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CLUSTER ANALYSIS FROM A RESEARCH STUDY ON DIGITAL COMPETENCES IN UNIVERSITY PROFESSORS

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ABSTRACT

This study aimed to analyze the relationship between variables: sex, academic degree, teaching experience, age, and type of employment contract, with the digital skills from university professors in the Sucre Department in Colombia. The questionnaire from Agreda *et al.*, (2016) was applied to a sample of 354 professors made up of four dimensions: 1. Use and technological literacy, 2. Educational methodologies through Information and Communication Technologies in the classroom (ICT), 3. Training of university professors in ICT and attitude towards ICT in higher education. For the information analysis, a segmentation process was carried out through cluster analysis. As a result, it could be established that the segment configuration through the clusters in each dimension suggests that there is no relationship between the variables: sex, academic degree, teaching experience, and type of employment contract with the dimensions of digital skills from the studied professors. There is only evidence of a relationship with the age variable, seemingly showing that younger professors have better digital skills than the older ones.

1. INTRODUCTION

Studying the digital skills from university professors has become an interest topic for academic schools in recent years since these skills are regarded as an

element of educational quality in the new context that set up ICTs for educational processes (Mas Torelló & Pozos Pérez, 2012), since they are considered tools that enrich student training and the professor knowledge (Aguirre Aguilar & Ruiz Méndez, 2012).

There are several methodologies being used to know the digital competences that university professors have in different contexts. Among them, it can be highlighted from the work from Castellanos Adarme *et al*., (2018), use of ethnography and a hermeneutical analysis method; in Fernández Márquez *et al*., (2018) and Carrera Farran & L. (2012), questionnaire use; in Pérez *et al.,* (2017) use of documented professional development or training experience with self-diagnostic examination; and in Sanabria & Ana Cepeda, (2014), documentary review. In this regard, Agreda *et al*., (2016) states that the questionnaire is the most used instrument in methodological designs to diagnose digital competences in university professors.

The objective of this research study is to analyze the possible relationship between variables such as sex, age, academic degree, employment contract type, and teaching experience, with dimensions of digital skills, such as: use and technological literacy, educational methodologies through ICT in the classroom, professional development of university professors in ICT, and attitude towards ICT in higher education. It is considered therefore, that the methodology that best suits these purposes is the cluster analysis.

Cluster analysis is a method currently used to segment or classify groups seeking to identify the most heterogeneous subjects among themselves but as homogeneous as possible within each group (Valderrey Sanz, 2010). Each segment or group will be called a cluster (Vega-Dienstmaier & Arévalo-Flores, 2014) and can be used in different knowledge areas in which diagnostic classifications are required, such as the digital skills from teachers, needed in the new era of virtual teaching and that became mandatory due to the COVID - 19 pandemic.

2. METHODOLOGY

This research study is of an applied-technological type and according to the used information and techniques, it is considered quantitative. The questionnaire on the Digital Competence of Higher Education professors was used and carried out by Agreda *et al.,* (2016), built from studies and research on the subject and made up of 112 items, distributed in four dimensions:

DIMENSION 1: Technology use and literacy
DIMENSION 2: Educational methodologies through ICT in the classroom.
DIMENSION 3: Professional development of university professors in ICT.

DIMENSION 4: Attitude towards ICT in higher education

Each question from each dimension became a study variable with a Likert scale that, for the first three dimensions, ranged from 1 to 4, with 1 meaning "null" knowledge or competence from the professor, and 4 meaning "Very high" knowledge or competence". In the dimension 4 case, the Likert scale also ranged from 1 to 4, but in this case 1 meant "Strongly disagree" with the dimension sentence and 4 corresponded to "Totally agree". 354 teachers were surveyed in total in the Sucre Department for a total of 39,684 data items divided by dimensions.

For each dimension, a segmentation process was carried out through cluster analysis, whose purpose is to find classifications in the data from the subjects of study for efficient grouping according to homogeneity. The number of groups is not known in advance, so it is defined in a first step by using the hierarchical method.

The hierarchical method is an algorithm that establishes the number of clusters starting with n clusters, where each one is a study subject. Later, it estimates the distances of each one with the other points in the matrix of distances n x n (Figure 1). In this matrix, distance of each one from itself is zero, and each element ij outside of that diagonal is the distance between data of subject i and subject j.

$$D = \begin{pmatrix} d11 & d12 & . & . & . & d1n \\ . & d22 & . & . & . & . \\ . & . & & & & \\ . & . & & & & \\ . & . & & & & \\ . & . & & & & \\ dn1 & dn2 & . & . & . & dnn \end{pmatrix}$$

Figure 1: Distance matrix

The algorithm starts from the smallest distance of the subjects forming a first group, to later find the second smallest, and form another group, and so on until forming (n -1) groups, *i.e.*, the distance matrix remains of size (n-1) x (n-1), which can be observed in the cluster history and in the dendrogram. There are multiple grouping methods, being highlighted the Ward Method, which does not use distances but seeks that there is the least possible variability within the group, *i.e.*, that each cluster is as homogeneous as possible

In general, the procedure for each dimension was as follows: first, cluster number determination using the Ward Link technique for classifying the variables into clusters. Secondly, each cluster validation to determine whether

there were indeed differences between the characteristics of the groups by means of a hypothesis test (Equation 1). The technique used for this validation stage was the one-way ANOVA since there were more than two groups.

$$Ho: \mu1 = \mu2; H1: \text{At least one } \mu i \text{ is different. (1)}$$

Finally, graphing of each one of the clusters was done by Principal Component Analysis (PCA) using two factors: F1 and F2; for all cases F1 being the horizontal axis and F2 being the vertical axis of the graph and differentiating the subjects of each cluster by means of a color code.

3. RESULTS AND DISCUSSION

3.1 Clusters Dimension 1

With the dendrogram graph, the cluster analysis result, it was found that teachers in the sample regarding dimension 1, could be grouped into 4 clusters. With the used algorithm, a new variable was created in the study's database as "Dimension 1 Cluster" and each teacher was assigned one belonging to each cluster, allowing to know the main characteristic variables of each one. With the list of Figures from 2 to it was possible to determine that most women are in cluster 1, and men in cluster By age, cluster 1 is made up of professors between 36 and 40 years old, like clusters 2 and 3, although in cluster 3 the range between 41 and 45 years is also more prevalent. Cluster 4 differs from the rest in that its majority is in the range of 51 and 55 years.
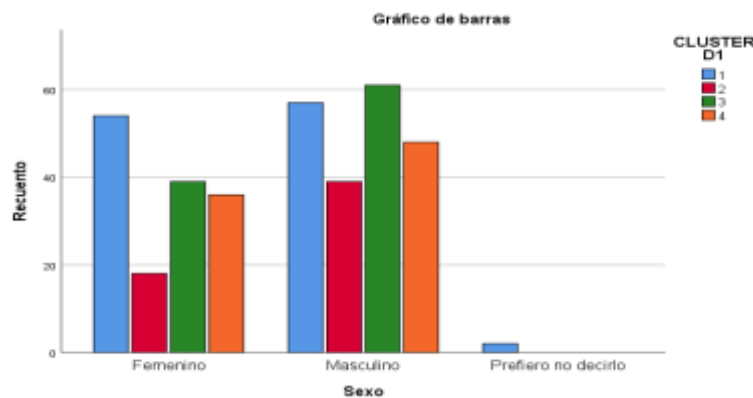

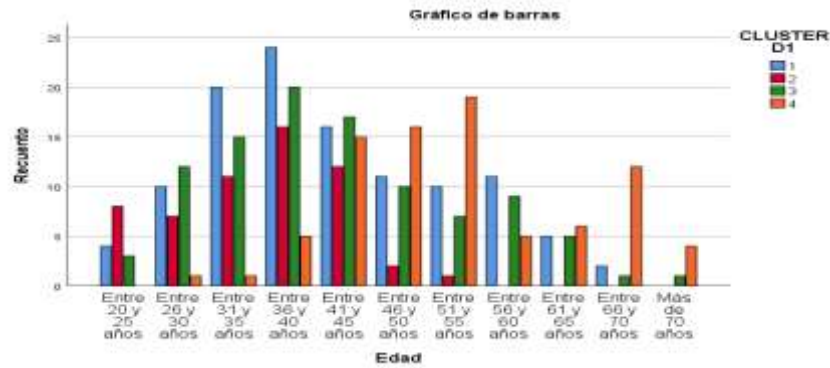Figure 1: Grouping by gender variable dimension 1

Figure 2: Grouping by variable age range dimension 1
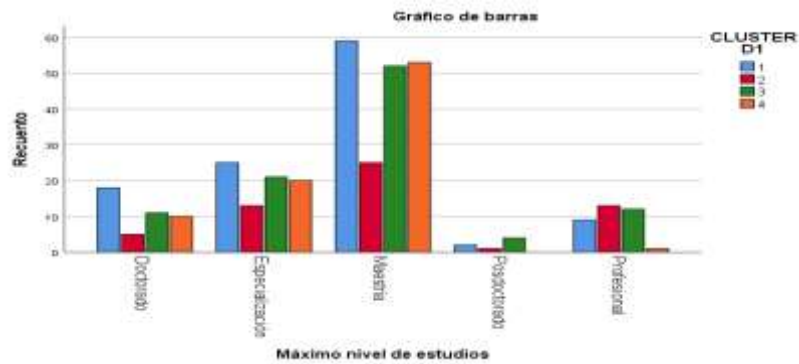

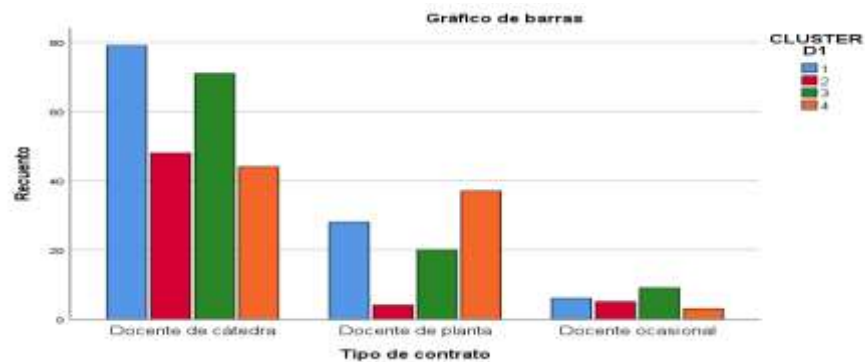Figure 3: Grouping by variable maximum level of studies dimension 1

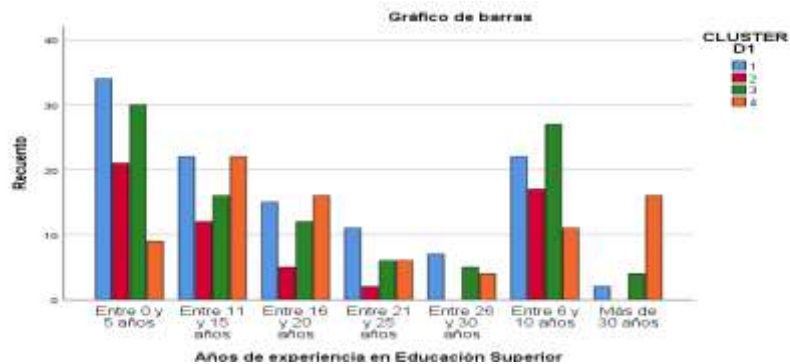Figure 4: Grouping by variable contract type dimension 1

Figure 5: Grouping by variable range higher teaching experience dimension 1

Regarding academic degree (Figure 4), although in all clusters there is a prevalence of the master's level, it can be observed that only with a professional level, cluster 2 is prevalent, and only with a doctoral level, cluster 1 prevails.

With the variable of type of employment contract, it is observed that most professors in general are professors with a teaching contract and, to a lesser extent, adjunct professors. The full-time professors are distinguished as belonging to cluster 4. Finally, with the education experience variable, it can be observed that in cluster 1 professors with less experience are predominant, while cluster 4 indicates the population with more teaching experience, coinciding with the age range analysis.

In the validation stage, first a comparison of the means of the variables of the dimension was made with the new variable mean, and later the hypothesis test was carried out with the independent variables age range, contract type, highest academic degree, and teaching experience.

Table 1. One-factor ANOVA Dimension 1

	Sum of squares	df	Quadratic average	F	Sig.
Between groups	463.118	3	154.373	35.631	0.000
Within Groups	1516.373	350	4.332		
Total	1979.492	353			

Given that the significance level found was less than 0.05 in every case, it can be concluded that at least one of the means is different and it can be established that for this dimension, the four clusters are well formed. Table 2 shows the KMO Test with a coefficient of 0.960 close to 1. Thus, it can be determined that the Principal Component Analysis is significant.

Table 2. KMO and Bartlett test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.960
Bartlett's sphericity test	Chi-square approximation	11965.322
	df	990
	Sig.	0.000

Scores of each variable in each factor are indicated on the Component Matrix (Table 3). According to the distribution of the obtained scores in this

research, the following names are assigned to each of the factors or components:

Table 3. Matrix of Main Components

	Componente	
	1	2
D1C1	.613	.359
D1C2	.585	.486
D1C3	.695	.091
D1C4	.709	.213
D1C5	.597	.474
D1C6	.687	.460
D1C7	.653	.370
D1C8	.620	.305
D1C9	.592	.477
D1C10	.654	.454
D1C11	.738	.360
D1C12	.503	-.012
D1C13	.551	-.192
D1C14	.536	.207
D1C15	.618	-.200
D1C16	.775	-.145
D1C17	.723	-.195
D1C18	.756	-.054
D1C19	.759	-.145
D1C20	.739	.103
D1C21	.746	.181
D1C22	.656	.146
D1C23	.599	-.173
D1C24	.655	-.123
D1C25	.679	-.081
D1C26	.640	-.456
D1C27	.639	-.493
D1C28	.678	-.105
D1C29	.694	-.278
D1C30	.684	-.234
D1C31	.684	-.023
D1C32	.674	-.028
D1C33	.590	.122
D1C34	.643	-.291
D1C35	.694	-.111

F1: Professors with basic technological use and literacy, such as knowledge of basic components of ICT (peripherals, external storage, digital whiteboards and projectors, word and image processors, spreadsheets and databases, email, browsers, and search engines), use of WhatsApp, online presentations, and Management and use of tools and storage within cloud environments such as Dropbox.

F2: Teachers with advanced technological use and literacy, such as Management and distribution of resources through web 2.0 applications (Blogs, Wikis, Forums, Videoblogs), Management and use of tools and storage within cloud environments other than Dropbox, Knowledge and use of management platforms, Management of device protection software, and care in data protection and Management and online publishing tools, among others. Considering the above, the scatter plot of Figure 7 was obtained, in which Factor 1 is found on the X axis and Factor 2 is found on the Y axis.
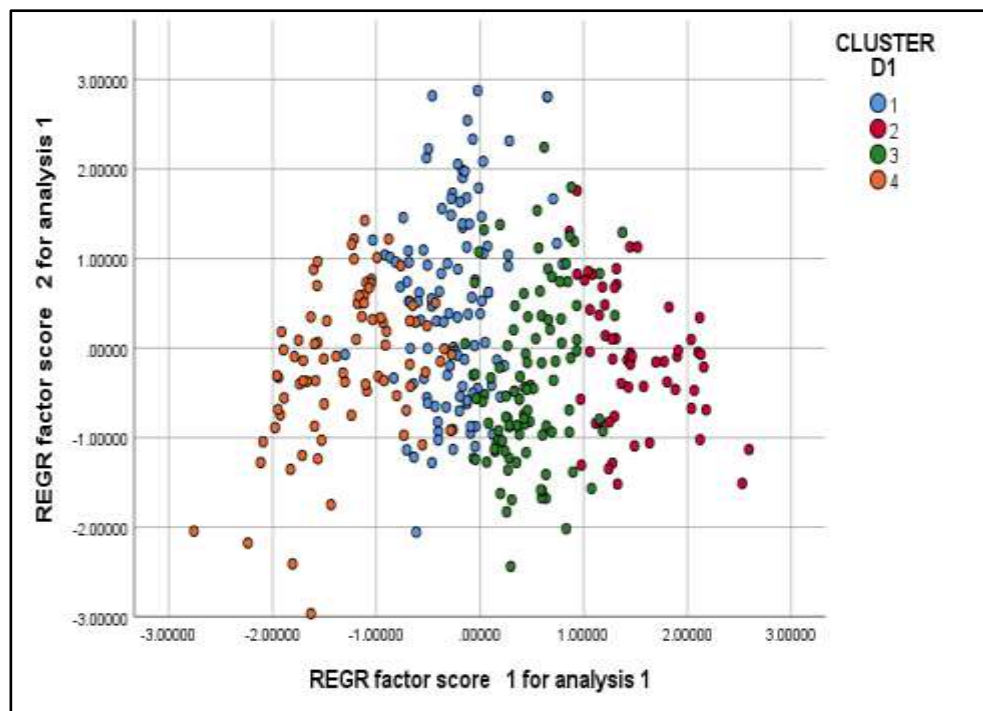
Figure 7: Scatter plot of professors grouped by cluster in the factors of the Principal Component Analysis

Each cluster is marked with a distinct color. Factor 1 is presented on the **x-axis**. A clear distinction can be observed in the use and basic technological literacy between the clusters, with those in cluster 4 (orange) being lower and those in cluster 2 (red), higher. Regarding Factor 2 of **advanced technological use and literacy** shown in the **y-axis**, there is cluster 1 (blue

color) with the highest average in scores and cluster 4 with the lowest, i.e., with fewer skills in the use and advanced technological literacy.

3.2 Clusters Dimension 2

With the dendrogram graph, result of the cluster analysis of the second dimension, it is found that the teachers in the sample can be grouped into 3 clusters. With the used algorithm, a new variable was created in the study's database as "Dimension 2 Cluster" and each professor was attributed to belong to a cluster, allowing us to know the main characteristic variables of each one.
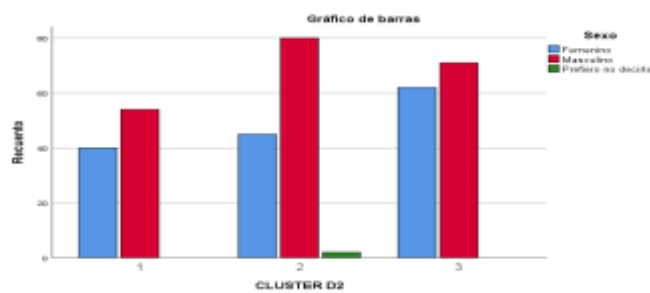
Figure 6: Grouping by gender dimension 2
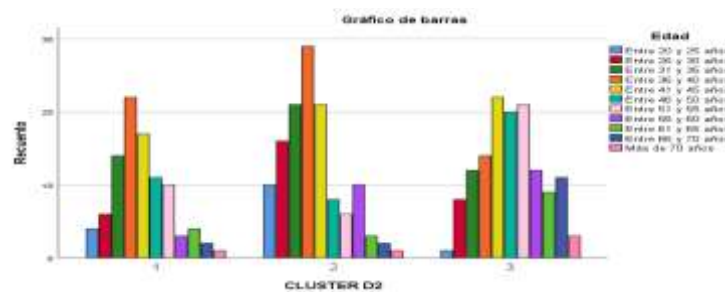
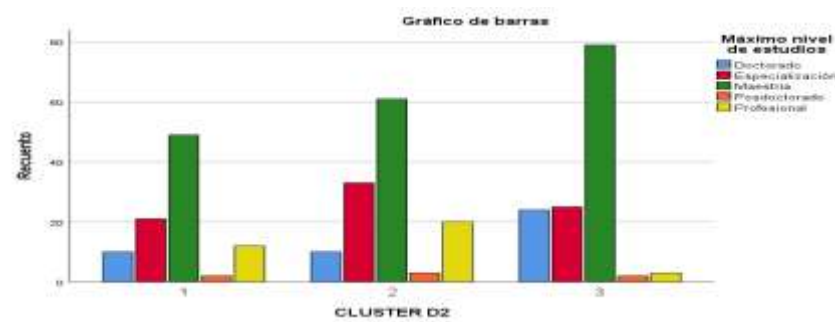Figure 7: Grouping by variable age range dimension 2

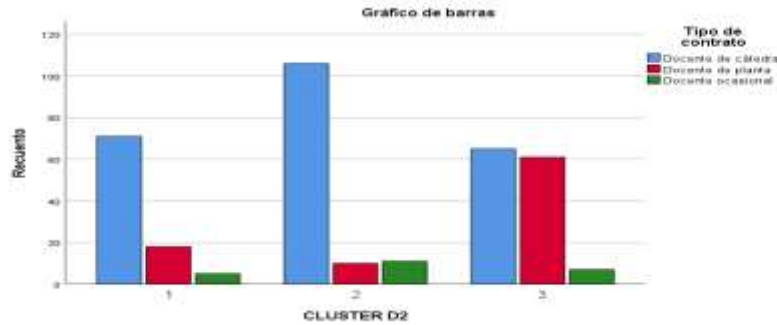Figure 8: Grouping by variable maximum level of studies dimension 2

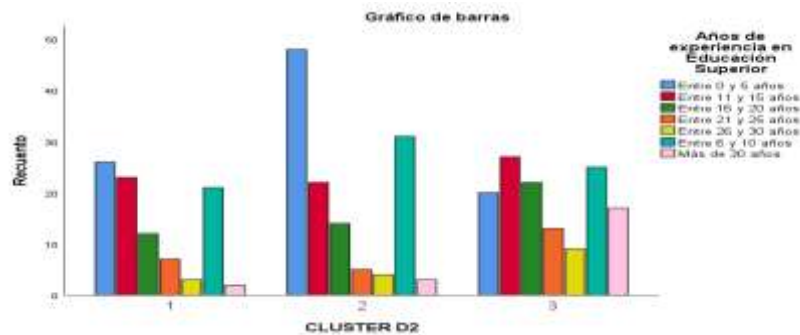Figure 9: Grouping by variable contract type dimension 2

Figure 10: Grouping by variable range higher teaching experience dimension 2

With the list of Figures from 8 to 12, it could be established that in this dimension 2, grouped into 3 clusters, men are more concentrated in cluster 2, while women are in cluster 3. Regarding age, Cluster 2 is characterized by belonging to most of the population with the age between 36 and 40 years; while in cluster 3 those with the age range between 41 and 45 years have more participation.

Regarding academic degree, although in the three clusters the largest number have a master's degree, these are more concentrated in cluster 3. By type of hiring contract, it can be identified that full-time professors are concentrated in cluster 2 and those full-time in cluster 3. Finally, regarding teaching experience, those with less experience are in cluster 2 (from 0 to 5 years) and those with more experience in cluster 3.

In the validation stage, first a comparison of the means of the dimension variables was made with the new variable mean and later the hypothesis test was carried out with the independent variables age range, type of hiring contract, academic, and teaching experience.

Table 4. One-factor ANOVA Dimension 2

	Sum of squares	df	Quadratic average	F	Sig.
Between groups	196.166	2	98.083	19.305	.000
Within Groups	1783.325	351	5.081		
Total	1979.492	353			

Given that the significance level found is less than 0.05 in all cases, it can be concluded that at least one of the means is different and it can be established that for this dimension, the three clusters are well formed.

Table 5 shows the KMO Test with a coefficient of 0.960 close to 1, so it can be determined that the Principal Component Analysis is significant.

Table 5. KMO and Bartlett Test Dimension 2

Kaiser-Meyer-Olkin measure of sampling adequacy		0.965
Bartlett's sphericity test	Chi-square approximation	9332.983
	df	465
	Sig.	0.000

Scores for each variable in each factor are indicated in the Components Matrix (Table 6). According to the distribution of the scores obtained in this research the following names were assigned to each of the factors or components:

Table 6. Matrix of Components

	Componente	
	1	2
D2C50	.713	.053
D2C51	.721	-.174
D2C52	.727	-.077
D2C53	.728	-.328
D2C54	.750	-.305
D2C55	.686	-.271
D2C56	.746	-.116
D2C57	.755	-.142
D2C58	.791	-.218
D2C59	.764	-.040
D2C60	.664	.486
D2C61	.660	.487
D2C62	.667	.452
D2C63	.735	-.116
D2C64	.763	.143
D2C65	.627	-.369
D2C66	.650	.059
D2C67	.819	-.127
D2C68	.730	-.265
D2C69	.814	-.217
D2C70	.750	.211
D2C71	.644	.077
D2C72	.750	-.230
D2C73	.704	.150
D2C74	.654	-.212
D2C75	.744	-.189
D2C76	.734	-.057
D2C77	.804	-.165
D2C78	.671	.605
D2C79	.664	.592
D2C80	.661	.611

F1: Professors with basic educational methodologies through ICT in the classroom, such as Implementation of experiences and creation of learning environments with ICT in the classroom, use of digital content as support within the classroom, e-activities inclusion, structuring of subject activities using virtual university campuses, access to educational resources and structuring of activities through different devices, ability to create a collaborative environment in and out of the classroom, use of video as classroom material for learning, use of social networks as a resource within the classroom, evaluation of the methodology through online questionnaires

answered by the students, and the management and knowledge of the functions of the virtual classroom.

F2: Professors with advanced educational methodologies through ICT in the classroom, such as the production of QR codes to compile relevant information about the curriculum, mandatory bibliography and to carry out activities or tasks; use of applications for the creation of augmented reality as an educational resource in the classroom; e-portfolio as an activity for self-development and student development; use of virtual simulators and video games in the classroom as an educational resource; approach and use of MOOCs as a complementary resource in learning; use and knowledge of the digital blackboard; and use of tools for creation of educational activities through Augmented Reality. Considering the above, the scatter plot of Figure 13 was obtained, where Factor 1 is found on the X axis and Factor 2 on the Y axis.
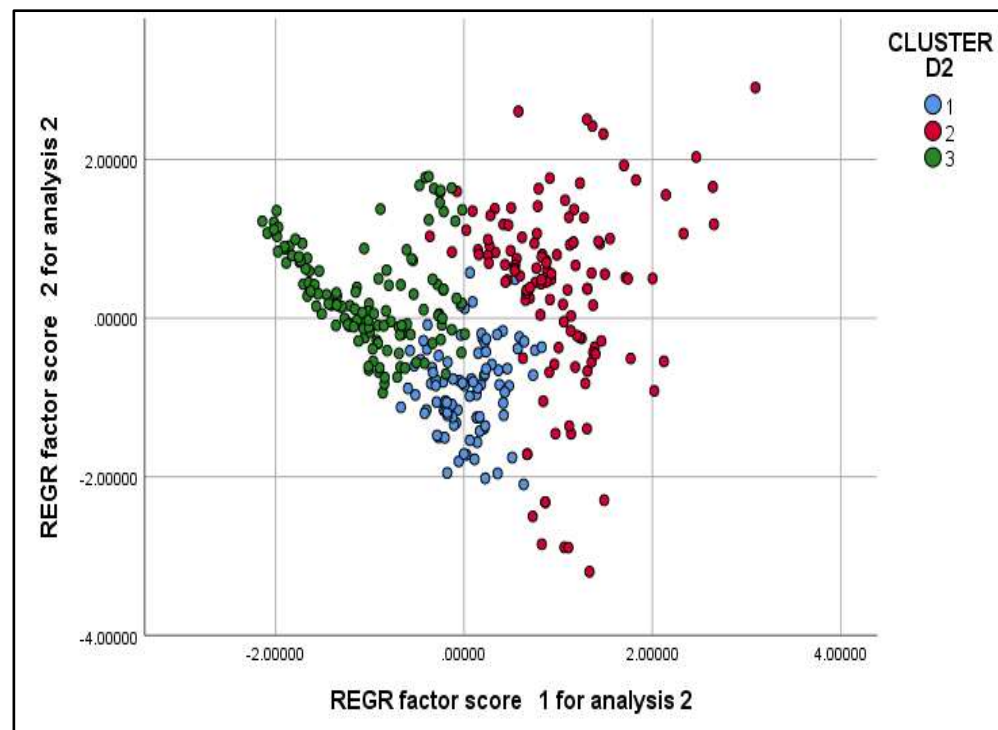

Figure 13: Scatter plot of professors grouped by cluster in the factors of the Principal Component Analysis dimension 2.

Each cluster is marked with a distinct color. On the X-axis, a clear distinction can be observed in the **use and knowledge of basic educational methodologies through ICT in the classroom** among the clusters; with those of cluster 3 (green color) having less, and those of cluster 1 (blue),

having and intermediate level, and those of cluster 2 (red color), a greater knowledge and use.

Regarding Factor 2, indicated on the "Y" axis of professors with **advanced educational methodologies through ICT in the classroom;** those in cluster 2 (red) have the highest score, followed closely by those belonging to cluster 3 (green) and with less use of advanced methodologies, those from cluster 1 (blue).

3.3 Dimension 3 Clusters

With the dendrogram graph, it was found that the professors in the sample can be grouped into 3 clusters as in dimension 2. With the histograms' analysis from Figures 14 to 18, it was determined that, by sex, most men are concentrated in cluster 2, and women in cluster 3. By age range, Cluster 2 is highly made up of professors between 36 and 40 years old, while Cluster 3 gathers most of the population with an age range between 55 and 60 years. Regarding the variable highest academic degree, cluster 3 gathers the majority with a master's degree and cluster 2 those with a specialization (Concentration Area).

On the other hand, cluster 2 concentrates most of the part-time professors and cluster 3, full-time. And lastly, cluster 2 groups teachers with less experience, from 0 to 5 years old, cluster 1 those with 6 to 10 years and cluster 3 those with more than 11 years of record experience. Table 7 indicates the hypothesis test with the independent variables: age range, type of employment contract, highest academic degree, and teaching experience.

Table 7. One-factor ANOVA Dimension 3

	Sum of squares	df	Quadratic average	F	Sig.
Between groups	149.813	2	74.906	14.370	0.000
Within Groups	1829.679	351	5.213		
Total	1979.492	353			
	Sum of squares	df	Quadratic average	F	Sig.
Between groups	196.166	2	98.083	19.305	0.000
Within Groups	1783.325	351	5.081		
Total	1979.492	353			

Given that the significance level found is less than 0.05 in every case, it can be concluded that at least one of the means is different and it can be established that for this dimension, the three clusters are well formed. Table 8 shows the KMO Test with a coefficient of 0.964 close to 1, so it can be determined that the Principal Components Analysis is significant.
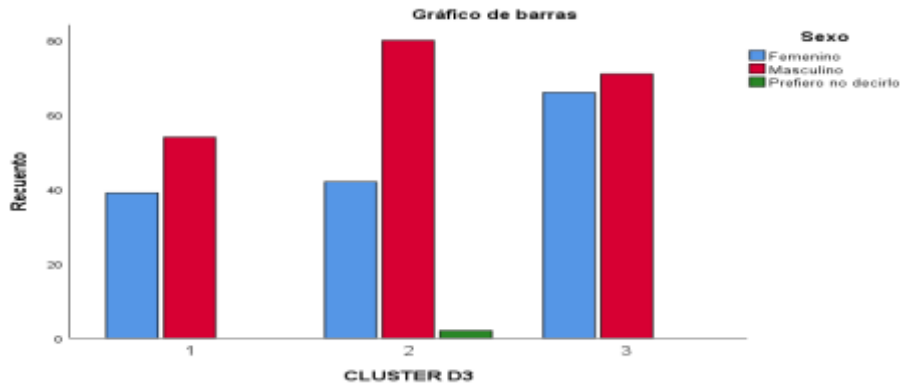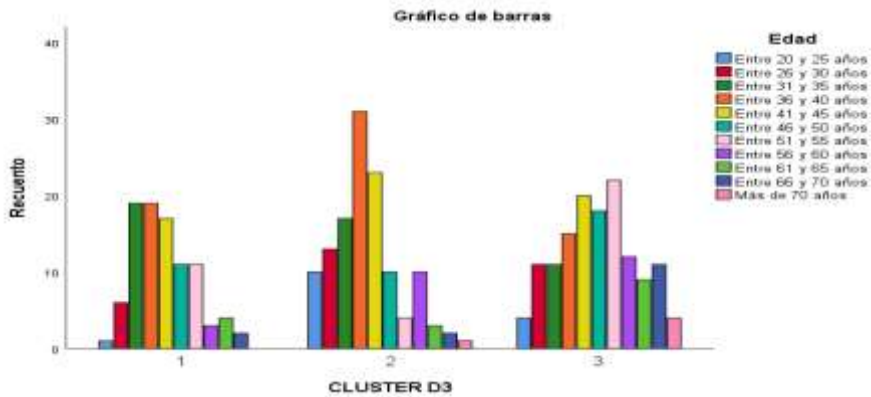
Figure 11: Grouping by gender dimension 3
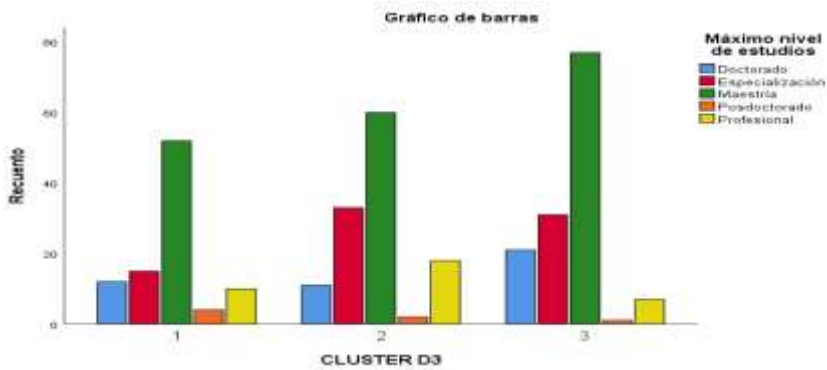
Figure 12: Grouping by variable age range dimension 3

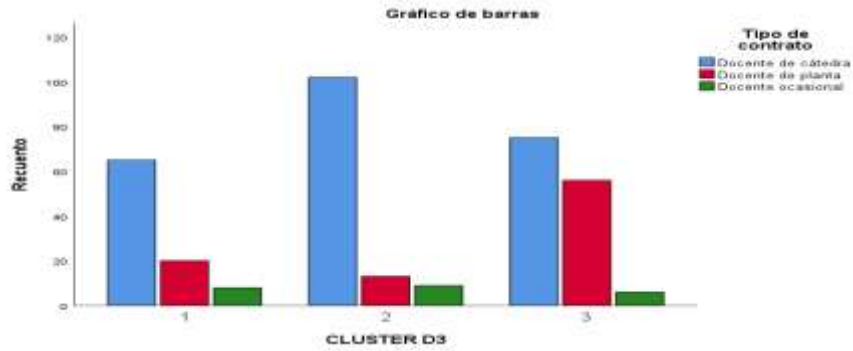Figure 13: Grouping by variable maximum level of studies dimension 3

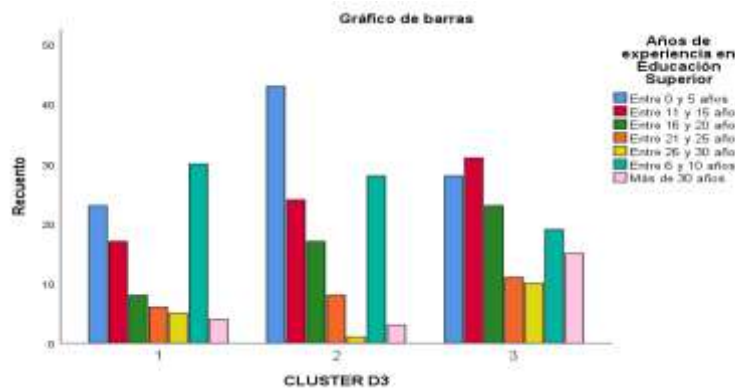Figure 14: Grouping by variable contract type dimension 3

Figure 15: Grouping by variable range higher teaching experience dimension 3

Table 8. KMO and Bartlett test dimension 3

Kaiser-Meyer-Olkin measure of sampling adequacy		0.964
Bartlett's sphericity test	Chi-square approximation	6457.947
	df	300
	Sig.	0.000

Scores of each variable in each factor by the analysis of principal components are indicated in Table 9. According to the distribution of the scores obtained in this research, the following names are assigned to each of the actor sor components:

Table 9. Component Matrix

	1	2	3
D3C81	.751	-.175	-.379
D3C82	.778	-.214	-.389
D3C83	.802	-.209	-.366
D3C84	.615	.329	-.203
D3C85	.689	.155	-.222
D3C86	.835	.029	-.096
D3C87	.808	.019	-.166
D3C88	.836	-.016	-.034
D3C89	.710	.218	.093
D3C90	.509	.339	-.027
D3C91	.734	-.115	.022
D3C92	.679	.494	-.013
D3C93	.652	.498	.043
D3C94	.652	.224	-.016
D3C95	.749	.141	.060
D3C96	.753	.183	.292
D3C97	.628	.371	.367
D3C98	.776	-.010	.115
D3C99	.773	-.074	.007
D3C100	.667	-.409	.213
D3C101	.712	-.433	.089
D3C102	.745	-.293	.107
D3C103	.785	-.259	.167
D3C104	.609	-.427	.274
D3C105	.739	-.091	.204

F1: Professors with basic training in ICT, with self-taught learning and experimentation of ICT, ability to solve problems through ICT, ability to use ICT as a pedagogical resource, Knowledge of "good practices" through ICT, integration of ICT in the curriculum and relationship with educational practice and curricular policy, lifelong learning and recycling in digital competence due to educational technology evolution, with a distinction

between different uses of ICT: educational resource, leisure, communication and so on; with the ability to select and discriminate different tools and data management for classroom use, solving learning problems and attention to diversity through ICT, understanding the importance of digital competence in future trainers, with aptitude to use the educational tools of the cloud in the classroom and create an interactive learning environment with students, ability to work in personal networks and learning environments in the cloud, updating and self-regulation of professors' own knowledge before ICT changes within the educational field, with a teaching role as a guide, mediator and apprentice of the teaching-learning process, bidirectional relationship with students, along with management and use of ICT in management and organizational processes of teaching and research tasks (files for monitoring students, absences, grades).

F2: Professors with advanced training in ICT, such as participation in ICT training courses of official educational institutions in person, professional development received in ICT through e-learning or b-learning, professional development received in the use of mobile devices as a pedagogical resource, training in software dedicated to research and data collection and processing, participation in innovation projects based on the ICT use, dissemination of their ICT experiences on the Internet, the creation and conservation of a contact network, and the notion and knowledge about the different reports that predict the inclusion of ICT technologies in the short and medium term (Horizon Report).

Considering the above, the scatter plot from Figure 20 was obtained, where Factor 1 is found on the X axis, previously mentioned, and Factor 2 is found on the Y axis.
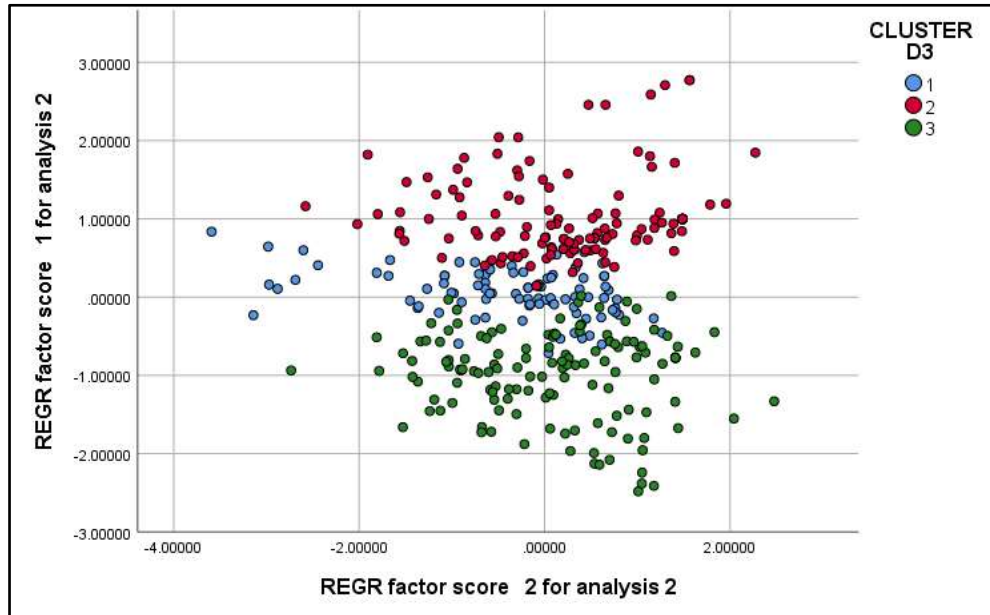
Figure 19: Scatter plot of professors grouped by cluster in the factors of the Principal Component Analysis dimension 3.

Each cluster is marked with a distinct color. On the X-axis, a difference can be observed in ICT professor training on the Y-axis, corresponding to the Factor of professors with advanced training, with those with the highest score being in cluster 2 and those with the lowest score being in cluster. 3. Regarding the X axis of basic training, no difference is observed between the distribution of professors

3.4 Dimension 4 Clusters

Analyzing the last dimension with the dendrogram graph, it was found that the professors in the sample can also be grouped into 3 clusters as in dimension 2 and 3.
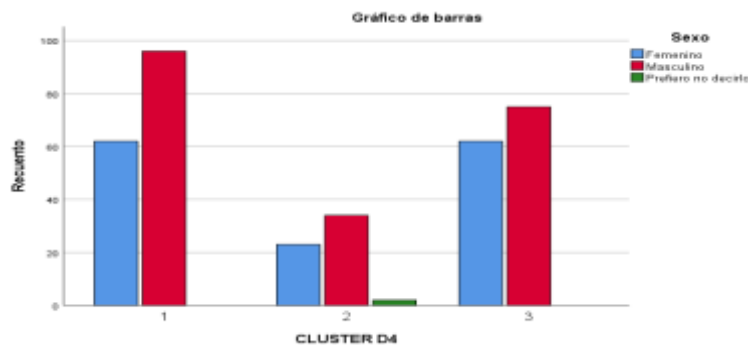

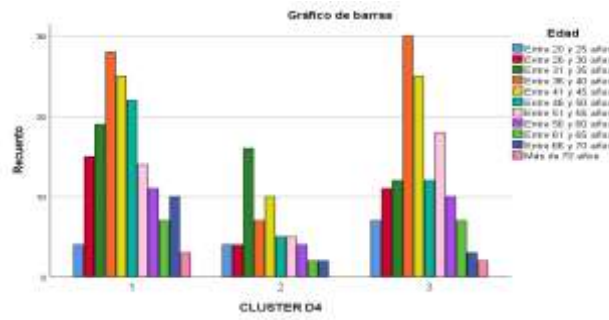Figure 16: Grouping by gender dimension 4
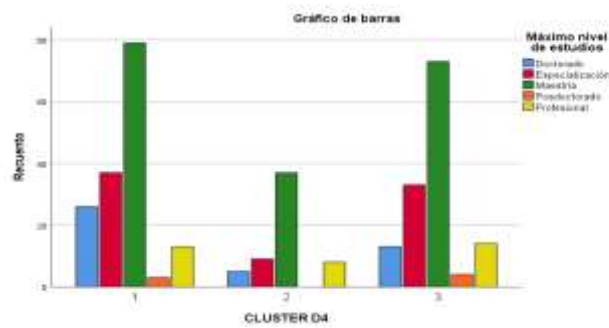
Figure 17:Grouping by variable age range dimension 4

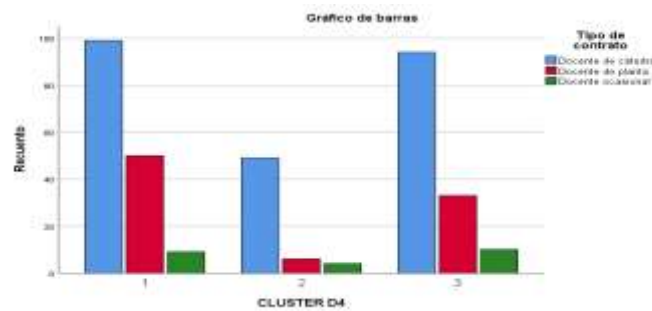Figure 18:Grouping by variable maximum level of studies dimension 4

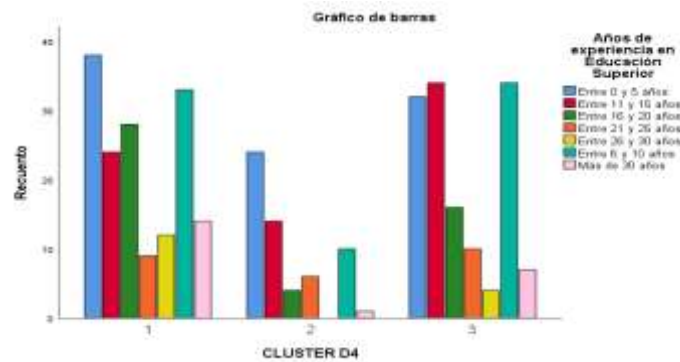Figure 19:Grouping by variable contract type dimension 4

Figure 20:Grouping by variable range higher teaching experience dimension 4

With the analysis of histograms from Figures 20 to 24, it is found that most of men are in cluster 1. By age range, there is a preponderance of age between 36-40 years, although this cluster mostly covers the oldest (between 51 and 55 years old). Cluster 2 groups the youngest between 31 and 35 years old, and in Cluster 1 there are mostly those between 46-50 years old.

Regarding the type of employment contract, part-time professors are distributed between clusters 1 and 3 and full-time professors are concentrated in 1. And finally, in terms of experience in higher education, those with less experience are concentrated in cluster 1, and those with more experience in cluster 3. Table 10. Indicates the hypothesis test with the variable type of hire contract.

Table 10. One-factor ANOVA Dimension 4

	Sum of squares	df	Quadratic average	F	Sig.
Between groups	7.569	2	3.784	5.162	0.000
Within Groups	257.304	351	0.733		
Total	264.873	353			

Given that the significance level found is less than 0.05 in all cases, it can be concluded that at least one of the means is different and it can be established that for this dimension, the three clusters are well formed. Table 9 shows the KMO test with a coefficient of 0.964 close to 1. Thus, it can be determined that the Principal Component Analysis is significant.

Table 11. KMO and Bartlett test dimension 4

Kaiser-Meyer-Olkin measure of sampling adequacy		0.889
Bartlett's sphericity test	Chi-square approximation	1702.471
	df	120
	Sig.	0.000

Scores of each variable in each factor by the analysis of principal components are indicated in Table 12. According to the distribution of the obtained scores resulted from in this research, the following names are assigned to each of the factors or components:

F1: Open and favorable attitude to ICT training and new methodologies.

F2: Favorable attitude to experience, self-learning and in general to teaching management through ICTs.

Considering the above, the scatter graph of Figure 20 was obtained, where Factor 1 is found on the X axis and Factor 2 is found on the Y axis.
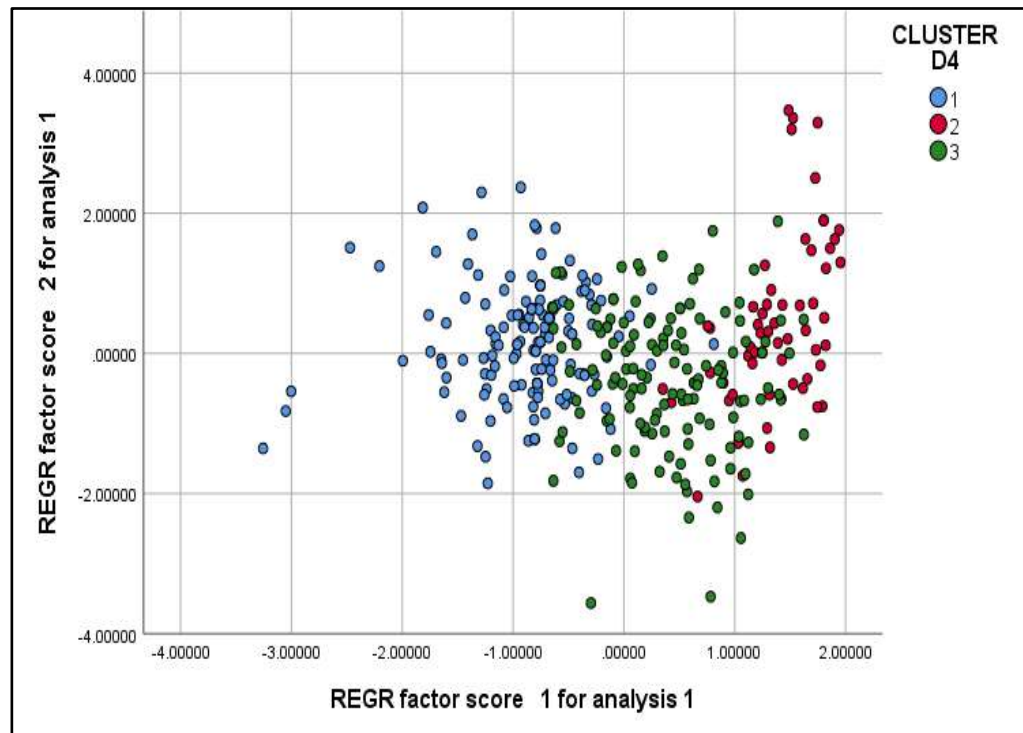

Figure 25: Scatter plot of professors grouped by cluster in the factors of the Principal Component Analysis Dimension 4.

Each cluster is marked with a distinct color. On the X-axis, a clear difference can be observed in the clusters in terms of willingness for training or professional development in ICTs and in new methodologies. The most open being those of cluster 2 and the least favorable those of cluster 1. Regarding the Favorable attitude to experience, self-learning and in general to teaching management through ICTs, a very similar distribution is found among the three clusters, although slightly higher in cluster 2.

4. CONCLUSIONS

The configuration of the segments through the clusters in each dimension suggests that there is no relationship between the variables sex, academic degree, teaching experience, and type of employment contract with the

dimensions of digital skills in the teachers studied, only a relationship is
evidenced with the age variable, which seemingly shows that younger
professors have better digital skills than older professors.

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