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Learning styles and academic performance in the digital era in Peruvian engineering students

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Abstract

The main objective of the research is to determine the relationship between learning styles and academic performance, in addition to discriminating the predominant learning style. The research is a descriptive correlational, non-experimental study. The target was the 297 students attending the School of Industrial Engineering and the sample of 233 surveyed. The Honey & Alonso - CHAEA - questionnaire with 20 questions for each style was applied. The questions analysed were those that were answered with a "YES". It was determined that there is a difference between the four styles, - p value $(0.0298) < \alpha (0.05)$ -; and that the reflective and active styles are statistically significantly different; academic performance is related to the four learning styles where the reflective style has the greatest impact with a coefficient of 0.462 followed by the theoretical style with a coefficient of 0.255; using Weka software in Machine Learning, allowed us to reaffirm that the dominant learning style is reflective, which will allow us to guide the actions of teaching and learning. It was demonstrated that there is a relationship between learning styles and academic performance $\rho = 0.833$ with $(1-\alpha) = 0.99$.

Keywords: Learning styles; academic performance; CHAEA Survey; teaching; students.

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Estilos de aprendizaje y rendimiento académico en la era digital en estudiantes peruanos de ingeniería

Resumen

El objetivo principal de la investigación es determinar la relación entre los estilos de aprendizaje y el rendimiento académico, además de discriminar el estilo de aprendizaje predominante. La investigación es descriptiva correlacional, no experimental. El objetivo fueron los 297 estudiantes que asisten a la Escuela de Ingeniería Industrial y la muestra de 233 encuestados. Se aplicó el cuestionario Honey & Alonso – CHAEA - con 20 preguntas para cada estilo. Las preguntas analizadas fueron aquellas que fueron respondidas con un “SI”. Se determinó que existe diferencia entre los cuatro estilos, valor $p(0.0298) < \alpha(0.05)$; y que los estilos reflexivo y activo son estadísticamente significativamente diferentes; el rendimiento académico se relaciona con los cuatro estilos de aprendizaje donde mayor impacto tiene el estilo reflexivo con un coeficiente de 0.462 seguido del estilo teórico con un coeficiente de 0.255; utilizar el software Weka en Machine Learning, permitió reafirmar que el estilo de aprendizaje dominante es el reflexivo, lo que consentirá orientar las acciones de enseñanza y aprendizaje. Se demostró que existe relación entre los estilos de aprendizaje y el rendimiento académico $\rho = 0.833$ con $(1-\alpha) = 0.99$.

Palabras clave: Estilos de aprendizaje; desempeño académico; Encuesta CHAEA; enseñanza; estudiantes.

Introduction

Academic performance is the indicator of students' learning and the indicator of their educational quality. It is related to a number of internal and external factors. At a worldwide level, many studies emphasise academic performance at the university level in a context where have evolved into knowledge and information and communication technologies.

Since the 1990s, higher education in Latin America has shown great interest in educational quality, with the emergence of a new vision of the market, the privatisation of public higher education, which led to an interest in studying the determinants of academic performance, finding a great diversity, among them: Personal factors (inherent to the student), social (inherent to the social environment) and institutional (Garbanzo, 2007). Of the diversity of factors associated with academic performance, the present research addresses

only learning styles, as an inherent part of the cognitive conditions referred to by Garbanzo in the personal factors.

There is a variety of research on learning styles around the world: In Spain, Arias, González & García (2020), oriented to identify the learning styles preferred by nursing students based on the Honey-Alonso questionnaire of Learning Styles (CHAEA); in Mexico, Campos & Campos (2018), administering a questionnaire of 44 questions identifies the levels of preferences in 8 dimensions grouped in pairs as established by the model of Felder and Silverman in 1988; sensory/intuitive, also visual/verbal, likewise active/reflective and finally sequential/global.

Most studies seek the relationship between learning style and academic performance, it is imperative to contribute with research related to subjects taught in higher education. Therefore, at present, teachers must acquire new teaching strategies as indicated by Tarazona et al. (2021): “The teacher must

influence, according to the complexity of the subject, and the individual and group characteristics, and differentiate which styles predominate in the classroom” (p. 294); and Chambi-Choque, Manrique-Cienfuegos & Espinoza-Moreno (2020): “Teachers and authorities must know about Learning Styles and the forms of knowledge acquisition that students put into practice” (p. 44).

However, the teacher when developing his synchronous and asynchronous sessions using a variety of media and techniques, does not guarantee that all students learn in the same way, taking into account that in a session similar conditions are considered globalising in a class; being the same study centre with the same uniform conditions both in requirements, capabilities, age and even the same teacher, results of evaluations are observed that confirm that not all students achieve uniform and satisfactory learning.

This evidence demonstrates that students have different learning capabilities or rates, which explains that each student has their own learning style, considering that they have different capabilities and that these evolve according to their needs, circumstances and time (Espinoza-Poves, Miranda-Vilchez & Chafloque-Céspedes, 2019; Esteves et al., 2020; Villacís et al., 2020; Polo et al., 2022).

It is necessary to consider that the academic performance results obtained by students not only rely on learning styles, but can also be influenced by other factors such as study habits, dysfunctional families, poor nutrition, students who combine work and study, and unconvincing teaching strategies that cause students to fail to achieve the learning that is imparted to them.

This research has only taken into account the Learning Styles as a determining factor in the academic performance of students, and our objective has been to determine whether there is a relationship between learning styles and academic performance and what are the predominant styles in Industrial Engineering students from the first to the ninth cycle university, the collection of data was conducted in the later years of 2021 through

the Honey survey, whose author states that “the fundamental bases on which the presentation of this questionnaire is based are part of the cognitive approaches to learning” (Alonso, Gallego & Honey, 1994, p. 107).

On the other hand, education and the way of learning in current times are no longer the same, the teacher is considered as a provider of new knowledge, and students as the builders of their own knowledge, and all this has been accentuated more in the “second decade of the XXI century, theories about learning vary, they are readjusted to the [different] contexts, emphasizing with respect to learning styles, there are different positions to achieve evaluate and understand learning in the student body” (Cantú-Martínez & Rojas-Márquez, 2018, p. 1).

One of the factors that has a great influence on academic performance is learning styles. Teachers, before entering the classroom, must know how students learn their new knowledge, “students learn in different ways, an element that causes each one to develop a learning style” (Tarazona et al., 2021, p. 294). It is there where learning styles constitute a pedagogical tool that makes students always motivated to receive new knowledge; therefore, it is necessary to consider that “learning constitutes a process in which knowledge is created in the mind of man through the transformation of experience” (Fernandez, 2019, p. 3).

Nowadays, organisations demand highly qualified professionals, who practice values and principles, who are capable of generating continuous and autonomous learning, who are proactive professionals, who are always designing new scenarios that have an impact on the well-being of organisations and society, hence, “one responsibility of teachers is to help students discover their style and learn to adapt it to the experiences of each situation” (Canalejas et al., 2005, p. 34).

In addition, it is necessary that students should base their actions on an active and independent participation in the new learning process, because they learn in different ways, for this reason “learning styles are seen as a

process of change that occurs in the organism, in behaviour, cognitive-cognitive abilities, motivation and emotions, as a result of the action or experience of the individual” (Bobadilla et al., 2017, p. 6).

All learning is acquired through experience, however students learn in different ways, and this leads us to reflect on the multiple factors that determine the ability to learn, hence “students’ learning preferences have been indirectly associated with student success in numerous university programmes” (Campos & Campos, 2018, p. 89).

Finally, we consider that learning styles should be understood as the ways in which students acquire new knowledge, therefore “students learn more effectively when they are taught using strategies according to their predominant learning styles” (Jiménez et al., 2019, p. 3).

The analysis of achievement is highly complex due to the many variables that influence it internally and externally, from psychological and physiological to pedagogical, socio-economic, family and especially educational. In the effort to conceptualise achievement from the assessments that students are subjected to, it is necessary to consider not only the individual student’s approach but also the effects as an influence that they receive from the educational and family perspective (Martínez, Renés & Martínez, 2019).

There are various factors that influence students’ learning and achievement or academic performance, including: Motivation, prior knowledge, aptitudes, beliefs, personality and learning styles; however, the complexity of establishing the most significant factors that favour performance can exclude some that, although secondary, are still decisive (Cabrera y Fariñas, 2007; Vivas, Cabanilla & Vivas, 2019).

Research concerning to academic performance conceptualises it as: 1) a quantitative outcome; 2) a quantified or unquantified evaluative judgement on academic training; or 3) a combined process and outcome, assuming performance as a process and outcome, on the student’s

capabilities and ‘know-how’ (Polo & Niño, 2018).

It has been discovered that the academic performance of students is regular and at the same time teachers are lacking knowledge of learning styles because most of them are trained as engineers (Yana et al., 2021), which states that “the higher the level of applicability of the different teaching styles, the better and higher the academic performance of students” (p. 133), the knowledge of these styles on the part of teachers could improve the academic performance of students.

In this research, the relationship between learning styles and academic performance has been determined. Likewise, identify the predominant learning style that is most related to the academic performance of Industrial Engineering students at the “Universidad Nacional José Faustino Sánchez Carrión” in Peru”.

Learning strategies are sequences of procedures that allow acquiring, storing and using knowledge (Pizano, 2012). This requires teachers to know the strategies and the functions of each one of them and how they can be used and complemented with motivation and work (Montes de Oca & Machado, 2011).

According to Honey and Mumford (1992); Guerra, Zuluaga & Saravia (2019); Esteves et al. (2020); Villacís et al. (2020); Polo et al. (2022) each person will manifest different ways of absorbing or assimilating knowledge to increase their comprehensive training; their style when learning: Active, Reflective, Theoretical, or Pragmatic; Therefore there will be Active learners: Those who fully involve and without prejudice in new experiences, getting involved in the affairs of others, as well as centering all activities around them, characterized by being entertainers, improvisers, risk-takers, spontaneous, adventurous, as well as creatives.

For their part, the Reflective: They reflect on all the alternatives before making a move or making a decision, they gather data by analysing it carefully, they observe others and create a slightly distant, as well as condescending, climate around them, they are

characterized by being receptive, analytical, observant, patient, prudent, as well as distant. Theorists: Refers to those who adapt and integrate observations within logical and complex theories, they like to analyze and synthesize, as well as seek rationality and objectivity, fleeing from the subjective and ambiguous; Therefore, they are methodical, logical, objective, critical, structured, as well as systematic.

Finally, the Pragmatic style: It refers to the fact that their strong point is the practical application of ideas, they like to act quickly and safely on those ideas, projects that attract them, not hesitating to put them into practice; Unlike the rest of the styles, these learners are described as experimenters, realistic, planners, organized, practical and direct.

The students of the School of Industrial Engineering in their learning process mostly use the reflective and pragmatic style, then, the appropriate strategy to be used within a class session should consider, just like those pointed out by Negrete (2012); and Flores et al. (2017):

a. Consider the general characteristics of the learners (level of cognitive development, background knowledge, motivational factors, among others).

b. The type of knowledge domain in general and of the curricular content to be addressed.

c. The intentionality or goal to be achieved and the cognitive and pedagogical activities to be undertaken by the learner in order to achieve it.

d. Constant monitoring of the teaching process (of previously employed teaching strategies, if pertinent), as well as of student progress and learning.

e. Determine the inter-subjective context (e.g. knowledge already shared) created with

the learners up to that point, if applicable.

The reflective learning style is identified by people who prefer to record experience by collecting data and analysing it carefully, being thoughtful, conscientious, receptive, analytical, as well as exhaustive (Cantú-Martínez & Rojas-Márquez, 2018; Polo et al. 2022).

1. Methodology

The research covers a non-experimental design in its descriptive correlational variant, because we have determined the relationship between the variables learning styles and academic performance. The population consisted of 297 students enrolled in the 2021-I academic semester from I to IX cycle at the School of Industrial Engineering of the “Universidad Nacional José Faustino Sánchez Carrión” in Peru, during the 14th week of classes and was answered by 233 students; in this sense, the sample was determined by convenience following the criteria of accessibility and availability. The sample inclusion criteria considered the students present at the time of the application of the survey.

The CHAEA survey was used, which consists of 80 questions with two dichotomous options (YES and NO). “YES” means agreeing with the question asked and “NO” means disagreeing. Its execution was under the supervision of the teacher of the subject at the time the instrument was applied. The questionnaire was structured as a web form whose link was provided to the students at the beginning of the virtual classes. Each learning style included 20 questions. The distribution is detailed in Table 1.

Table 1
Distribution of items for each learning style

Number	Active	Reflective	Theoretical	Pragmatic
1	3	10	2	1
2	5	16	4	8

Cont... Table 1

3	7	18	6	12
4	9	19	11	14
5	13	28	15	22
6	20	31	17	24
7	26	32	21	30
8	27	23	34	38
9	35	36	25	40
10	37	39	29	47
11	41	42	33	52
12	43	44	45	53
13	46	49	50	56
14	48	55	54	57
15	51	58	60	59
16	61	63	64	62
17	67	65	66	68
18	74	69	71	72
19	75	70	78	73
20	77	79	80	76

Source: Own elaboration, 2022 from Alonso et al. (1994).

The results of the students' academic performance were provided by the academic records office at the end of semester 2021-I. For statistical processing we used ANOVA tool, to test the equality of the means of the students' learning styles, this "procedure is based on the assumptions that the selected samples are independent and the populations involved are normal with equal variance (homoscedasticity condition), although unknown" (Durand & Ipiña, 2008, p. 317).

Complementary to ANOVA, we used Tukey's criterion for pairwise comparison (Webster, 2005). Likewise, the multiple linear regression test has also been used, which according to Levin & Rubin (2011) "the correlation between two variables may be insufficient to determine a reliable estimating equation; however, if we aggregate data from more independent variables, we can determine an estimating equation that more accurately describes the relationship" (p. 566).

The analysis performed with Machine Learning, which is a software supported by algorithms belonging to the field of Artificial

Intelligence, is processed on high-performance computers, data mining identifies patterns of behaviour housed in Big Data; this allows to run predictive processes and arborisation for business decision making; here, it is sought not to incur in type I error where the treatment having no effect, it is decided to accept the null hypothesis; or type II error where the treatment if it has an effect, we do not accept it and therefore reject the hypothesis. On the other hand, once the data mining is executed, it is processed probabilistically for decision making, as well as the hypothesis testing, and finally the unsupervised process is executed.

To complete the structured statistical process, we used Spearman's Rho test, which is a non-parametric measure to determine the dependence relationship between two variables. For the processing of the information, we have used statistical software such as: Excel 2019, XLSTAT 2022.1.2, Statistical Package for the Social Sciences (SPSS) version 25, Minitab 18.1 and Machine Learnig - Weka 3.9.5.

2. Results and discussion

The CHAEA instrument was tested, consisting of 80 questions for the four learning styles: Active (1), Reflective (2), Theoretical (3) and Pragmatic (4), with 20 questions each.

The results obtained show the knowledge or proficiency in one or more learning styles. The Reflective and Theoretical learning styles were the most preferred by industrial engineering students with 27.3% and 26.1% respectively (see Table 2).

Table 2
Most preferred learning styles of Industrial Engineering students

Styles	Amount (*)	%
Active	2,994	21.5%
Reflective	3,804	27.3%
Theoretical	3,632	26.1%
Pragmatic	3,491	25.1%
Total	13,921	100%

Note: * The frequencies refer to the preference of each style based on the “Yes” answers according to CHAEA. Includes the 233 students surveyed in cycles I to IX.

Source: Own elaboration, 2022.

These results were analysed by the five procedures detailed below:

2.1. Procedure 1: Analysis of Variance Test (ANOVA)

This test was applied to analyse whether the proficiency of the four styles on average is similar or whether there is one style that stands out. The hypotheses are:

H₀: $\mu_1 = \mu_2 = \mu_3 = \mu_4$; **H₁:** At least one of the styles is different from the others.

The results in Table 3, indicate that there is sufficient evidence to support the claim that the four means are not equal, concluding that the proficiency of the four styles shows some significant difference. This is supported by the fact that the calculated “F” is greater than the critical “F” and also that the p-value (0.0298) < α (0.05).

Table 3
ANOVA analysis of variance test results

Source	SS	df	MS	F	F _{critical}	p-value	
Between	17715,94	3	5905,31	3,15	2,72	0,0298	Reject
Within	142462,3	76	1874,5				
Total	160178,2	79					

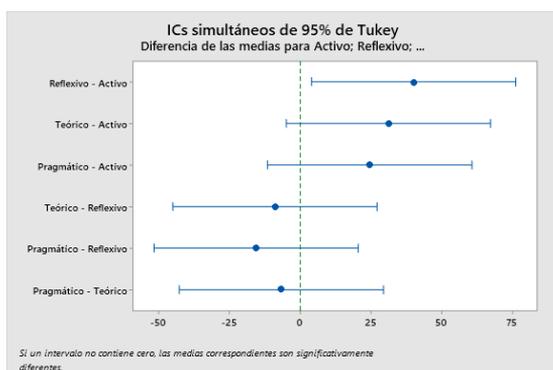
Note: Significance level $\alpha=5\%$. Processed with SPSS version 25.

Source: Own elaboration, 2022.

2.2. Procedure 2: Tukey's test

In order to determine which styles show significant difference, Tukey's pairwise comparison was performed, which indicates

that the reflective style and the active style are significantly different (not including zero). The other pairs of styles show no significant difference. The details are shown in Figure I.



Note: Processed in Minitab 18.1.

Source: Own elaboration, 2022.

Figure I: Tukey's pairwise comparison

2.3. Procedure 3: Multiple linear regression test

For the modelling of the research we used the multiple linear regression test for the

Learning Styles and Academic Performance variables. The highest mean value corresponds to the reflective style and the lowest to the active style (see Table 4). The equation of the multiple linear regression model is:

$$RA = +0,145 * E.Active + 0,462 * E.Reflective + 0,255 * E.Theoretical - 0,030 * E.Pragmatic$$

(1)

This equation will allow to theoretically establish academic performance, with the

assumption that the variable that determines it is the student's mastery learning style.

Table 4
Summary for quantitative variables

Variable	Media	Standard deviation
E Active	12,863	3,082
E Reflective	16,339	2,236
E Theoretical	15,541	2,624
E Pragmatic	14,644	2,861

Note: Processed in XLSTAT.

Source: Own elaboration, 2022.

It can be seen from the equation that the Reflective Style has the greatest impact on academic performance with a value of +0.462, followed by the Theoretical Style with +0.255 (see Table 5). These two styles are the most important for the academic performance of the students. The Pragmatic Style has no impact on academic performance.

Table 5
Research model parameters

Parameter	Value	Standard deviation	Student's t-test	Pr > t	Lower limit 95 %	Upper limit 95 %
Intersection	0,000	-	-	-	-	-
X1 E Active	0,146	0,052	2,788	0,006	0,043	0,249
X2 E Reflective	0,462	0,062	7,442	0,0001	0,340	0,585
X3 E Theoretical	0,255	0,068	3,745	0,000	0,121	0,389
X4 E Pragmatic	-0,030	0,070	-0,424	0,672	-0,168	0,108

Note: Processed in XLSTAT.

Source: Own elaboration, 2022.

2.4. Procedure 4: Machine Learning - Weka

By performing an unsupervised statistical analysis with the Machine Learning software Weka and processing the static information contained in the cluster, without considering the supervision variable - academic performance -, two centroids are determined which measure the Euclidean distances forming nodes; after activating the

unsupervised filters in the pre-processes, the attribute from numeric to binary to consider the dichotomous variables in the learning styles, and, sequentially selecting the clustering option for the evaluation of the clusters, activating the simple K-means algorithm selecting the use training set mode, it is found for the 233 students that the Reflective style (1, 1) and the Theoretical style (1, 1) represent 82 % of the domain of the styles (see Figure II).

```

Final cluster centroids:

Attribute                Full Data          Cluster#
                        (233.0)           (42.0)           (191.0)
=====
i>ESTILOACTIVO_binarized      0           0           0
ESTILOREFLEXIVO_binarized     1           1           1
ESTILOTEORICO_binarized       1           1           1
ESTILOPRAGMATICO_binarized    0           0           0
RENDIMACADEMICO              13.176     11.0476     13.644
    
```

Note: Processed in Machine Learning software Weka, using the data matrix of 233 surveys.

Source: Own elaboration, 2022.

Figure II: Identification of dominant learning styles

When executing the split percentage evaluation, in which the software discriminates and determines valid data and separates those that have distorted and illogical responses, in the cropped sample of 153 students, it can

be seen in Figure III, which is the Reflective style (1, 1) with which students learn best, with 35% mastery of the style, compared to 65% distributed for the other three styles.

```

Missing values globally replaced with mean/mode

Final cluster centroids:

Attribute                Full Data          Cluster#
                        (153.0)           (109.0)           (44.0)
-----
i»jESTILOACTIVO_binarized    0                0                0
ESTILOREFLEXIVO_binarized    1                1                1
ESTILOTEORICO_binarized      1                1                0
ESTILOPRAGMATICO_binarized   0                0                1
RENDIMACADEMICO              13.1111         12.9633         13.4773

Time taken to build model (percentage split) : 0 seconds

Clustered Instances

0      52 ( 65%)
1      28 ( 35%)
    
```

Note: Processed in Machine Learning software Weka, using the discriminated data matrix 153 surveys.

Source: Own elaboration, 2022.

Figure III: Identification of the dominant learning style

2.5. Procedure 5: Spearman's Rho test

Once the results had been analysed using the four previous procedures, the hypotheses set out in the research were validated. Spearman's correlation model was chosen, which determines that there is a relationship between learning styles and academic performance and that this relationship is not due to chance, but is statistically significant. The following hypotheses were put forward:

H₀: Learning styles are not related to academic performance in the digital era in engineering students in Peru.

H₁: Learning styles are related to

academic performance in the digital age in engineering students in Peru.

Spearman's Rho test was performed with 181 pairs of data, which were left by eliminating those that generated distortion in the data, such as cases of high mastery of styles and low academic performance. A correlation of 0.833 and a p-value = 0.000 were found (see Table 6). As the p-value = 0.000 < 0.01 we can state, with 99% confidence, that there is a relationship between learning styles and academic performance in the digital age in engineering students in Peru, having a high positive correlation of 0.833 (83 %).

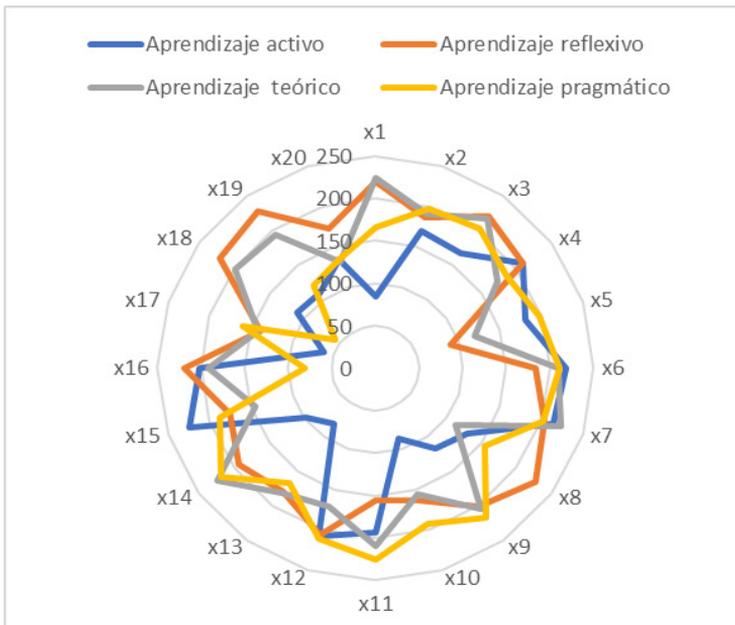
Table 6
Spearman's Rho correlation

Spearman's Rho		Style	Academic performance multiple regression
Style	Correlation coefficient	1,000	0,833*
	Sig (Bilateral)		0,000
	N	181	181
Performance Acad. multiple regression	Correlation coefficient	0,833*	1,000
	Sig (Bilateral)	0,000	
	N	181	181

Note: * Correlation is significant at the 0.01 level (bilateral). Processed in SPSS v25.

Source: Own elaboration, 2022.

Likewise, Figure IV shows the learning styles of industrial engineering students, demonstrating that the predominant style is reflective, followed by theoretical.



Note: Based on Kolb Model. Processed with Excel.

Source: Own elaboration, 2022.

Figure IV: Learning styles of industrial engineering students

The research carried out determined a statistical value of the p-test value of 0.000 lower than the assumed significance level of 0.01, so it can be conclusively state that there is a relationship between the variables learning styles and performance, this coincides with Tarazona et al. (2021), who state that there is a direct relationship between learning styles and academic performance of students in the course of differential calculus of the I cycle of the school of fluid mechanics of the Universidad Nacional Mayor de San Marcos.

The research by Chambi-Choque et al. (2020), indicates that learning styles in nursing interns at the public university are dominated by reflective learning (0.80), followed by theoretical learning (0.75), which coincides with the present research, where it has been determined that the reflective style has the greatest impact with a value of +0.462, followed by the theoretical style with +0.255.

Unlike this research, which determined that there is a relationship between the variables of learning styles and academic performance, Vivas et al. (2019); and Chambi-Choque et al. (2020), found no significant statistical evidence of association between learning styles and academic performance respectively.

Conclusions

The present research determined the existence of a direct and significant relationship between learning styles and academic performance in engineering students in Peru. The statistical analysis shows that the reflective style has a greater impact on student performance, followed by the theoretical style. These results highlight the importance of considering individual learning styles in engineering education processes to implement more effective teaching strategies that improve academic performance.

The study also found significant differences between the four styles evaluated through variance analysis. Specifically, the reflective and active styles showed greater

variability among students. This finding provides evidence of the distinctions that exist in the learning methods of industrial engineering students.

Moreover, multiple linear regression enabled the mathematical modeling of the relationship between the main variables, confirming the positive effect of the reflective and theoretical styles on performance. This model provides a quantitative representation of the differentiated influence of each learning style.

On the other hand, unsupervised data processing with Machine Learning corroborated the predominance of the reflective style among the students in the sample. This Artificial Intelligence technique adds robustness to the identification of the most frequent learning styles in this population.

In summary, the findings agree with previous research that links the reflective style with better academic performance. Therefore, it is valuable for teachers to know the individual styles of their students to implement effective educational strategies that positively enhance their performance.

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