mathematical · Creativity · Engineering education · Students Conceptions

## 1 Introduction

Currently, it gets increasingly difficult for teachers to motivate students and encourage the learning of several technical subjects important for their future. The use of different methodologies and learning contexts are essential to assist the teaching and learning process and to promote the development of creativity on students and future engineers.

Creativity is an essential ingredient in modern societies, but its definition is not simple. Today, the importance of creativity has been acknowledged, particularly in an educational context. We should motivate our students for learning the different subjects, developing their creativity, and promoting their academic success. Simultaneously, it is important that higher education keeps the pace with the engineers' labor market, in order to prepare everyone, society and people, for new changes fostering innovation and creativity.

Some researchers are focused on developing a clear concept of the terms creativity and innovation and investigate their possible relation with engineering education (e.g., [1–9]). However, in order to help promoting creativity in engineering education, we believe that it is essential to know which are the conceptions of creativity in engineering students. Therefore, to address the conceptions of creativity, we developed a study centered in an open-question survey presented to students of the first year of higher education in the engineering area, in two consecutive academic years. Stepping from the results, we reflected on how to enhance creativity in engineering education from different approaches in different subjects of the curricula.

## 2 Theoretical Framework

According to Morell [10], "Engineering education (…) plays a central role in our increasingly technology-based societies. The education of engineers must prepare them for the multidisciplinary nature of the problems they will face developing a new set of skills and competencies." Morell [10] also

> lists five things engineering education can do to better respond to society's needs: innovate, reform the engineering curriculum and the learning experience, focus on learning (not on teaching), foster creativity and innovation across the ecosystem, implement continuous assessment and accreditation to drive excellence and educate the engineering professor of the future.

More recently Sola [11, p. 11] recognized that

> Engineers are in the business of innovation, and creativity is the foundation of that business. With this foundation, engineers create the solutions needed to address the challenges of the world. To better understand the implications of creativity and innovation, we must first understand what these concepts truly encompass.

Today, in any profession, creativity must be taken into account, because only creative people can be different, boost their careers, innovate in their jobs, creating new things and solving problems. Then, one may question what creativity is for the future engineer.

### *2.1 What Is Creativity?*

It is difficult to find a consensual definition for "creativity." We understand that "Creativity is an essential ingredient of modern societies, associated with progress in the general welfare at the population level, since it may give answers to the present and future requirements." [12, p. 864].

Paul Torrance was a pioneer researcher on creativity, who dedicated "his life's work to study the nature of creativity and how it can be taught to students of all ages" ([12], p. 1). According to Torrance (1963, quoted by Stouffer et al. [13, p. 1]), creativity is "the process of sensing problems or gaps in information, forming ideas of hypotheses, testing, and modifying these hypotheses, and communicating the results. This process may lead to any one of many kinds of products—verbal and nonverbal, concrete and abstract."

Several other researchers gave definitions for creativity. For example, for Farid et al. [14], creativity is "the awareness, observation, imagination, conceptualization, and rearrangement of existing elements to generate new ideas." For Court [15, p. 141], "creativity may also be considered as a physical process that one must undertake to achieve a particular goal, as well as an individual quality that one naturally possesses." Several papers are devoted to creativity and different conceptions/definitions may be found (e.g., [3, 8, 16–18]). Klausen [18] attempted

to define and understand creativity, informed by the methods and debates of contemporary philosophy. Sometimes, creativity is associated with the art and literature [19], but actually, creativity is also associated with the science area. Starko [20] defined creativity as the development of ideas that are novel and appropriate.

Some authors offered other definitions of creativity, such as the one proposed by Vernon (quoted by Lai [21]), where creativity is "a phenomenon related to the ability to produce ideas (imagination), restructuring (innovation), discoveries (inventions), new and original artistic objects (creation and originality), and all these types of abilities are needed for thinking (thinking, therefore critical thinking)."

Some studies were developed with students in all levels of education to know their definitions of creativity (e.g., [22]). Using Vernon's definition, Catarino et al. [23] studied the conceptions of creativity of university students' in the first year of engineering subjects. The results showed that the students' definitions "were affected neither by gender nor by the original area of study and both genders and undergraduate course showed the predominance (mode) of grouped implicit categories (creation, imagination, and originality)."

In the current study, we extended Catarino et al. [23] work, adopting once more the Vernon's definition, for creativity.

## 2.2 *Is Creativity Important in the Performance of an Engineer?*

Cropley et al. [1, p. 211] state

> At the level of the individual engineer, considerations of the global marketplace and the creative skills regarded as essential for a successful career in engineering have also raised the issue of fostering creativity in engineering education.

Cropley et al. [1, p. 210] defend that "the most important characteristic of engineering creativity is to perform tasks or solve problems. In solving problems, any new and useful ideas could be potential solutions. The value of creativity could be helpful for solving problems, whereas one could also accept problem-solving as one kind of creativity."

According to Maiden et al. (2001 quoted by Dallman et al. [24]), creativity is viewed as a central part of requirements engineering (RE) and call for the recognition of the creativity importance on the RE process. Dallman et al. [24] revised the understandings of creativity in RE and suggested that further understanding of the nature and context of creativity is required to promote and encourage creative RE practices. The work of Nguyen and Shanks [25] also built a theoretical framework for understanding creativity in RE that included five elements: product, process, domain, people, and context. They defend that "RE researchers and practitioners need to recognize different creativity elements and integrate them

within RE approaches. Creativity elements should be applied at an appropriate situated level with a view to developing ICT[1] innovations for business" [25].

Some of the questions raised by Stouffer et al. [13] in 2004 remain unanswered today. One of them was "what is creativity and how can you teach it to engineering students?" Stouffer et al. [13, p. 1] examined "these questions to make the case that fostering creativity knowledge, skills, and attitudes is vital for the future of engineering and engineering education."

Systematic creative methods do exist to fill the lack of creativity in graduating engineers; one of them is the theory of inventive problem-solving (TRIZ), introduced by Ogot and Okudan [26] in the first year of a student's academic career in a required Introduction to Engineering Design course. This course "employs a design-driven curriculum with emphasis placed on skills such as teamwork, communication skills (graphical, oral, and written), computer-aided design and analysis tools" [26, p. 109]. The results showed that the first-year students adhered in a positive way to TRIZ as a creativity method.

The work of Badran [3] focused on developing a clear concept of the terms creativity and innovation, and investigate their possible relation with engineering education. He concludes his study stating that engineering education should introduce "relevant co-curricular multidisciplinary activities, engineering projects at all levels, early exposure to industry."

Other researchers studied the competencies required by engineers. For example, Male et al. [27] presented an Australian study on the generic competencies required by engineers. Their results indicated that both the non-technical, attitudinal and the technical competencies were perceived as important. Some examples of attitudes are commitment, honesty, self-motivation, demeanor, creativity, and concern for others. Also, two of the major competency factors identified as important to the work of engineers were "Creativity/Problem-solving" and "Innovation." In this study, the generic graduate attributes corresponding to "Creativity/Problem-solving" were "Ability to undertake problem identification, formulation, and solution; ability to utilize a systems approach to design; and operational performance" [27, p. 160].

Zhou [4] focused on the question of how engineering students perceive the strategy of integrating creativity training into a problem- and project-based learning curriculum. Results showed that the training program was thought useful and students got benefits such as gaining project work skills, creative concepts, and confidence in being creative.

Ibrahim [28], who explored the relationships among creativity, engineering knowledge, and team interaction on senior engineering design product outcomes, stated that "A better understanding on the interaction of these three constructs would help engineering educators to design and establish a better curriculum for our future engineering student candidates" [28, p. 180].

[1]Information and communications technology.

Fostering creativity in the engineering classroom had also lead to more successful students and better student-professor interactions. For Cropley [8, p. 155], "[c]reativity is a fundamental element of engineering", and "of special importance is embedding creativity in engineering education". In Cropley's [8, p. 160] opinion, "two basic components are needed by engineers entering the field of creativity to answer the question what is creativity?" The first component was clearly described by Plucker et al. [29]—"[c]reativity is the interaction among aptitude, process and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (p. 90)—while the second component is characterized by the 4Ps: "Person, Product, Process and Press (environment)" [8, p. 161].

For Charyton [30, p. 135], "a creative act needs acceptance of an idea, product, or process by the field, such as engineering, and the domain, such as science or Science, Technology, Engineering and Mathematics (STEM). Today's engineers must be creative and innovative. The problems faced by engineers today request original thinking. To remain competitive globally, engineering firms rely on creative individuals and creative teams to develop new products for innovation."

According to Cropley [8, p. 161] "creativity in engineering is concerned with solving problems; however, the solutions engineers devise do not emerge in a single step. Engineers understand that there is a sequence of stages that is followed starting with the recognition that there is a problem to be solved, and followed by the determination of possible ways of solving that problem, narrowing these down to one, or a few, probable solutions, before selecting the best option for development and implementation. Creativity in engineering is embedded across this sequence of stages"

The "problem-solving" is an important technique that should be implemented in all subjects within any engineering curricula. Karataş et al. [31] on the views of the nature of engineering and their implications for engineering degrees noticed that the students in their study held tacit beliefs that engineering is a form of applied science, but our emphasis goes what they stated as it involves problem-solving and design of artefacts or systems subject, and also referred that teamwork is needed.

Recently, the empirical study presented by Martín-Erro et al. [32], with engineering students and professors, rejects the first idea reported in the literature that "creativity is not valued into engineering educational environment, which shows an evolution on engineering student's opinions," That study revealed efforts made by professors in teaching according to creative approaches, such as the project-based learning and open problems, which confirm their interest on enhancing creativity. The majority of the participants (95%)—professors and students—agreed that creativity is important for engineering; 92% of the professors also agreed that is more important to stimulate creativity through the practice than by teaching creative techniques.

In the opinion of Sola [11] "[c]reativity and critical thinking are essential tools for engineers. Without them, engineers may face challenges that they are ill-prepared to solve. By better understanding the various aspects of creativity and critical thinking, (…) engineers can improve their problem-solving performance.

This is not only beneficial for these individuals, but is bound to also provide benefits to everyone through their resulting ground-breaking discoveries and solutions" [32, p. 127].

In summary, we may say that both employers and universities have been researching and committed with the development of the twenty-first-century interpersonal, applied skills—creativity included—required to all professionals, but specifically to engineers. As written by Kivunja [33], "the 4Cs of critical thinking and problem solving, communication, collaboration, and creativity plus innovation, [are] the super skills in the 21st century because they are foundational essentials for success in college, university, career, and life outside educational institutions."

In line with this framework, this study focused on the conceptions of creativity held by first-year students of higher education collected during two academic years (2014/2015 and 2016/2017), considering different genders and undergraduate courses. The creativity remains unquantifiable (e.g., [34, 35]). With this aim, we decide to do an exploratory study based on these first-year undergraduates' conceptions about "creativity," following the Vernon categories (Vernon, 1989, quoted by Lai [21]).

## 3 Research Methodology

### *3.1 Research Participants*

An online survey on Google Drive (GD) was made available to a group of first-year engineering students from a northeastern Portuguese university that enrolled a Linear Algebra (LA) course. In 2014/2015, a total of 61 students from four degrees participated in the survey (Table 1): Biomedical Engineering (Biomedical Eng., 27.9%; $n = 17$); Bioengineering (Bioeng., 19.7%; $n = 12$); Mechanical Engineering (Mechanical Eng., 37.7%; $n = 23$); and Energy Engineering (Energy Eng., 14.8%; $n = 9$). Men were the mode (41 men, 67.0%, vs. 20 women, 33.0%). Men were the mode (41 men, 67.2%, and 20 women, 32.8%). The participants' ages ranged between 17 and 25 years old, although women were younger, ages ranged between 17 and 19 years old.

In 2016/2017, a total of 67 students from four degrees participated in the survey (Table 1): Biomedical Eng. (26.9%); Bioeng. (20.9%); Mechanical Eng., 27 students, 40.3%; one woman, 3.7%, 96.3% men); and Integrated Master's in Industrial Management and Engineering (MIEGI, 11.9%). Men were also the mode (29 women, 43.3% and 38 men, 56.7%). The age of participants ranged between 17 and 26 years old; also, in this academic year, the women were younger, presenting the same age range as in the previous year.

**Table 1** A simple overview of the dimension and hierarchy levels related to engineering schools

| School year | Degree | Female (%) | Male (%) | Total (%) |
|---|---|---|---|---|
| 2014/2015 | Biomedical Eng. | 58 | 42 | 17 (27.9) |
| | Bioeng. | 67 | 33 | 12 (19.7) |
| | Mechanical Eng. | 4 | 96 | 23 (37.7) |
| | Energy Eng. | 11 | 89 | 9 (14.8) |
| 2016/2017 | Biomedical Eng. | 88.9 | 11.1 | 18 (26.9) |
| | Bioeng. | 64.3 | 35.7 | 14 (20.9) |
| | Mechanical Eng. | 3.7 | 96.3 | 27 (40.3) |
| | MIEGI | 37.5 | 62.5 | 8 (11.9) |

## *3.2 Data Collection and Analysis' Steps*

The survey's participants in either academic year shared the same LA teacher; some students had two or three registrations in the LA course. To compare the results with data issue from Catarino et al. [23] study, the same methodology of content analysis was followed. The content analysis disclosed groups of words in the students' texts respecting their understanding of creativity; thereby, the categories derived from the raw data in each student text as well as creativity definitions [23, 36]. The survey asked the students to answer by their own words to the question "What do you understand by creativity?" besides recording also their gender and their age. The questionnaire had to be answered in the last 15 min of a LA class, in the first semester of the academic years 2014/2015 and 2016/2017. It is important to say that no creativity definitions were given to the students and they had to write it individually.

A mixed study was implemented, qualitative to deepen students' conceptions on creativity and quantitative to study the differences between some proportions and variables crossing [36]. As qualitative methods, content analysis and words clouds were used. The students' answers (128 in total, 61 in 2014/2015, and 67 in 2016/2017) were categorized in order to describe their understanding of creativity. Two of the authors did the categorization for each answer inductively based on all of the written text: words and sentences. After that, the other authors confirmed the categorization and the subcategories were established. Each answer was included in a subcategory. Finally, due to the amount of subcategories, the authors agreed to reduce them to broader categories. Therefore, this content analysis was applied "to the manifested content that is to words, paragraphs, and sentences written, and we established the content analysis categories" [23, 37], which was students' written understanding of creativity. We read all the 128 texts word-by-word and derived codes by highlighting their important meanings, and all of them were considered anonymously. Next, we analyzed the personal involvement of the students, as in Maksić and Pavlović [38]. Finally, we adopted the same categories for creativity that emerged in Catarino et al. [23], namely "implicit" (creation, imagination, and originality) and "explicit" (innovation, inventions, and thinking). The content

analyses were performed directly in a spreadsheet, since it was the original format downloaded from GD. Schematically, the students' definitions are given using a word cloud, where "words are arranged artistically in close proximity and the size of each word's type is proportional to the word's frequency or to the size of a numeric variable associated with the word" [39].

The quantitative analysis used counting, percentages, tables, graphs, and crossed tables in IBM-SPSS version 24. Collected data were tested for differences between the categories proportions ($p$ value < 0.05, the proportions were considered different) for either the total sample (all the 128 students) or the academic year (61 students in 2014/205 and 67 students in 2017/2016). Each subset of variable versus categories was tested for independence ($p$ value < 0.05, the variables were dependent).

## 4 Data Analysis and Discussion

Like in Maksić et al. [38], the study began with the analysis of the existence and categorization of the personal involvement established in definitions of creativity of the students. Next, the implicit and explicit Vernon categories [21] were analyzed crossing the results with gender and degrees, and finally, we build and analyze the words clouds. In each section, we present tables with examples of categories options in Portuguese followed by the translation into English.

### *4.1 Personal Involvement in the Creativity Definitions*

Most students answered the survey with sentences or paragraphs. Some words and sentences used by the students were such as "for me "I believe that," "in my opinion," "in my view," "from my perspective," "I understand that," "I consider that" (Tables 2 and 3). Involving us all, we also considered the use of the first person plural (Table 3). The text of the students also may be considered a writing style artifact, but they reflect the view of the student and their way of writing about it. In order to explain the categories in this section, a single example of the expressions implying the students' personal involvement in their creativity definitions is presented both in English (translation) as in Portuguese (original sentence, Tables 2 and 3).

In Table 4, we listed the students' definitions denoting personal involvement, which were used by 17 of 61 students (28%) in 2014/2015 and 24 of 67 students (36%) in 2016/2017. The use of the first person plural was another group considered: 4 of 61 students (7%) in 2014/2015, and 3 of 67 students (4%) in 2016/2017. In both academic years, 40 students provided non-personal definitions, representing 65% of the students in 2014/2015 (40 of 61 students) and 60% in 2016/2017 (40 of 67 students); but no differences were found between the two years ($p$ = 0.56). In the

**Table 2** Words and sentences implying personal involvement of the students

| | 2014/2015 | | 2016/2017 | |
|---|---|---|---|---|
| Words and sentences | Example of participants' answers | Original sentence in Portuguese | Example of participants' answers | Original sentence in Portuguese |
| "*for me*" | To me, creativity is a person's ability to have new ideas, different, interesting, to have the power to change the world and to be useful to us in our day-to-day | Para mim a criatividade é a capacidade de uma pessoa ter ideias novas, diferentes, interessantes, capaz de poder revolucionar o mundo e de ser-nos útil no nosso dia-a-dia | To me, creativity is to be able to create new things, to imagine beyond the possible and to try to make it come true. A way to face everyday life in a different way, a way to create change, one of the ways to see beauty in smaller things | Para mim a criatividade é ser capaz de criar coisas novas, imaginar para lá do possível e tentar torná-lo realidade. Uma maneira de olhar para o quotidiano de outra forma, uma maneira de criar a mudança, uma das maneiras de ver a beleza nas coisas mais pequenas |
| "*I believe that*" | I believe that creativity grows with the experience and practice of new ideas | Acredito que a criatividade cresce com a experiência e com a prática de novas ideias | – | – |
| "*in my opinion*" | In my opinion, creativity is when, thinking at any theme, a number of ideas arise about how to do something fun and complete, full of imagination! | Na minha opinião a criatividade é quando, ao pensar num tema qualquer, nos surgem diversas ideias sobre como fazer algo divertido e completo, cheio de imaginação! | In my opinion, creativity is a tool that fewer and fewer people have. Another way to look at all-day life, a way to create change, one of the ways to see beauty in smaller things | Na minha opinião, criatividade é uma ferramenta, que cada vez mais menos pessoas a possuem. Uma maneira de olhar para o quotidiano de outra forma, uma maneira de criar a mudança, uma das maneiras de ver a beleza nas coisas mais pequenas |
| "*in my view*" | In my view, creativity is to achieve what has not been achieved by any other person | A meu ver, criatividade consiste em alcançar o que ainda não foi alcançado por qualquer outra pessoa | In my view, creativity is the art of imagining far away, is having the ability to create something new… | No meu ponto de vista a criatividade é arte de imaginar mais além, é ter a capacidade de criar algo novo… |

**Table 3** Words and sentences implying personal involvement of the students (conclusion)

| | 2014/2015 | | 2016/2017 | |
|---|---|---|---|---|
| Words and sentences | Example of participants' answers | Original sentence in Portuguese | Example of participants' answers | Original sentence in Portuguese |
| "*from my perspective*" | Creativity, from my perspective, is something that allows us to innovate, something that makes us different from others, because when we are creative, we do things different from others | A criatividade, na minha perspetiva, é algo que nos permite inovar, algo que nos torna diferente dos outros, porque ao sermos criativos, fazemos coisas diferentes dos outros | – | – |
| "*I understand that*" | I understand that creativity is to be original and think differently from others. Think by his own head and be able to see that nobody saw | Entendo que criatividade é ser original e pensar de forma diferente dos outros. Pensar pela sua própria cabeça e ser capaz de ver o que ainda ninguém viu | – | – |
| "*I consider that*" | I also consider that creativity exists in all the people and in all the situations, because when several people have something to do, none of them do those things the same way as others, so we are all creative, and thanks to this creativity is we are to evolve scientifically, because creativity is the greatest tool of science, art, is "out for adventure" | Considero também, que a criatividade existe em todas as pessoas e em todas as situações, visto que quando várias pessoas têm algo para fazer, nenhuma destas pessoas faz essas coisas igual as outras, por isso todos nós somos criativos, e graças a essa criatividade é que estamos a evoluir cientificamente, pois a criatividade é a maior ferramenta da ciência, da arte, é o "sair para a aventura" | – | – |

(continued)

**Table 3** (continued)

| | 2014/2015 | | 2016/2017 | |
|---|---|---|---|---|
| Words and sentences | Example of participants' answers | Original sentence in Portuguese | Example of participants' answers | Original sentence in Portuguese |
| Use of the first person plural | Creativity is our ability to innovate and create new ideas and/or products | Criatividade é a capacidade que possuímos de inovar e criar ideias e/ou produtos novos | Creativity is the way we apply our skills in a creative process, the ease with which we solve or create something instantly and well | Criatividade é a forma como aplicamos as nossas aptidões num processo criativo, a facilidade com que se resolve ou se cria algo de forma instantânea e bem conseguida |

**Table 4** Words and sentences implying personal involvement of the students in their conceptions of creativity

| Words and sentences | Number of references (%) | |
|---|---|---|
| | 2014/2015 | 2016/2017 |
| "for me" | 8 (38.0) | 21 (77.0) |
| "I believe that" | 1 (4.8) | – |
| "in my opinion" | 3 (14.3) | 2 (8.0) |
| "in my view" | 1 (4.8) | 1 (4.0) |
| "from my perspective" | 1 (4.8) | – |
| "I understand that" | 2 (9.5) | – |
| "I consider that" | 1 (4.8) | – |
| Use of the first person plural | 4 (19.0) | 3 (11.0) |
| Total | 21 (100) | 27 (100) |

category of personal involvement, the sentence most used by students was "for me" with a bigger weight in 2016/2017 (77% vs. 38% in 2014/2015).

As in Maksić and Pavlović [38], we also observed that students frequently use relatively low levels of personal involvement in their creativity concepts. Nevertheless, in 2016/2017, the percentage of students using expressions with personal involvement was higher than in 2014/2015 ($p < 0.001$).

## *4.2 Outlook of Students' Creativity Definitions*

A single example retrieved from the student's sentences following the Vernon's creativity definition is presented in Tables 5 and 6 for each of the considered categories, in both the English translation and the Portuguese original words or sentences.

**Table 5** Words and sentences with examples of the students' definitions about creativity implicit categories by school year

| Groups | Categories | 2014/2015 | | 2016/2017 | |
|---|---|---|---|---|---|
| | | Example of part of an answer | Original sentence in Portuguese | Example of part of an answer | Original sentence in Portuguese |
| Implicit | Creation | Creativity is the ability to create | Criatividade é a capacidade de criar | Creativity is the ability to accomplish something in several possible and different ways | Criatividade é a capacidade de realizar algo de várias maneiras possíveis e diferentes |
| | Imagination | It is also a "way" to practice our imagination | É ainda uma "forma" de pôr em prática a nossa imaginação | Creativity is the ability to imagine something new, or existing in its own way. To be able to pick up an object and change it so that it has something of itself | A criatividade é a capacidade de imaginar algo novo, ou existente à sua maneira. Poder pegar num objeto e alterá-lo, de forma a ficar com algo de si mesmo |
| | Originality | To be original | Ser original | Creativity is an original way of facing obstacles and overcoming them in a different way. It is an unusual form of thinking and a way of being active… because nowadays we have to excel by originality | Criatividade é uma forma original de encarar os obstáculos e ultrapassa-los de forma diferente. É uma forma invulgar de pensar e uma maneira de estarmos ativos na sociedade em que vivemos, pois hoje em dia temos de primar pela originalidade |

Table 7 presents the counting for the categories and subcategories contained on Vernon creativity definition [21]. In each academic year, the mode in the implicit categories was creation (2014/2015: 27%; 2016/2017: 29%). In addition, in both

**Table 6** Words and sentences with examples of the students' definitions about creativity explicit and others categories by school year

| Groups | Categories | 2014/2015 | | 2016/2017 | |
|---|---|---|---|---|---|
| | | Example of part of an answer | Original sentence in Portuguese | Example of part of an answer | Original sentence in Portuguese |
| Explicit | Innovation | Creativity or to be creative, is the ability to innovate, to do something that does not exist or change a reality and give it a new use | Criatividade ou ser criativo, é a capacidade de inovar, fazer algo que não existe ou alterar uma realidade e dar-lhe uma nova utilidade | Creativity is the ability to create new things, to innovate, to go further, to think of something that no one had ever thought [before] | A criatividade é a capacidade criar coisas novas, de inovar, de chegar mais longe, pensar em algo que nunca ninguém tinha pensado |
| | Inventions | Creativity is the creation of a new and different solution/idea to solve a given problem, that is, "invent" something that can effectively solve our obstacle | Criatividade é a criação de uma nova e diferente solução/ideia para resolver determinado problema, isto é, "inventar" algo que possa eficazmente solucionar o nosso obstáculo | Ability to invent something new, using the imagination | Capacidade de inventar algo novo, recorrendo à imaginação |
| | Thinking | Creativity is the ability that one has to put what it is, feels, thinks and argues in everything we do, so that the end result also shows what the person is | A criatividade é a capacidade que cada um tem de pôr aquilo que é, sente, pensa e defende em tudo aquilo que faz, de forma a que o resultado final mostre, também, aquilo que a pessoa é | Creativity to me is the inventiveness that we all have inside our head, from which we can develop ideas that can become something important or not for society | Criatividade, para mim, é um engenho que temos todos dentro da cabeça, a partir do qual podemos desenvolver ideias que se podem tornar algo importante ou não para a sociedade |
| Others | | Creativity is almost like a gift | A criatividade é quase como um dom | It is the ability to wander in a world with a variable dimension depending on the rational understanding of each one | É a capacidade de divagar num mundo com dimensão variável dependendo da compreensão racional de cada um |

**Table 7** Words and sentences according to Vernon's definition of creativity

| Groups | Categories | Number of references | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2014/2015 | | | 2016/2017 | | |
| | | Female | Male | Totals (%) | Female | Male | Totals (%) |
| Implicit | Creation | 10 | 21 | 31 (27) | 8 | 12 | 20 (29.0) |
| | Imagination | 7 | 6 | 13 (11) | 3 | 2 | 5 (7.2) |
| | Originality | 9 | 15 | 24 (21) | 1 | 6 | 7 (10.1) |
| Explicit | Innovation | 8 | 14 | 22 (19) | 11 | 9 | 20 (29.0) |
| | Inventions | 6 | 5 | 11 (10) | 3 | 2 | 5 (7.2) |
| | Thinking | 1 | 1 | 2 (1) | 3 | 7 | 10 (14.5) |
| Others | | 1 | 12 | 13 (11) | 0 | 2 | 2 (3.0) |
| Total (%) | | 42 (36) | 74 (64) | 116 (100) | 29 (42) | 40 (58) | 69 (100) |

academic years in the explicit categories, the mode was innovation (2014/2015: 19%; 2016/2017: 29%). However, in neither case, the proportion differences had statistical significance ($p = 0.56$ and $p = 0.13$ for the implicit and explicit categories, respectively). The percentages of the categories by gender are presented in Table 7.

The students' definitions of creativity were independent from gender in either academic year (2014/2015: chi-squared = 0.21, $p = 0.65$; 2016/2017: chi-squared = 0.86, p = 0.36).

The implicit grouped categories were predominant (mode) in both genders in 2014/2015, Fig. 1 (left). Curiously, in 2016/2017, the mode was the implicit grouped categories for men, while for female, the mode was the explicit grouped categories, Fig. 1 (right).

Even though devoid of statistical significance, differences were observed in the way that men and women value some attributes within creativity categories. Within the implicit categories, male undergraduates valued less the imagination attributes than female counterparts (2014/2015: 8.1% vs. 16.7%, $p = 0.05$; 2016/2017: 5% vs. 10%, $p = 0.45$). Within the explicit categories, the term inventions was used less

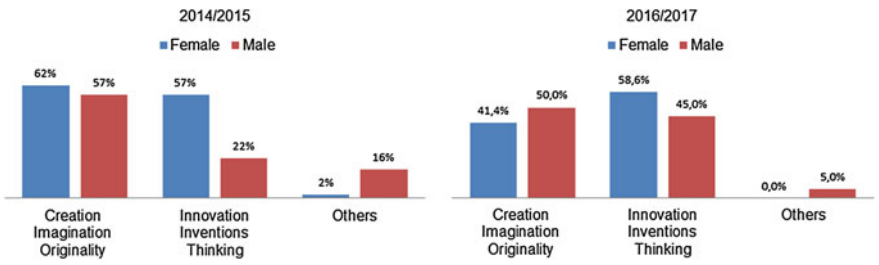


**Fig. 1** Grouped categories by gender and by academic year

frequently by males than females (2014/2015: 6.8% vs. 14.3%, $p = 0.056$; 2016/2017: 5% vs. 10%, $p = 0.45$). Interestingly, statistical differences were found in the use of terms not included on Vernon's based categories—named as "others"—which was more frequent in male undergraduates' students than in female's, but only in 2014/2015 (2014/2015: 16.2% vs. 2.4%, $p = 0.011$; 2016/2017: 5% vs. 0%, p = 0.148).

For the word clouds, the same methodology as for the counting and graphs was used: by gender and by degree. Figure 2 presents the word cloud representing the female students' definitions according to the academic year. In 2014/2015, the word "way" stood out followed by "ideas," "imagination," and "original" while with a lower emphasis appeared words like "different" and "thinking." In 2016/2017, the word "new" stood out, followed by "different," "things," "way" and "ideas" and "innovate." Despite differently sized and colored in the images, "way" and "new" were common in both school years.

In line with several authors (e.g., [3, 11, 30, 33]), the female students' definitions of creativity mentioned innovation (or a similar word); its inclusion was more frequent in 2016/2017 than in 2014/15.

Figure 3 presents the word cloud for the male students' definitions of creativity by academic year. The word "new" stands out in both images followed by "way," "ideas" and "original," and finally "person" in both years; with a lower emphasis appear the words "think," "imagination," and "innovative." Curiously, despite the differences in the colors and location within the image, the word clouds for male students highlights the same words, and as occurring in females (Fig. 2), "way" and "new" are common to both academic years.

Once again, as stressed by several authors (e.g., [3, 11, 30, 33]), these students' definitions of creativity mentioned the term innovation (or a similar word).

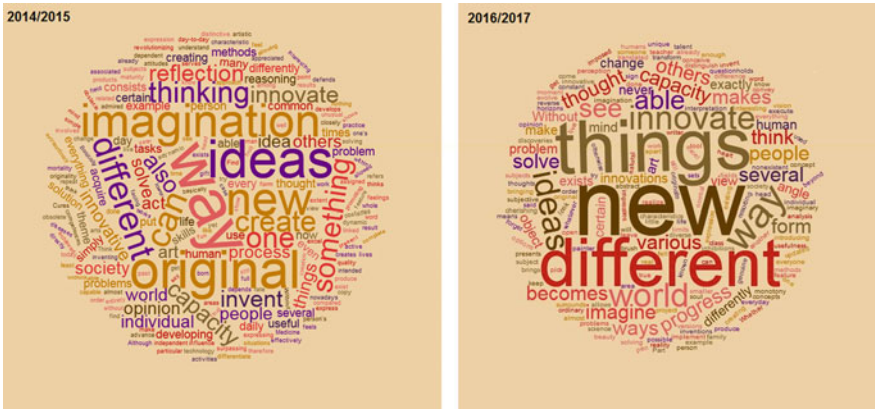


**Fig. 2** Word clouds for female students by academic year


**Fig. 3** Word clouds for male students by school year

Table 8 summarizes the results for the creativity definitions according to the students' degree. The two categories (implicit and explicit) were independent from the students' courses (chi-squared = 1.8, $p = 0.61$, 2014/2015; chi-squared = 0.37, $p = 0.54$, 2016/2017).

Figure 4 shows the predominance of the implicit grouped categories in all the degrees in 2014/2015 and in 20167207, except for the few students of MIEGI that favored the explicit grouped categories. Distribution in the Bioengineering students' definitions about creativity was uniform among the three groups analyzed in 2014/2015, but in 2016/2017 with fewer students, the distribution is irregular. Those students referred to imagination more often in 2014/2015 (18.4%), but did not refer it at all in 2016/2017. Regarding invention, 13.1% of the Bioengineering students mentioned it more frequently than in the other undergraduates' courses in 2014/2015, while in 2016/2017, this same category had very few references. Only the Biomedical Engineering students mentioned the thinking category in 2014/2015; in 2016/2017, only MIEGI students failed to refer it.

The word clouds were only built for the groups of Bioengineering and Biomedical Engineering together in both academic years and for Mechanical Engineering in both school years.

The word clouds issued from the definitions of creativity by the Bioengineering and Biomedical Engineering students taken together by academic year are presented in Fig. 5. In both years, the word "new" popped up, in 2014/2015 followed by "different" and in 2016/2017 by "ideas." Next, the word "way" appeared followed by different words in 2014/2015 "things," "ideas," and "unique" and in 2016/2017 "innovative," "imagination," and "original" and with a lower emphasis appear the words "different" and "thinking." Despite being differently colored, "way" and "new" are common to the definitions in both academic years, supporting the mentioned by some (e.g., [3, 11, 30, 33]) respecting the close association of innovation (or a similar word) to creativity in definitions, particularly for the texts collected in 2016/2017.

**Table 8** Global results for the students' definitions of creativity according to their degree and academic year

| Groups | Categories | | 2014/2015 | | |
|---|---|---|---|---|---|
| | | Bioeng. [Biomedical Eng.] | Mechanical Eng. | Energy Eng. | Totals (%) |
| Implicit | Creation | 8 [4] | 12 | 7 | 31 (27) |
| | Imagination | 7 [2] | 3 | 1 | 13 (11) |
| | Originality | 7 [5] | 9 | 3 | 24 (21) |
| Explicit | Innovation | 7 [6] | 6 | 3 | 22 (19) |
| | Inventions | 5 [6] | 3 | 2 | 11 (9) |
| | Thinking | 0 [6] | 0 | 0 | 2 (2) |
| Others | | 4 [6] | 7 | 0 | 13 (11) |
| Totals (%) | | 38 (33) [22 (19)] | 40 (34) | 16 (14) | 116(100) |

| Groups | Categories | | 2016/2017 | | |
|---|---|---|---|---|---|
| | | Bioeng. [Biomedical Eng.] | Mechanical Eng. [Energy Eng.] | MIEGI | Totals (%) |
| Implicit | Creation | 5 [5] | 7 | 3 | 20 (29) |
| | Imagination | 0 [3] | 2 | 0 | 5 (7) |
| | Originality | 3 [1] | 3 | 0 | 7 (10) |
| Explicit | Innovation | 2 [6] | 10 | 2 | 20 (29) |
| | Inventions | 1 [2] | 0 | 2 | 5 (7) |
| | Thinking | 4 [1] | 5 | 0 | 10 (15) |
| Others | | | 1 [0] | 0 | 2 (3) |
| Totals (%) | | | 16 (23) [18 (26)] | 27 (39) | 69(100) |

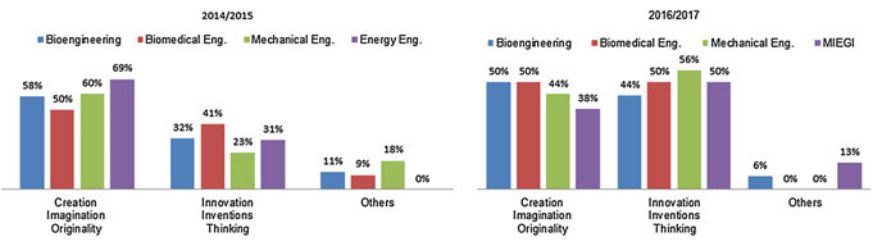


**Fig. 4** Grouped categories by degree and academic year


**Fig. 5** Word clouds for Bioengineering and Biomedical Engineering students by academic year

The word clouds for the Mechanical Engineering students by school year are sketched in Fig. 6. In both school years, the word "new" also popped up, in 2014/2015, followed by "way" and in 2016/2017 by "things." In both academic years, the word "way" emerged (bigger in 2014/2015) and different words follow it. In 2014/2015, "person," "ideas," and "original, and in 2016/2017, "person," "imagine," and "capacity," and with a lower emphasis the words "different" and "thinking" appeared. Once again, despite the size and the colors, "way" and "new" are common in both school years.


**Fig. 6** Word clouds for Mechanical Engineering students by school year

## 5 Final Considerations

Like the report by Maksić and Pavlović [38], few students used the personal involvement in their definitions of creativity. Conversely, we also found definitions that used the first person plural, giving the idea that creativity is a skill common to most people, but these were also more sporadic.

In the present study, the exploratory analysis of students' definitions, based on the grouped categories proposed in Vernon's definition, showed that students' definitions were not affected neither by gender nor by the original study field; it was also evidenced that both the genders and degree have the predominance (mode) of grouped implicit categories (creation, imagination, and originality) in 2014/2015. The same occurred in 2016/2017; an exception was the few MIEGI students who showed predominance (mode) of grouped explicit categories (innovation, inventions, and thinking).

The use of word clouds highlighted the focus put by students on words like "new" and "way" in their definitions of creativity. The tendency to connect creativity with the innovation (or a similar word) mentioned by some authors (e.g., [3, 11, 30, 33]) was further evidenced in the word clouds, namely on those representing the gender and the Bioengineering and Biomedical Engineering degrees. Other words less weighted—such as "thinking," "ideas," "imagination," "unique"—were mentioned in the students' definitions, as it was also referred by some authors (e.g., [14, 21]) in their texts about creativity.

Although this was an exploratory mixed study, it was interesting to note that in the students' definitions of creativity some of the literature mentions also arose.

The crossing of variables failed to evidence the existence of dependencies between variables, which suggests that either none existed because the students answered an open question without previous talking about creativity in classes or that the sampling of definitions analyzed was still in small number. So, further studies using the same methodology should be continued in future.

Starting with the students' definitions, we should be able to engage students in learning strategies or activities that may be perceived by them as empowering or encouraging creativity skills. Since in the profession, engineers' creativity is often challenged when facing problems, the use of problem-solving or project-based learning (e.g., [8, 31]) would foster students' confidence by training their openness to recognize different level of problems and by triggering their curiosity for new approaches toward common problems, and challenging their ability to propose and select the most suitable solution. We should work with our students as engineers!

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## References


1. Cropley DH, Cropley AJ (2000) Fostering creativity in engineering undergraduates. High Ability Stud 11(2):207–219. https://doi.org/10.1080/13598130020001223
2. Christiaans H, Venselaar K (2005) Creativity in design engineering and the role of knowledge: modelling the expert. Int J Technol Des Educ 15(3):217–236. https://doi.org/10.1007/s10798-004-1904-4
3. Badran I (2007) Enhancing creativity and innovation in engineering education. Eur J Eng Educ 32(5):573–585. https://doi.org/10.1080/03043790701433061
4. Zhou C (2012) Integrating creativity training into problem and project-based learning curriculum in engineering education. Eur J Eng Educ 37(5):488–499. https://doi.org/10.1080/03043797.2012.714357
5. Zhou C (2012) Fostering creative engineers: a key to face the complexity of engineering practice. Eur J Eng Educ 37(4):343–353. https://doi.org/10.1080/03043797.2012.691872
6. Walsh E, Anders K, Hancock S, Elvidge L (2013) Reclaiming creativity in the era of impact: exploring ideas about creative research in science and engineering. Stud High Educ 38 (9):1259–1273. https://doi.org/10.1080/03075079.2011.620091
7. Cropley DH (2015) Promoting creativity and innovation in engineering education. Psychol Aesthet Creat Arts 9(2):161–171. https://doi.org/10.1037/aca0000008
8. Cropley DH (2015) Creativity in engineering. In: Corazza GE, Agnoli S (eds) Multidisciplinary contributions to the science of creative thinking. Springer, London, pp 155–173
9. Kazerounian K, Foley S (2007) Barriers to creativity in engineering education: a study of instructors and students perceptions. J Mech Des 129(7):761–768. https://doi.org/10.1115/1.2739569
10. Morell L (2010) Engineering education in the 21st century: roles, opportunities and challenges. Int J Technol Engineering Educ 7(2):1
11. Sola E (2016) An experimental investigation of the state of creativity, critical thinking and creativity training in undergraduate engineering students. Dissertation, University of Central Florida
12. Cardoso AP, Malheiro R, Rodrigues P, Felizardo S, Lopes A (2015) Assessment and creativity stimulus in school context. Procedia-Soc Behav Sci 171:864–873. https://doi.org/10.1016/j.sbspro.2015.01.202
13. Stouffer WB, Russell JS, Oliva MG (2004) Making the strange familiar: creativity and the future of engineering education. In: Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, USA, 20–23 June 2004
14. Farid F, El-Sharkawy AR, Austin LK (1993) Managing for creativity and innovation in A/E/C organizations. J Manag Eng 9(4):399–409. https://doi.org/10.1061/(ASCE)9742-597X(1993)9:4(399)
15. Court AW (1998) Improving creativity in engineering design education. Eur J Eng Educ 23 (2):141–154. https://doi.org/10.1080/03043799808923493
16. Morrison A, Johnston B (2003) Personal creativity for entrepreneurship: teaching and learning strategies. Act Learn High Educ 4(2):145–158. https://doi.org/10.1177/1469787403004200 3
17. Runco MA, Jaeger GJ (2012) The standard definition of creativity. Creat Res J 24(1):92–96. https://doi.org/10.1080/10400419.2012.650092
18. Klausen SH (2010) The notion of creativity revisited: a philosophical perspective on creativity research. Creat Res J 22(4):347–360. https://doi.org/10.1080/10400419.2010.523390

19. Nadjafikhah M, Yaftian N, Bakhshalizadeh S (2012) Mathematical creativity: some definitions and characteristics. Procedia-Soc Behav Sci 31:285–291. https://doi.org/10.1016/j.sbspro.2011.12.056
20. Starko AJ (2005) Creativity in the classroom: schools of curious delight. Routledge, New
21. Lai ER (2011) Critical thinking: a literature review. Pearson's Res R 6. http://images.pearsonassessments.com/images/tmrs/CriticalThinkingReviewFINAL.pdf Accessed 15 Jun 2016
22. Gilat T, Amit M (2013) Exploring young students creativity: the effect of model eliciting activities, PNA 8(2): 51–59. http://hdl.handle.net/10481/29578
23. Catarino P, Nascimento MM, Morais E, Silva H, Payan-Carreira R (2016) Take this waltz on creativity: the engineering students' conceptions. In: Proceedings of the 2nd international conference of the Portuguese Society for engineering, IEEE Conference Publications, Vila Real 20–21 Oct 2016
24. Dallman S, Nguyen L, Lamp J, Cybulski J (2005) Contextual factors which influence creativity in requirements engineering. In: Proceedings of the 13th European conference on information systems, information systems in a rapidly changing economy, Regensburg, Germany, 26–28 May 2005
25. Nguyen L, Shanks G (2009) A framework for understanding creativity in requirements engineering. Inf Softw Technol 51(3):655–662. https://doi.org/10.1016/j.infsof.2008.09.002
26. Ogot M, Okudan GE (2006) Integrating systematic creativity into first-year engineering design curriculum. Int J Eng Educ 22(1):109–115
27. Male SA, Bush MB, Chapman ES (2011) An Australian study of generic competencies required by engineers. Eur J Eng Educ 36(2):151–163. https://doi.org/10.1080/03043797.2011.569703
28. Ibrahim B (2012) Exploring the relationships among creativity, engineering knowledge, and design team interaction on senior engineering design projects. Dissertation, Colorado State University
29. Plucker JA, Beghetto RA, Dow GT (2004) Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. Educ Psychol 39(2):83–96. https://doi.org/10.1207/s15326985ep3902_1
30. Charyton C (2015) Creative engineering design: the meaning of creativity and innovation in engineering. In: Charyton C (ed) Creativity and innovation among science and art. Springer, London, pp 135–152
31. Karataş FÖ, Bodner GM, Unal S (2016) First-year engineering students' views of the nature of engineering: implications for engineering programmes. Eur J Eng Educ 41(1):1–22. https://doi.org/10.1080/03043797.2014.1001821
32. Martín-Erro MA, Espinosa MM, Domínguez M (2016) Creativity and engineering education: a survey of approaches and current state. In: Proceedings of the 9th International Conference of Education, Research and Innovation, Seville, Spain 14–16 Nov 2016
33. Kivunja C (2015) Exploring the pedagogical meaning and implications of the 4Cs "super skills" for the 21st century through Bruner's 5E lenses of knowledge construction to improve pedagogies of the new learning paradigm. Creat Educ 6(02):224–239. https://doi.org/10.4236/ce.2015.62021
34. Bleakley A (2004) 'Your creativity or mine?': a typology of creativities in higher education and the value of a pluralistic approach. Teach Higher Educ 9(4):463–475. https://doi.org/10.1080/1356251042000252390
35. Ivcevic Z, Mayer JD (2009) Mapping dimensions of creativity in the life-space. Creat Res J 21(2–3):152–165. https://doi.org/10.1080/10400410902855259
36. Cohen L, Manion L, Morrison K (2013) Research methods in education. Routledge, New York
37. Krippendorff K (2004) Content analysis: an introduction to its methodology. Sage, Thousand Oaks

38. Maksić S, Pavlović J (2011) Educational researchers' personal explicit theories on creativity and its development: a qualitative study. High Ability Stud 22(2):219–231. https://doi.org/10.1080/13598139.2011.628850
39. American Heritage Dictionary of the English Language (2016) (5th Ed.). Houghton Mifflin Harcourt Publishing Company. http://www.thefreedictionary.com/word+cloud Accessed 15 June 2016

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