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SELF ORGANIZING MAPS (SOM) AND STATISTICAL METHODS FOR DESCRIBING THE PHYSICOLOGICAL PROFILE OF UNDERGRADUATES STUDENTS OF ENGINEERING

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Abstract

To meet a Brazilian guideline for engineering courses, which advocates the use of active learning in applied disciplines, this research studies new students entering an Engineering course at an important university in Brazil. It was applied to them a traditional MTBI (Myers–Briggs Type Indicator) questionary with the aim of finding out if there is recurrence of psychological profiles and to understand the characteristics of the freshmen to learning. This information was subjected to statistical analysis to observe the recurrence of the psychological characteristics of freshmen over the years (2017 to 2021). The data was also subjected to the Self Organizing Maps (SOM) machine learning technique, to delineate and group the psychological profiles observed in the students, enabling the analysis of the psychological characteristics and the comparison with the results obtained via statistics. After that, the results from the MBTI Traditional and the SOM clustering were submitted to comparison methods through multivariate statistics and Multiple Correspondence Analysis (MCA). It was found that there is recurrence of psychological characteristics between the years of collection, what were the psychological profiles of these freshmen as to how they learned. It was found that the freshmen surveyed mostly belong to Generation Z (or iGen) and characteristics pertinent to this group were observed. A scenario is obtained to point out the best active learning techniques for these students with the verification of recurrence of profiles and other correlated psychological characteristics, aiming to provide the most effective teaching in the engineering course.

Keywords – Descriptive statistics; SOM clustering; Correspondence analysis; Generation Z; Psychological profile of students.

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1. Introduction

The techniques derived from active learning allow the teacher to use different and innovative resources in the classroom, changing the axis of traditional teaching, where the teacher is the center of academic dialectics,

into attitudes of experimentation and actions of students before the theoretical concepts, constituting skills for these entrants to higher education. The change of this academic paradigm implies in the evolution of the educational methods used, leading the student to compose his education in a hands-on mode.

Particularly in Brazil, engineering education is going through moments of reflection and reinvention. There is resistance from professors to change teaching techniques (Neves, Lima & Mesquita, 2021). There is also indication that academic curricula may be outdated and rigid (Oliveira, 2022). However, the Brazilian Ministry of Education (MEC) applied directive aiming to favor the application of the active learning concept in engineering courses (MEC-CNE/CES resolution #2 of 04/24/2019), and to adjust academic curricula being more attractive & actual to higher education level. There is also, in this regulatory document, the attribution of responsibility to the higher education institution to apply learning improvements with governance of the process. The directive has driven discussions at engineering education conferences and in academic articles, where numerous techniques are tested and presented as alternatives to encourage engineering students to obtain skills needed for what the future labor market requires (Oliveira, 2022).

A reflection should be made by the teacher: What is the tool that will be most effective for the learning of my group of students? After this reflection, the teacher can categorize some teaching tools and can test them in his/her classes, however without the guarantee that the technique will work the same way it worked in the literature, because the use of the techniques presented cannot not be validated with the class to which it was applied (Felder, Woods, Stice & Rugarcia, 2000).

There are several factors that influence teaching: gender, ethnicities, nationalities, number of students in the class, among other class characteristics, etc. However, a very incisive characteristic is the psychological factor (Weissberg, Durlak, Domitrovich & Gullotta, 2015). Still in the sense of understanding the factors that influence teaching, Light (2001) mentions in his work that two factors stand out in students´ reports of how small classes make an especially strong impact. First, such classes enable a professor to get to know each student reasonably well, second, a professor can use certain teaching techniques that are hard to implement in large classes.

Thus, there is the importance of analyzing which is the way that a certain group of students feel more comfortable to learn and develop new skills. This pushes the teacher to analyze the way of learning presented by his class, knowing who his students are and their ways of learning, there is higher possibility that his teaching will be more effective and remarkable (Felder et al., 2000).

This study seeks to present a form of psychological delineation of student learning by obtaining information through the self-report technique Myers-Briggs Type Indicator (MBTI), which is indicated one of best-known instrument user to assess learning styles (Felder, Felder & Dietz, 2002). Besides this resource, in this study, statistical analysis techniques were associated with the objective of indicating whether there are differences between the recurrences of the profiles found in the observations made in the years of collection. Part of the data was subjected to a SOM (Self Organizing Maps) an unsupervised machine learning technique, which favors a graphic observation producing a low-dimensional representation of a higher dimensional data set for analysis and findings, in a simple and objective way. In addition, it has been used to characterize personality profiles by data affinity and minimizing biases related to the tie between psychological types.

In this way, by analyzing the collective characteristics of undergraduate students and using a personality profiling technique, the research aims to obtain a model for decision making as to the most appropriate way of teaching that meets the students' needs and seeks to improve learning in the field of engineering.

1.1. A brief Description of the MBTI

The Myers-Briggs Type Indicator (MBTI) methodology is widely used in several areas such as jobs and human resource corporations (Cohen, Ornoy & Deren, 2013), relationships, problem solving (Myers, 1998) and learning (Felder et al., 2002), because this resource is simple to apply and very efficient in its results.

The MBTI test is based on concepts from Carl G. Jung's theory of psychological personality types. These types are obtained from two forms of interaction of the individual with his or her environment: World Orientation, where the person chooses Introversion (I) or Extraversion (E); and Basic Mental Processes, where the person chooses to gather information from the world with Perception (P) or Judgment (J) (Higgs, 2001).

Perception (P) can be divided into two ways of obtaining information by the individual, which are Sensation (S) and Intuition (N); the same goes for Judgment (J), where the individual chooses to use either Thinking (T) or Feeling (F) to deal with information around him (Myers, 1998). For better understanding, these psychological types presented are shown in Table 1.

Other characteristics can be provided through the combination of MBTI psychological types, which allow for a deeper understanding of the individual's way of acting. Table 2 was prepared according to Myers (1998), which shows that associations between psychological types present other characteristics for personal preferences.

		Basic mental processes			
		Perception (P)		**Judgment (J)**	
World Orientation	Introversion (I)	Sensation(S)	Intuition(N)	Thinking(T)	Feeling(F)
	Extroversion (E)	Sensation(S)	Intuition(N)	Thinking(T)	Feeling(F)

Table 1. Combination of Carl G. Jung's theory - World Orientation of the Individual with the Basic Mental Processes (Myers, 1998)

Psychological association	**MBTI type**
Learning Styles / Career Interests	SF/NF/ST/NT
Use of information	ES/IS/EN/IN
Leading/Following Styles	EP/IP/EJ/IJ
Temperaments	SJ/SP/NF/NT
Dealing with Change	IJ/IP/EP/EJ

Table 2. Association of psychological characteristics (Myers, 1998)

Some characteristics of the main and associated psychological functions were discussed by Myers (1998) are shown in Table 3 and will assist in the analysis of this study. According to the model for the learning profile proposed by Jung, the individual learns best if the information comes from the psychological area in which there is effective control over their dominant function (Myers, 1998). The most significant channels for learning are Sensation (S) and Intuition (N), with the supporting participation of other psychological functions. Individuals related to Sensation (S) find it easy to receive information objectively, while metaphors or symbolism hinder the learning process. For individuals related to intuition (N), they lose patience with the well-developed and profound constructions of reasoning practiced by their sensory colleagues.

For Culp and Smith (2009), people with a preference for Sensation (S) are attentive to the practical, like real, tangible information presented in a logical way, while Intuitive (N) individuals don't like details and look at the overall context of things. With regard to the psychological types that support learning, Myers (1998) shows that extroverts (E) learn by talking, while introverts (I) need time, silence and space. People with Judgmental characteristics (J) require structure, dedicated time, a stipulated deadline, and those related to Perception (P) require flexibility to explore.

The Judgment-Perception dichotomy may be the most controllable pair of preferences for a student; students who are of Perception (P) type tend to develop better organization and time management skills (Schurr & Ruble, 1986).

	Function		Characteristics and preferences
Dichotomy	Sensing (S)		Receive real and tangible information; Observers of the specifics; Prefer practical realities; Factual and concrete; Build carefully and thoroughly toward conclusions; Understand theories through practical applications; Trust experience
	Intuition (N)		Has an overview of everything to receive information; They like to grasp patterns; Oriented to future possibilities; Imaginative and verbally creative; Draw conclusions quickly, follow hunches; Needs clarify theories before putting them into practice; Trust inspiration
Learning Style / Career Interests	ST	Learning	Facts about real things; Useful, practical information about everyday activities; Learn best by doing, hands-on activities; Need Precise, step-by-step instructions; Logical, practical reasons for doing something; Want from teacher to be treated fairly
		Career	Factual; Objective analysis and experience; Practical and analytical; Technical skills
	SF	Learning	Useful, practical; Information about; People, and a friendly environment; Doing, hands-on; good with activities with others; Precise, step-by-step; instructions; needs frequent friendly interaction and approval; Sympathy, support, needs individual recognition
		Career	Factual; Personal warmth, concern for others; Sympathetic and friendly; Practical help and services for people
	NF	Learning	New ideas about how to understand people; Symbolic and metaphorical; activities; lmagining, creating with others, writing; General Direction with freedom to do it their own creative way; Needs frequent positive feedback; Warmth, enthusiasm, humor, needs individual recognition
		Career	Sees possibilities; Perspective to people's potentials; Insightful and enthusiastic; Understanding and encouraging people
	NT	Learning	Theories and global explanations about why the world works the way it does; Learn Categorizing, analyzing, applying logic; To be given a big problem to solve, needs an intellectual challenge, and then to be allowed to work it out; Needs to be treated with respect, to respect the teacher's
		Career	Sees possibilities; Theoretical concepts; Logical and analytical; Theoretical and technical frameworks
Use of Information	IS	Thoughtful Realists	Knowledge is important to establish what is true
	IN	Thoughtful Innovators	Knowledge is important for its own sake
	ES	Action-Oriented Realists	Knowledge is important for its practical uses
	E N	Action-Oriented Innovators	Knowledge is important for changing reality
Leading/ Following Styles	TJ	Logical Decision Makers	Analytical, decisive leaders; Make decisions based on principles and systems; Overall impacts, and rational assessment outcomes, and can be tough-minded in implementing those decisions; Effective implementers of policies, if they respect the leader
	TP	Adaptable Problem Solvers	Lead by example; Value and display technical expertise, and create consistent and orderly frameworks for working; Objective, skeptical, and curious; Will change course as new information comes in; Effective problem solvers, if interested
	FP	Supportive Coaches	Warm, flexible, and encouraging leaders; Support individual work styles and like to involve others in decisions; Prefer collegial relationships, shared rewards, and consensus in decisions; Energetic followers if treated with respect
	FJ	Values-Based Decision Makers	Warm, decisive leaders; Make decisions based on their personal values and empathy with others; Strive for harmony, consensus, and a supportive environment, are expressive and often inspiring; Loyal followers if the leader honors their values

	Function		Characteristics and preferences
Temperaments	NF	Idealists	Search for unique identity and meaning; Value empathic, meaningful relationships; Generally enthusiastic; Want to make the world a better place; Trust their intuition and imagination; Think in terms of integration and similarities; Focus on developing potential in others, finding a purpose in life, and bridging differences; Want to be authentic
	NT	Rationals	Theory oriented; Seek to understand the principles on which the world and things in it world; Trust logic and reason; Skeptical and precise; Think in terms of differences, categories, definitions, and structures; Focus on strategies and designs that achieve long-range goals and lead to progress; Want competence and thorough knowledge;
	SP	Artisans	Action and impact oriented; Hunger for spontaneity; Optimistic; Trust luck and ability to handle whatever comes up; Absorbed in the moment; Read people and situations and adapt to changes to get the job done; Seek adventure and experiences; Think in terms of variations; Focus on tactics to help others and get desired results; Want freedom to choose their next action;
	SJ	Guardians	Hunger for responsibility and predictability; Like standard operating procedures to protect and preserve; Serious and concerned; Trust the past, tradition, and authority; Think in terms of comparisons, sequences, and associations; Focus on logistics to support people, maintain organizations, and achieve objectives; Want security, stability, and to belong;

Table 3. Main and associated MBTI roles (Myers, 1998)

2. Methodology

The MBTI test is initiated by filling out a self-report form, which is the data input for obtaining the individual profile configuration. For this purpose, the form for the test was obtained from the American Psychological Association (APA), drawn up in accordance with The Myers-Briggs Type Indicator: Manual (1962) (Myers, 1962) and contains 70 questions. Each of the questions on this form involves choices between two opposite options within a psychological dichotomy, and the answers obtained are grouped and framed within characteristic type profiles. A simple sum of answers of a given dichotomy of psychological characteristics will determine the psychological profile frame.

The traditional collection methodology may allow the result of the individual's choices to be in a region of hesitation, that is, in a region of a tie between two dichotomies, which will result in indeterminacy between the two terms, requiring observation of other characteristics of the individual's choice after the test.

For the research, the MBTI questionnaire was applied to entering students in the Department of Metallurgical Engineering and Materials of the Polytechnic School of the University of São Paulo between the years 2017 and 2021. There was a total of 252 forms, with 55, 38, 47, 60 and 52 respondents in the years of 2017, 2018, 2019, 2020 and 2021 respectively. The information collected followed the flow demonstrated by Figure 1.

The students themselves, under orientation, filled out the tabulation of points, summed up the questions on a tabulation form, and obtained their psychological type by defining the MBTI profile. In case of blurring between two psychological characteristics, the respondent was instructed to indicate the characteristic he/she best identifies itself within the tied dichotomy. Later these forms were collected, and the data obtained were grouped in electronic spreadsheets, which consolidated the basis of results for the elaboration of basic statistics.

In order to verify whether there was a recurrence of personality patterns , the data was submitted to multivariate statistical analysis to verify the existence of differences between the groups, according to conditions for the execution of this analysis. Next, the SOM computational method was applied to the data with the objective of observing patterns of psychological profiles and to observe the clustering of these profiles, because this method groups personality patterns by data affinity, which favors the accuracy of the profiles obtained as output data. In this way, the statistical method and the computational method will complement each other in their results.

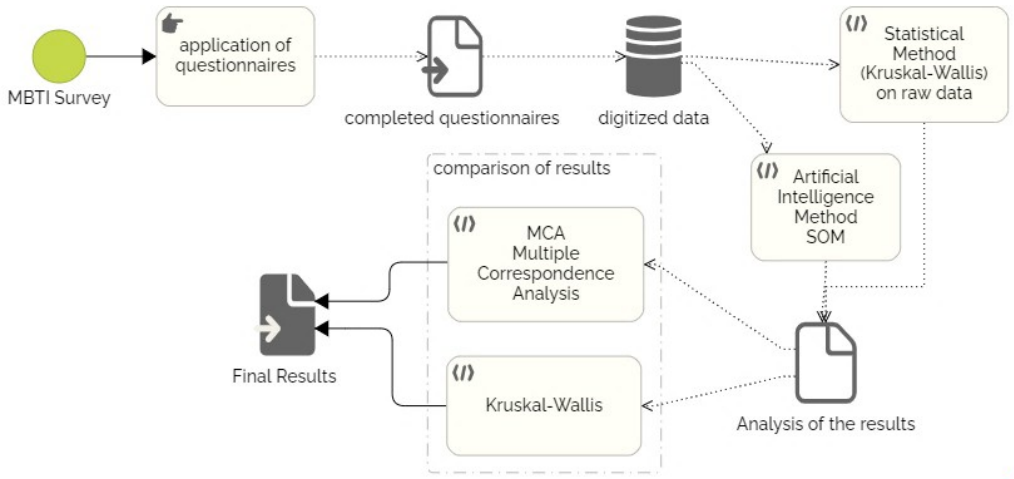

Figure 1. Flow of data and analysis methods used in this study

The psychological patterns found were then analyzed as to the way the students learn, according to the precepts of learning MBTI profiles, providing a basis for indicating the best teaching strategies for this group of students.

Finally, then the information was submitted to two comparative methods, the KRUSKAL-WALLIS statistic and the Multiple Correspondence Analysis (MCA), in order to verify differences between the results from traditional MBTI pattern and the SOM clustering.

3. Results

3.1 Statistical Method

The data collected with the MBTI profiles is shown in Table 4. It is observed that the MBTI ISTJ profile was represented by 21.83% of students in all years of collection. Another profile that prevailed in the tabulation was ESTJ, represented by 19.44% of freshmen. On the other hand, the least recurrent profiles were ESFP, ISFP, and ESTP.

	2017	2018	2019	2020	2021
ESTJ	10.9%	23.7%	25.5%	21.7%	17.3%
ESTP	3.6%	2.6%	2.1%	-	1.9%
ESFJ	7.3%	-	4.3%	3.3%	1.9%
ESFP	1.8%	-	2.1%	-	3.8%
ISTJ	18.2%	15.8%	19.1%	28.3%	25.0%
ISTP	10.9%	-	-	1.7%	-
ISFJ	1.8%	2.6%	10.6%	3.3%	1.9%
ISFP	1.8%	-	-	-	1.9%
ENTJ	3.6%	10.5%	6.4%	10.0%	13.5%
ENTP	3.6%	-	2.1%	1.7%	3.8%
ENFJ	-	7.9%	2.1%	-	3.8%
ENFP	1.8%	2.6%	4.3%	6.7%	3.8%
INTJ	12.7%	15.8%	8.5%	13.3%	11.5%
INTP	5.5%	5.3%	6.4%	1.7%	5.8%
INFJ	9.1%	13.2%	6.4%	6.7%	3.8%
INFP	7.3%	-	-	1.7%	-
	100%	100%	100%	100%	100%

Legend	
E	Extroversion
I	Introversion
S	Sensation
N	Intuition
T	Thinking
F	Feeling
J	Judgment
P	Perception

Table 4. Percentage values of psychological type observed in entering students

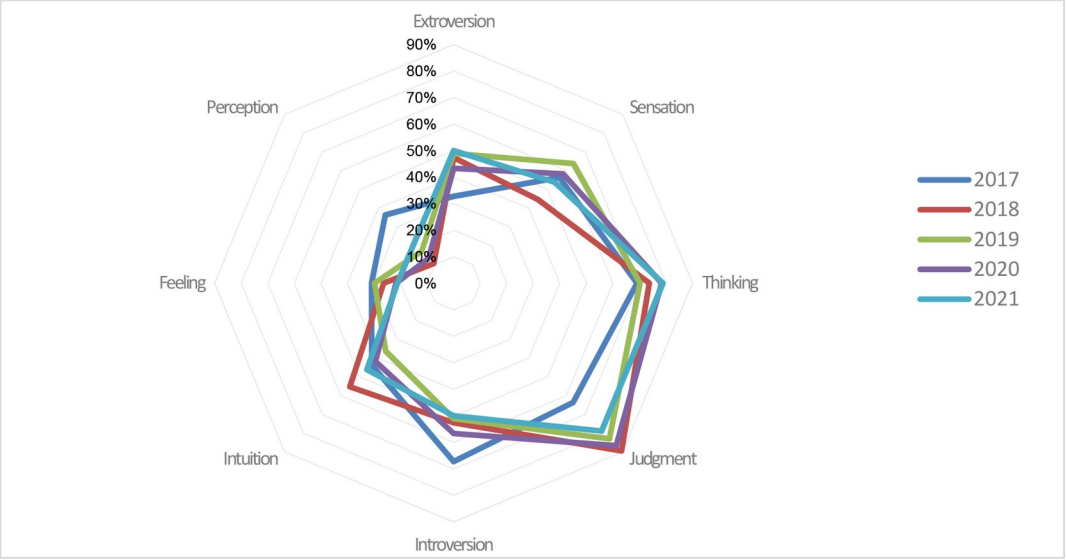

Figure 2. MBTI types of characteristics of students entering the Engineering School between the years 2017 to 2021

This data was consolidated, and a radar chart was made. It was observed that the psychological characteristics are hypothetically recurrent over the years (Figure 2), given the symmetry between the lines generated by each year of data collection.

To verify whether there are recurrences of psychological profiles over the years, it was decided to choose a multivariate statistical method in which the data collected would be suitable. This data come from choice dichotomies, that is, the person only had one or another option to answer the questions and, therefore, there are only two classes and the data do not present a normal distribution (Larson & Farber, 2010). Naturally this type of tabulation generates non-parametric data, which will directly implicate the technique for evaluating this information.

The data was separated by year and each year was subjected to analyses according to the MBTI Types and psychological type of preference of the individual (Introversion/Extroversion, Sensation/Intuition, Thinking/Feeling, Judgment/Perception).

The multivariate statistical analysis was preceded by the Fligner-Killeen test of homogeneity of variance. According to Niu (2004), this methodology performs median centering on each sample and is more robust against normality deviation. The equation (1) used for the test is:

$$X^2 = \sum_{j=1}^{k} n_j \left(\bar{A}_j - \bar{a}\right)^2 / V^2 \quad (1)$$

where:

$\bar{A}_j$ is the average score for the sample *jtesimal;*

$\bar{a} = \frac{1}{N}\sum_{i=1}^{N} a_{N,i}$ is the overall average score and;

$V^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(a_{N,i} - \bar{a}\right)^2$.

The results obtained from the Fligner-Killeen test are available in Table 5 and indicate that there is homogeneity in the variance of the data under study.

	χ^2	df	p-value
General	1.3572	4	0.8516
Extroversion	2.236		0.692
Introversion	0.913		0.923
Sensation	1.488		0.829
Intuition	3.894		0.421
Thinking	2.524		0.640
Feeling	5.326		0.255
Judgment	2.128		0.712
Perception	1.963		0.743

Table 5. Fligner-Killeen homogeneity of variance test for all grouped data and for each of the eight preference types observed in MBTI tests

Another analysis performed was the verification of the existence of Outliers in the data. The existence of this anomaly among the data directly implies the choice of the statistical method to be used. The Outlier detection method foresees two levels of incidence of the statistical phenomenon, according to equations (2) and (3):

$$Q3 + (1{,}5 \times IQR) \quad and \quad Q1 - (1{,}5 \times IQR) \quad \text{(for } Outliers\text{)} \tag{2}$$

$$Q3 + (3 \times IQR) \quad and \quad Q1 - (3 \times IQR) \quad \text{(for Extreme Points)} \tag{3}$$

Where:

Q1 and *Q3* are the first and third quartile of data, and;

IQR is the interquartile range, given by *IQR* = *Q*3 – *Q*1.

The results from this analysis indicate the existence of Outliers in all data scenarios (general data and the data separated by psychological type - Table 6). Attempts were made to transform the data, either to a base modeled in square roots or logarithmic modeling and exclude the Outliers but were unsuccessful in excluding these anomalies for the analyses.

			2017		2018		2019		2020		2021	
Preference type	E Extroversion	Outliers	ESTJ		ESTJ		ESTJ		ESTJ		ESTJ	ENTJ
		Extreme										
	I Introversion	Outliers							ISTJ		ISTJ	
		Extreme										
	S Sensation	Outliers			ESTJ	ISTJ			ESTJ	ISTJ	ESTJ	ISTJ
		Extreme										
	N Intuition	Outliers									ENTJ	
		Extreme										
	T Thinking	Outliers					ENTJ					
		Extreme										
	F Feeling	Outliers			INFJ		ISFJ					
		Extreme										
	J Judgment	Outliers					ESTJ					
		Extreme										
	P Perception	Outliers							ENFP			
		Extreme										
General		Outliers					ESTJ	ISTJ	ESTJ	ISTJ	ESTJ	ISTJ
		Extreme										

Table 6. Identification of Anomalies or Outliers in the data population

The MBTI profiles ESTJ and ISTJ appear several times as OUTLIERS, since these two profiles greatly exceed the dimensions of the other profiles presented, therefore they are anomalous when compared to the other profiles.

Given this scenario where the original data comes from dichotomies and the existence of outliers in all models submitted to analysis, there are restrictions for applying this data in parametric statistical modeling. Thus, the option is to choose a non-parametric method that meets a universe of multivariate data and that accepts the observed characteristics. The method used for the analysis was the Kruskal-Wallis, which presents as null hypothesis assuming that samples come from the same population or from identical populations with the same median (μ). This method is defined by means of the equation (Fávero & Belfiore, 2017):

$$H_{cal} = \frac{12}{N \times (N+1)} \times \sum_{j=1}^{k} \frac{R_j^2}{n_j} - 3 \times (N+1) \quad (4)$$

Where:

k: number of samples or groups;

n_j*:* number of observations in the sample or group *j;*

N: number of observations in the overall sample;

R_j*:* sum of positions in the sample or group *j;*

The result of this Kruskal-Wallis statistical analysis is presented in Table 7. It was found that the null hypothesis of the method was satisfied for all scenarios evaluated, that is, there are no significant differences between the models compared.

		χ^2	df	p-value
E	Extroversion	1.925	4	0.750
I	Introversion	1.594		0.810
S	Sensation	1.757		0.780
N	Intuition	0.566		0.967
T	Thinking	0.349		0.986
F	Feeling	1.551		0.818
J	Judgment	0.712		0.950
P	Perception	7.778		0.100
General		1.352		0.853

Table 7. Kruskal-Wallis multivariate evaluation application for the preference types and for the total data

The authors gave a more in-depth demonstration of this statistical treatment in another publication (Weingärtner-Junior, Piedemonte-Antoniassi, Ferreira-Bindo & Bernardo-Lenz e Silva, 2022).

3.2. SOM Clustering

Self-Organizing Maps (SOM), or Kohonen Maps, is an Artificial Intelligence (AI) tool. It provides an examination of high dimensional data in discrete low dimension maps (two dimension) for analysis, while preserving the data's topology (Asan & Ercan. 2012).

For this analysis. a neural network is used for three processes: competition, cooperation, and synaptic adaptation. The neurons in this type of network are hierarchical, as a discriminant function performs the competition between them. The neuron with the lowest value obtained by the discriminant function is selected. The position of the selected neuron is determined in the network and the neurons in the direct vicinity are adjusted with the selected neurons value, creating an affinity neighborhood and cooperating

for allocates (Haykin. 2009). The groups, or clusters, are formed from the feature affinity of these neighborhoods.

In this research. the MBTI profile data is organized by intensity of the characteristic type (E/I, S/N, T/F and J/P) in the allocation of the neighboring neuron formed. It is important to note that the data continues between the vertical and horizontal borders, as it was organized in the form of a pseudo-toroid map, with the radial axis in the horizontal orientation. This project was set up with 136 cells and 16 clusters to insert the process data from the SOM analysis.

The results of de SOM analysis are shown in Figure 3, the types of dichotomies are described in the rows, and the columns indicate the way the individual interacts with the world.

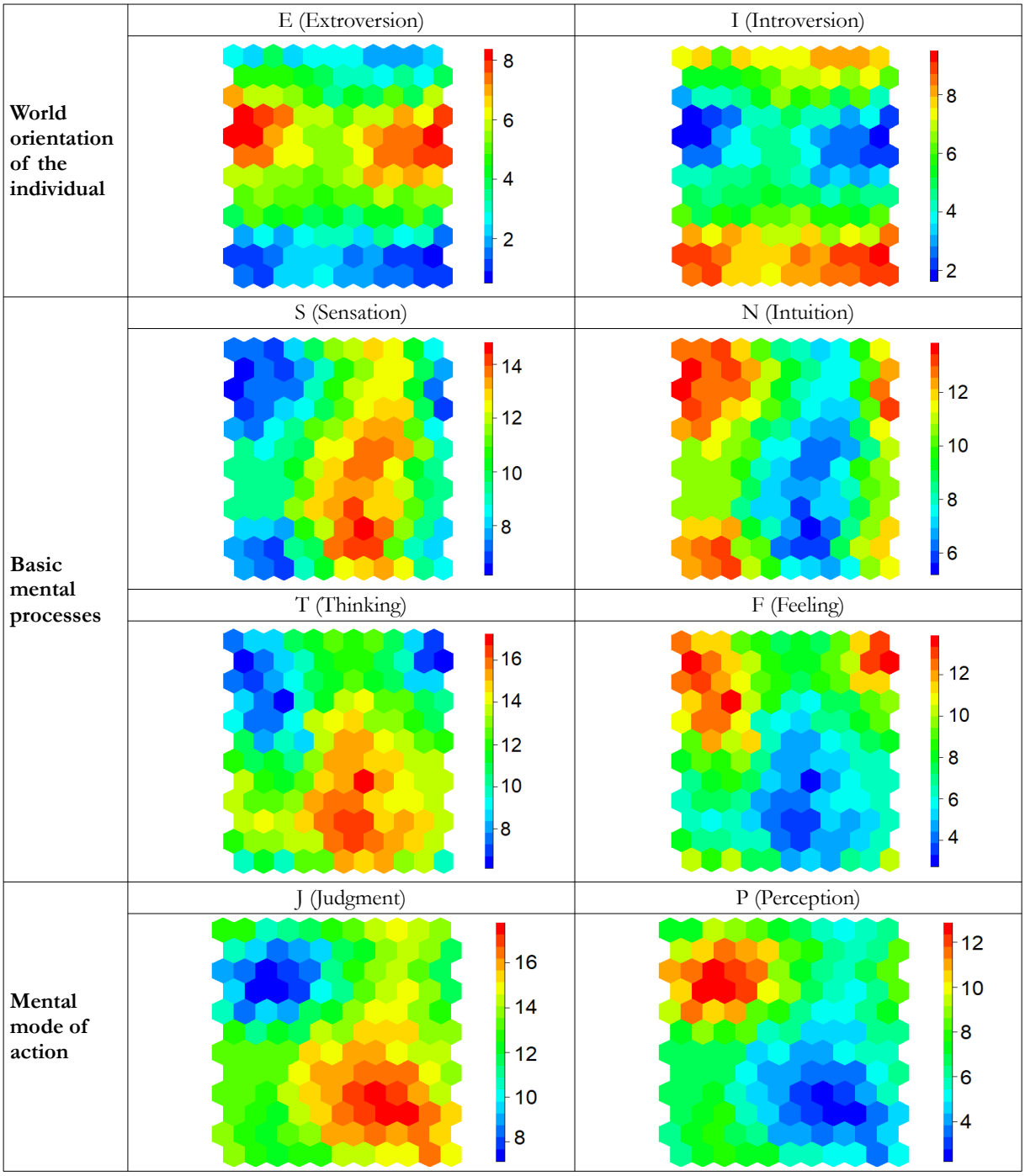

Figure 3. SOM analysis for the characteristic psychological types in the group of entering students in the years 2019 to 2021

The result obtained by grouping of psychological profiles by affinity obtained clusters with the profiles ISTJ, ESTJ, INTJ, ENFP, ENTJ, INFJ, INTP, INFP, ENFJ and ISFJ (Figure 4). It was observed that in the input data there were some incoming student profiles that showed undefined dichotomies in at least 1 dichotomous pair and therefore the artificial intelligence did not fit them into a particular group. Other less critical indistinctiveness was fit by AI with other profiles according to their affinity, as the traditional MBTI tabulation has no power to fit a particular blurred type to a particular group.

CLUSTER	MBTI
1	ISTJ
2	ESTJ
3	INTJ
4	ENFP
5	ENTJ
6	INFJ
7	INTP
8	INFP
9	ENFJ
10	ISFJ

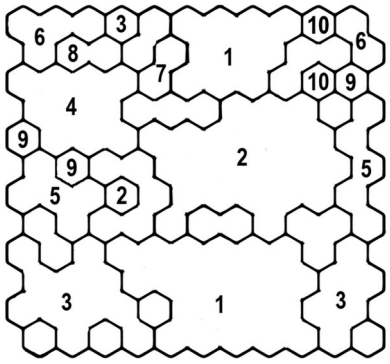

Figure 4. SOM profile grouping and respective MBTI profiles

3.3. Comparison of SOM and MBTI Results

The Kruskal-Wallis statistical technique was again applied to the results from the SOM analysis and the equivalent models obtained by the multivariate statistical analysis (Table 8). This second application of the Kruskal-Wallis analysis returned that there are no differences between the results of the SOM analysis and the data analyzed by the nonparametric statistical (Table 9).

	Traditional MBTI		SOM	
	2019 to 2021		2019 to 2021	
ESTJ	36	26.5%	30	22.1%
ESTP	2	1.5%	0	0%
ESFJ	5	3.7%	0	0%
ESFP	3	2.2%	0	0%
ISTJ	33	24.3%	34	25%
ISTP	1	0.7%	0	0%
ISFJ	7	5.1%	0	0%
ISFP	0	0%	0	0%
ENTJ	14	10.3%	20	14.7%
ENTP	5	3.7%	0	0%
ENFJ	4	2.9%	0	0%
ENFP	6	4.4%	19	14%
INTJ	12	8.8%	16	11.8%
INTP	1	0.7%	3	2.2%
INFJ	7	5.1%	14	10.3%
INFP	0	0%	0	0%
Total	136	100%	136	100%

Table 8. Tabulation of profiles of the 136 surveys used for the analysis by the traditional MBTI method and by SOM

The Multiple Correspondence Analysis (MCA) is a multivariate method that allows the study of associations between two or more categorical variables and between their categories, besides allowing the

evaluation of the intensity of these associations. To make comparisons by this method, it is necessary to evaluate pairs of variables by means of a test χ^2 (the concept of this test is demonstrated in the topic Statistical Method). If the associations of variables are not significant, it is recommended to exclude the variable from the correspondence analysis (Fávero & Belfiore, 2017).

		χ^2	df	p-value
E	Extroversion	1.5687	5	0.905
I	Introversion	2.9722		0.704
S	Sensation	4.2195		0.518
N	Intuition	0.5356		0.991
T	Thinking	0.2571		0.998
F	Feeling	2.4001		0.791
J	Judgment	0.6345		0.986
P	Perception	9.4137		0.094
General		2.1462		0.829

Table 9. Kruskal-Wallis evaluation in relation to the types observed after SOM processing (rows with dichotomies) and to the data obtained year by year (General row)

Correspondence Analysis provides graphs that are perceptual maps, where data are entered by means of coordinates, based on axes that represent Dimensions. These dimensions are calculated through Burt matrices, as defined by Fávero and Belfiore (2017):

$$B = \begin{pmatrix} Z_1' \cdot Z_1 & Z_1' \cdot Z_2 & \cdots & Z_1' \cdot Z_Q \\ Z_2' \cdot Z_1 & Z_2' \cdot Z_2 & \cdots & Z_2' \cdot Z_Q \\ \vdots & \vdots & \ddots & \vdots \\ Z_Q' \cdot Z_1 & Z_Q' \cdot Z_2 & \cdots & Z_Q' \cdot Z_Q \end{pmatrix}_{J \times J} \quad (5)$$

The Table 10 presents the results of the tests χ^2 applied to the data using 5% for significance. The information with significant differences was submitted to the MCA test.

Psychological characteristics	P-value
Extroversion X Introversion (E/I)	0.466
Sensation X Intuition (S/N)	0.005
Thinking X Feeling (T/F)	0.886
Judgment X Perception (J/P)	0.611
Learning Styles / Career Interests (SF/NF/ST/NT)	9.2e-5
Use of information (ES/IS/EN/IN)	0.034
Leading/Following Styles (EP/IP/EJ/IJ)	0.021
Temperaments (SJ/SP/NF/NT)	0.003
Dealing with Change (IJ/IP/EP/EJ)	0.775
The 16 types MBTI	1.0e-4

Table 10. Tests χ^2 performed using combinations of psychological types

The dichotomous characteristics Extroversion/Introversion (E/I), Thinking/Feeling (T/F) and Judgement/Perception (J/P) will not be listed in the MCA method, as well as the association IJ/IP/EP/EJ. which shows the individual´s characteristics for Dealing with Change.

The 16 MBTI types were within significance as to the existence of statistical differences between the patterns. This variable will not be considered throughout the comparison, due to the complexity that the

various categories (16 types) bring. increasing the degrees of freedom, which consequently increases the dimensions under analysis and decreases the degree of explanation obtained in each pair of dimensions analyzed. This analysis containing the MBTI Types involves 27 explanatory dimensions and the relation dimension 1 X dimension 2 equals 33.2%. while the analyses without MBTI Types presents 14 explanatory dimensions and the relation Dimension 1 X Dimension 2 equals 49.8%.

Therefore, only the presentation of MBTI Types will be shown in a graphic analysis of the Figure 5 and the continuity of comparisons will be done without the variable MBTI Types. Without the presence of MBTI Types, the positions of the characteristics on the graph remain the same, not harming the analysis.

As presented in Figure 5, the data groups pertinent to the MBTI Traditional and SOM clustering model are very similar (MBTI Traditional – circle in pink / SOM clustering – circle in blue), and the same is evidenced from the group vector center distance data obtained for dimensions 1, 2 and 3 (0.203, 0.010, 0.534 relative to the intersection of the dimension axes respectively for each group data).

It is clear from the figure that dimension 1 is related to the perceiving characteristics Sensation and Intuition (dichotomy S/N), with the vertical dashed line indicating the transition from one dichotomy to the other, Dimension 2 highlights the characteristics Thinking and Feeling (Dichotomy T/F), with Thinking below the dashed line and Feeling above. These features define the two dimensions under analysis for the graph.

Another observation is the well-defined clusters regarding the distribution of the data. The analysis shows cluster 1, where the types ESFP, ESFJ and ISFJ are very similar in their characteristics regarding the analyzed dimensions, and are close to the psychological associations SF (Sympathetic/Friendly) and SP (Artisans), being the characteristic SP a point a little distant from the others. Note that this cluster is quite centered on the transition line between Thinking (T) and Feeling(F).

The highlighted cluster 2 in the chart shows the proximity of ESTJ. ISTJ. ESTP and ISTP types. These characteristics are closely related to the Sensation (S) profile and the associations SJ (Guardians), IS (Thoughtful Realists), ES (Action-Oriented Realists), ST (Practical/Analytical) and TJ (Logical Decision Makers), the latter a little further apart. Note that these types are closely related to the group of data coming from the Traditional MBTI. On the other hand, the centralization of SOM clustering data is more isolated with a greater tendency for Intuition (N).

Characteristics pertinent to the associations of Intuition(N) and Feeling (F) are presented in cluster 3. Is observed that the types ENFP, ENFJ and INFJ are grouped with the associated characteristics FJ (Value-based Decision Makers) and FP (Supportive Coaches).

Cluster 4 is located just below the transition line between Thinking (T) and Feeling (F), with a greater tendency towards Thinking. In this cluster are found the characteristics Intuition (N), EN (Action-Oriented Innovators) and IN (Thoughtful Innovators). Note that these characteristics are correlated to clusters 3 and 5. being that EN (Action-Oriented Innovators) has a slight tendency to cluster 3 and IN (Thoughtful Innovators) have a little more affinity with cluster 5.

The types ENTJ, INTJ, ENTP and INTP are arranged close together in cluster 5 in graph. As associated characteristics. TP (Adaptable Problem Solvers) and NT (Logical/Analytical) are observed for Temperament, Learning and Career.

An important attribute observed in the group of data analyzed is that the psychological types and associations related to Sensation (S) are close to or above the transition line between Thinking (T) and Feeling (F), with a greater tendency toward Feeling (F), besides not being as acute for Sensation (S). However, they are close to the transition line between Sensation (S) and Intuition (N). The characteristic most related to Thinking (T) in this group under analysis is TJ (Logical Decision Makers), related to the leader/following characteristics.

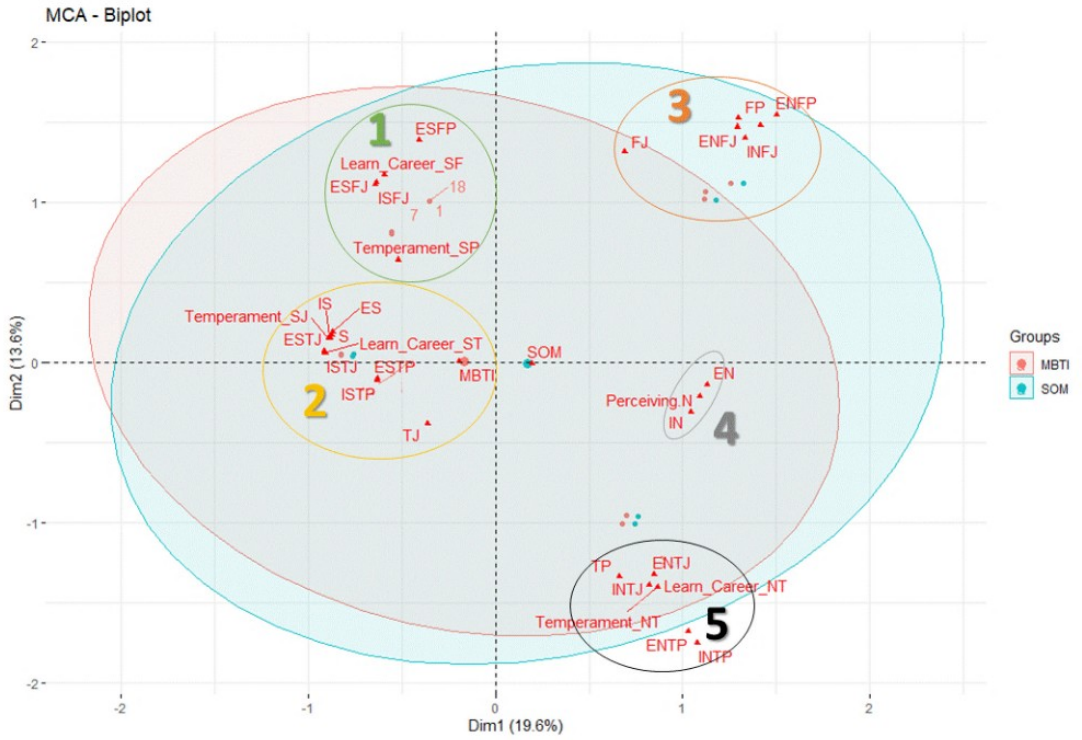

Figure 5. Distribution regions of MBTI Traditional and SOM clustering data in relation to dimensions 1 and 2

There is a great distance between clusters 3 and 5, indicating that characteristics associated with TP (Adaptable Problem Solvers) and NT (Logical/Analytical) are very distinct to FJ and FP's (Values-Based Decision Makers and Supportive Coaches respectively) when evaluated under dimension 2 (Thinking/Feeling). In analogous analysis, there is greater proximity between clusters 1 and 2, related to Sensation(S), and individuals in these groups are more connected in their choices.

In Figure 6 the MBTI Types were not included, aiming for better interpretation and significance of analysis. The graph shows the associated characteristics and the S/N dichotomy that relate to the MBTI Traditional and SOM clustering groups. It can be seen that dimension 3 relates to the accuracy of the MBTI and SOM groups in relation to the Learning/Career, Use of Information, Temperament and Leading/Following Styles functions.

The affinity of the SOM clustering group is related to Use of Information (ES/IS/EN/IN) and Leading/ Following Styles (EP/IP/EJ/IJ) given the proximity of the data. The Traditional MBTI group, on the other hand, has a greater relationship with the Learning/Career and Temperament roles.

Related to Sensation (S), the associated role SP (Artisans) is quite distant in relation to the other features under analysis, as is the role SF (Sympathetics/Friendlys), Functions ES (Action-Oriented/Realists), SJ (Guardians). ST (Practical/Analytical), TJ (Logical/Decision Makers) are clustered near the transition axis of dimension 3.

For the group related to Intuition (N), the associated roles TP (Adaptable Problem Solvers) and FJ (Value-based Decision makers) are at moderate distance from the others and are characteristic of Leading/Following Styles. A cluster is configured with the roles NT (Logical/Analytical), IN (Thoughtful Innovators), EN (Action-Oriented Innovators), FP (Supportive Coaches) and NF (Insightful/Enthusiastic) very close to the transition axis of dimension 3.

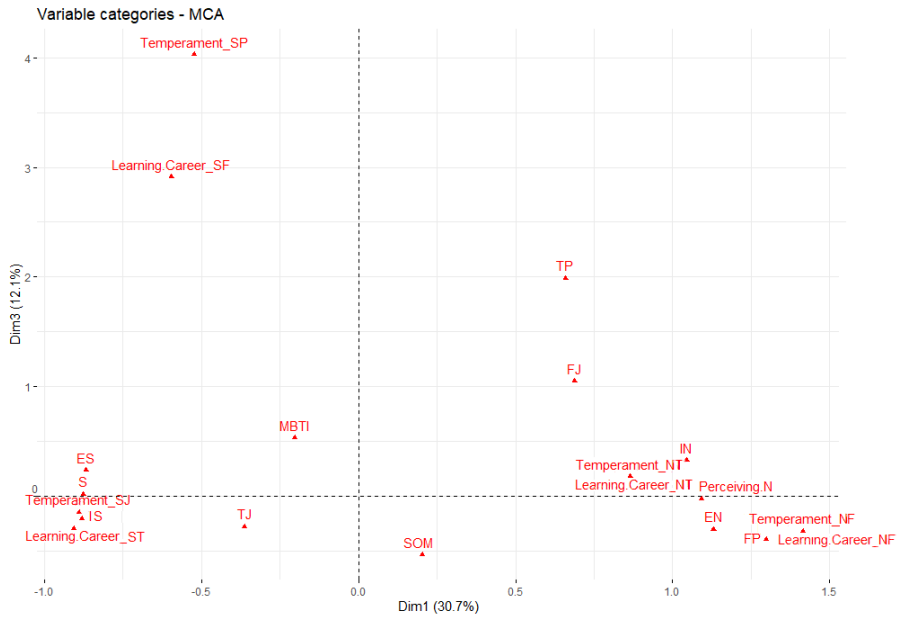

Figure 6. Distribution of Traditional MBTI and SOM clustering data in relation to dimensions 1 and 3

Figure 7 shows dimension 1 *versus* dimension 4 which is related to Leading/Following Styles, Use of Information and Temperaments. Analyzing the groups related to Intuition (N), the more introverted types are below the horizontal transition line and the extroverts are above. Here is observed that the FJ (Value-based Decision Makers) are close to the IN's (Thoughtful Innovators), while the individuals with the EN (Action-Oriented Innovators) characteristics are related to the TP (Adaptable Problem Solvers) and FP (Supportive Coaches) characteristics.

While in the Sensation (S) group, there is a closer proximity of the associated characteristics TJ (logical Decision Makers), SF (Practical/hand-on), SJ (Guardians), ST (Analytics/Objectives), ES (Action-Oriented Realists), IS (Thoughtful Realists), all close to the transition line of dimension 4.

One group that was isolated in this dimension were those with the characteristic SP (Artisans), related to Extroversion (E) and Sensation (S), which are very dispersed from the others.

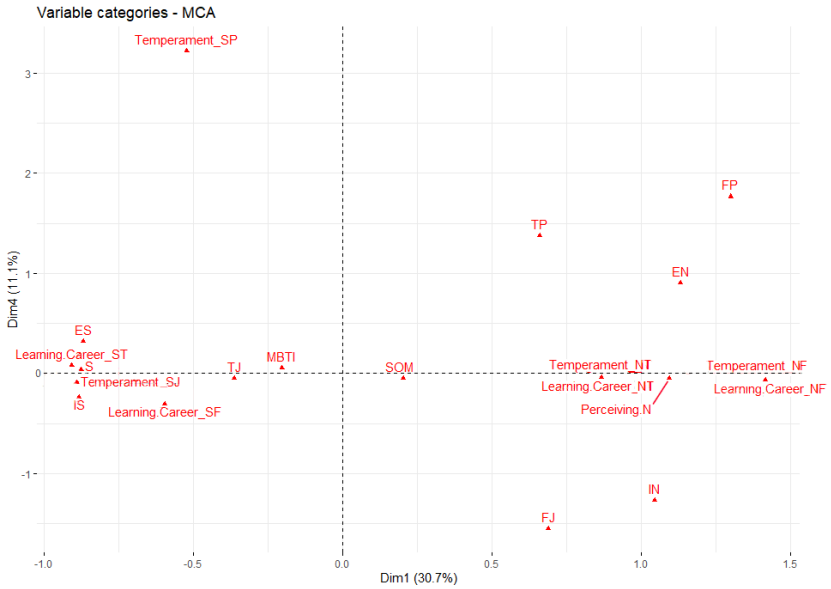

Figure 7. Distribution of Traditional MBTI and SOM clustering data in relation to dimension 1 and 4

4. Conclusions

4.1 Regarding Learning Form

Literature indicates many ways of learning that are presented by individuals, who can learn by observation, practice, writing, logical processing, or even by other not so conventional ways (Fry, Ketteridge & Marshall, 2009). The diversity implies a great challenge to the preceptor, who must maintain a balance between the formalism of the presentation of content and how this information will be applied to the student, so that they can be fixed by the students (Felder et al., 2000). The objectives will not be achieved if the teacher fails in this challenge.

The combinations of psychological types impact on peculiar learning characteristics, according to Myers (1998) as indicated in Table 11, which also presents the percentages of entering students according to their learning pattern that were observed in this research during the data collection period. The percentage presented in the table shows the portion of entering students in front of these patterns and in front of the data analysis method.

Types	ST	NT	NF	SF
MBTI traditional	43.0%	28.2%	15.9%	9.9%
SOM	47.1%	28.7%	24.3%	0%
Learning mode (Myers,1998)	They learn best through hands-on activities; They need information about useful. practical things that they can use in everyday life; Well-defined instructions are fundamental.	They learn from theories about how things work; Need to analyze and apply logical concepts; Need to be challenged to solve problems	Perform better with symbolic and metaphorical activities. which use imagination and creativity; Require individual recognition of their merits	They learn by doing the activities; Need instructions and friendly interactions.

Table 11. Combination of MBTI types regarding learning

The ISTJ and ESTJ profiles are the most observed psychological types, together representing 47.1% of the results under the SOM Artificial Intelligence method and proving to be very relevant in the analysis of outliers. These groups require defined activity rules regarding deadlines and course organization.

Specifically, for ISTJ profiles, there is a strong sense of responsibility in their relationships, they prefer to work alone, but can act in a group when the activity is carried out correctly. They usually focus only on logic, are systematic, practical, sensitive and realistic. They can get frustrated and negativistic if they are not able to use their skills. As for the ESTJ group, they usually think logically and analytically, are decisive, clear, assertive, and pragmatic. They tend to be good managers. However, they can be intrusive, think they are experts about situations, and are impatient with people who don't follow the rules (Myers, 1998).

The Judgment preference type (J) is presented in 83.9% of the types in the result from the SOM algorithm. This implies that teachers should pay more attention to the organization of concepts, delimitation of activities and pre-established periods for the completion of tasks. For the 16.1% of students who represent the Perception (P) preference, it is required freedom and flexibility to perform tasks.

Through the statistical evaluation of the students' psychological patterns, it was observed that there is a recurrence of psychological profile in the students entering in an engineering department of a Brazilian university. This fact is evidenced through non-parametric multivariate analysis, which shows that certain MBTI psychological profiles stand out in relation to other minority profiles, besides the emphasis of certain profiles that stood out in univariate analysis of Outliers.

The SOM clustering of psychological profiles by affinity confirmed the results observed in the non-parametric multivariate analysis regarding the psychological patterns, since a Kruskal-Wallis analysis performed with the aim of comparing the results of the SOM analysis and the initial Non-Parametric Multivariate Analysis indicated that there are no differences between the two models. Therefore, for application of psychological profiling analysis, the SOM AI technique demonstrated a good result compared to conventional MBTI modeling, and presents the possibility to demonstrate the intensity of these psychological characteristics that are covered up in the conventional MBTI system.

The SOM analysis also indicates that 53.2% of the entrants use their Intuition (N) as an important function for learning development. These students develop well when metaphors, theories about how things work, and encouragement of the use of imagination are used.

Multiple Correspondence Analysis (MCA) was another method for comparing statistical models and SOM clustering, obtaining results that confirm that there is similarity between the models. MCA also contributed to the correlation between psychological types and associations, assisting in understanding the characteristics of the students under learn.

Thus, in the analysis of MCA dimensions 1 and 2. it was observed the correlation between the dichotomies S/N and T/F, which are directly related to learning issues of individuals. It was observed that students with the psychological trait Sensation (S) present greater similarity in their preferences in relation to those holding the Intuition (N) type, which present greater distance between characteristics clusters.

Another important feature is the tendency of clusters 1, 2, 3 and 4 to the psychological function Feeling (F), and only cluster 5 is arranged in Thinking (T). For the most part these students are part of the iGen (Net Generation. Centennials or Generation Z – since 1995) represented by 97.9% of the surveyed students, and the rest of the students do not declare their age on the questionnaire (Figure 8). Twenge (2017) highlights those individuals of this Generation live conflicted with their feelings and mental health. The author indicates among the characteristics of this Generation hyperconnectivity, individualism, insecurity in attitudes, and the vagueness of some aspects of life, in addition to slow emotional maturation. Kosic (2018) reports that these students have scholastic difficulties with the act of failure. Maulina, Abdurrahman, Sukamto, Kartika and Nurulsari (2020) reaffirms the emotional openness, preference for teamwork, goal-oriented, thrives on instant gratification related to Generation Z.

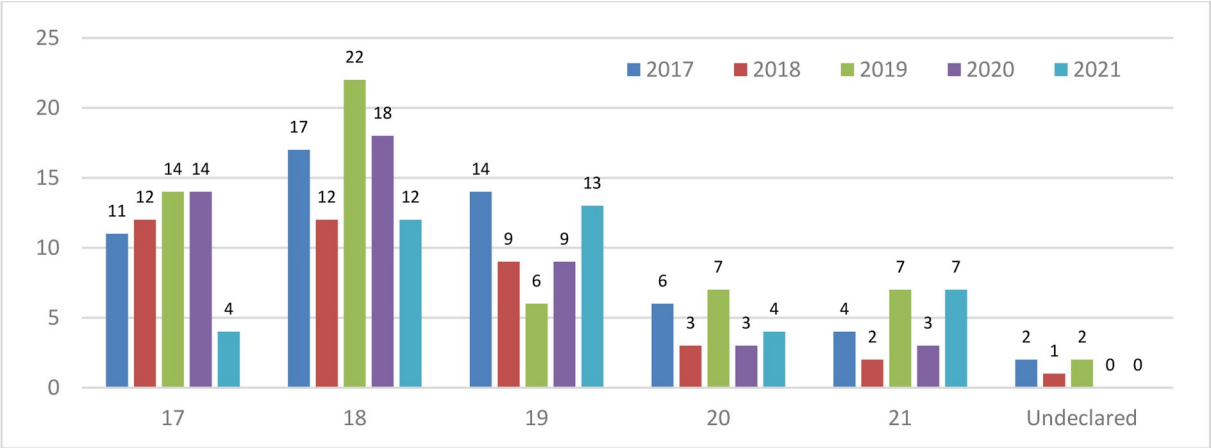

Figure 8. Age of freshmen when they entered the Engineering school. The vertical axis is the number of respondents and the horizontal axis is the entry age

The use of active learning resources can be enhanced with the knowledge about the learning channels presented by the students, and the tool about MBTI psychological types can guide the educational approach to be adopted, and allows the concepts covered in engineering courses to achieve the goal of constituting qualified professionals for the future labor market more effectively. This is valid even with the

challenge imposed to the way of presenting content to the students from generation Z, who present characteristics and attitudes that are very different from the previous generations.

For the group of metallurgical and materials engineering students at the Polytechnic School of the University of São Paulo, teaching techniques such as moments of reflection, group assessment, case studies, the use of technologies applicable in the classroom, investigative learning and experiential learning meet the personality needs of these students. The use of metaphors and imagination should be used sparingly, but explanations with theories about things should be used more massively.

Declaration of Conflicting Interests

The work was structured in a scientific manner, with the use of tools already established in the characterization of psychological types, combined with the use of new analysis technologies, such as artificial intelligence techniques applied to the model, in order to enable the repetition of the modeling. The goal is to search for alternatives to achieve better results in learning through the knowledge of psychological characteristics of students. The authors declare that they have no interest in the results or in the citations provided and there are no competing interests.

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