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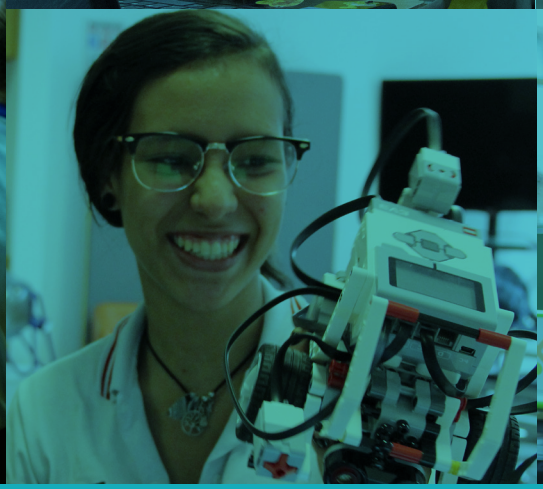

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MULTIVARIATE INDEX OF USE AND APPROPRIATION OF ICT IN SCHOOLS

ARTICLE

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Multivariate index of use and appropiation of ICT in schools

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ABSTRACT

The present study proposes and validates empirically a mul- tivariate index to assess the use and appropriation of ICT in school teachers, using a quantitative scale based on the UbiTAG model. Data is collected from 121 schools in Colombia, where 24 schools where intervened by a program that integrates ICT in learning environments in a local town in Colombia since 2013. The rest of the schools are located in 5 departments in Colombia, and are used as a control group in this analysis. Our findings provide empirical evidence that the theoretical model and its corresponding intervention im- proves the use and appropriation of ICT with educational purposes by teachers. Using exploratory factor analysis we also validate statistically our instrument, and the usefulness of the proposed metric for ICT use in an education environment.

ACM Classification Keywords

G.3 Multivariate statistics, J.1Education, K.3.m New method for validating human learning

INTRODUCTION

The fast and constant development of technology has gen- erated a widespread use of information and communications technologies (ICT). ICT has an impact on several aspects of our society and lives, including education. There is shared conviction that ICT transform teaching and learning pro- cesses, and that this transformation will result in increased learning for students [4]. Nevertheless, ICT use in education has not shown a positive impact in the traditional education outcomes [17].This study argues that this result is to some ex- tent a consequence of a poor measurement of the ICT use in education. Therefore, we propose a new metric for schools teachers ICT use, which could also be extended to students.

The proposed measure is based on a theoretical model that assumes that the pedagogical use of ICT as an un- observable variable, which is affected simultaneously by three groups of individual and institutional charac- teristics: access to tech- nology, learning and change management. These elements are required to genera- te learning environments that transcend schools physi- cal infrastructure [31].Therefore, we created an instru- ment of Use and appropriation of ICT that includes the different dimensions that determine an effective ICT use for teaching.

Given the unobservable nature of the dependent variable, our methodological approach makes use of a multivariate anal- ysis method, specifically exploratory factor analysis (EFA). This methodology determines the latent underlying structure of a set of manifest variables, validating our theoretical con- structs, and reduces attri- bute space from a larger number of variables to a smaller number of factors [18].

Empirical evidence of the strength and effectiveness of our proposed metric is provided using the data, collected with the ”Use and appropriation of ICT” instrument, from 121 public schools in Colombia, where 24 schools have been intervened by a program called Plan Digital TESO[1]. This program in- tegrates ICT in learning environments to improve quality of education in a local town in Colombia. The intervention is based in the same theoretical model we describe above.

1. http://planteso.edu.co/

Results show that the distributions of the multivariate index, in each dimension and in the aggregate, are statistically higher to teachers after the intervention in 2015 with respect to base- line in 2013, and that treatment group of teachers have also statistically higher distribution than the control group. Addi- tionally, we find evidence that support the hypothesis of our theoretical model, which postulates that the tree dimensions, must grow evenly to ensure that the level of use and appro- priation of ICT by school teachers also grow. The change in the educational paradigm confirms the importance of ad- equately measuring the literacy and pedagogical use of ICT by teachers. In the information society, the smart use of tech- nology for teaching and learning may determine the success of learning process. This is required because teachers are not any more providers of knowledge, but learning facilitators. In addition, teachers determine students success in terms of aca- demic achievement, desertion, grade repetition and access to higher education [2]

The remaining of this article is divided as follows. Section 2 presents the theoretical model and literature review. Section 3 presents the methodology divided into the instrument of use and appropriation of ICT and the exploratory factor analysis subsection. Chapter 5 presents the results and the construc- tion of the multivariate index and section 6 concludes.

THEORETICAL FRAMEWORK

Measuring ICT competence is a topic that has been studied by researchers and policy makers for years; [28] in their lit- erature review argue that there are three traditional ways to measure these types of competences: (1) questionnaires fo- cusing on frequency of use and the ways that teachers use ICT as a measure for pedagogical implementations, (2) tests that attempt to measure whether digital competence is given as cross-curricular area, and (3) a group of initiatives that use performance assessment-based tasks as a measure strategy.

The most common initiatives are those using survey methods to assess teachers level of technology integration. Within this type of measures, existing surveys tends to focus on teachers self-assessment of their level of technology use [10, 23]. However, most of

the analysis is limited to use single variables, ordinal or categorical, assuming that the pedagogical use of ICT by teachers can be measured only with the level of use of some technological devices [5, 8, 21].

Nevertheless, the wide range of skills needed for assertive use of ICT in education suggests that the technological revolution should affect not only how we measure the use of ICT by educators, but the different aspects that should be taking into account for an effective integration of technology on teaching practice.

The most accepted model to understand the pedagogical use and appropriation of ICT by teachers has been framed in recent years under the concept of Technological Pedagogical Content Knowledge (TPACK). TPACK is a conceptual framework that describes what teachers need to know in order to effectively integrate ICT into their practice. The framework is based in the relationship between three basic components of knowledge: technology, pedagogy and content [23].The interaction of the three constructs generates a teacher with the necessary knowledge to properly use ICT in their classes and generate the total PACKage for effectively teaching with technology [27, 29].

Nevertheless, many studies have tried to validate TPACK constructs and they have found that it is not possible to reproduce the components of the TPACK framework [1, 22, 28, 30]. The main empirical difficulty is to differentiate the three knowledge domains [25]. Besides, [11] argue that teachers knowledge is a necessary but not sufficient condition. They suggest that context variables, such as school environment, are essential to effectively teach with technology. However, it is not clear how knowledge interacts with the context.

In that sense, there exist some barriers that limit the effectiveness of the programs incorporating ICT in schools, which are not understood in the theoretical framework based on knowledge [9]. The main barriers found in the literature are: on the one hand, absence or deficiency in equipment and technological infrastructure and institutionalization of ICT, and, on the other hand, beliefs, attitudes, motivations, knowledge and skills of teachers [9, 13, 15, 26].

Then, more complex models such as the concentric circles have appeared responding to the need for a theoretical framework that account for both, the knowledge of the teacher, and the level of technological infrastructure and institutional characteristics. The model is founded in the existence of 5 cir- cles that influence the use of ICT by teachers. The core of the model is the type of use of technology in the classroom, which is divided into basic knowledge, the use of technology as an information tool and the use of technology as a learning tool. This classification is performed in order to determine the teachers and school characteristics that explain each type of use.

Thereby, authors categorize the determinants of the use between teachers and institutions characteristics. Teachers characteristics at the same time are separated into cultural and structural characteristics. Cultural characteristics are related to the beliefs of teachers and attitudes related to ICT. While structural characteristics are related to experience in technology, gender or age. Meanwhile, the institutions characteristics are categorized into contextual and cultural school characteristics. Contextual characteristics are related to the level of infrastructure provided by the institution, and cultural char- acteristics, reflects the institutionalization variables like leadership or ICT policy. This concentric model seems to integrate the characteristics of previous models and aggregates new features to transform the understanding of ICT use into a holistic process.

In general all models of this type have into account the ICT institutionalization and infrastructure, not because they explicitly talk about it but because all these models have a con- struct of external variables, in which institutionalization and ICT infrastructure can be framed. On the other hand, each model understands the teachers needs in its own way. For example, some plans focus on level of knowledge, others in experience and use of ICT, and others in attitudes ; but none include all these characteristics to understand the level and appropriation of ICT.

With the aim to reconciling all teachers and institutional characteristics, we present our theoretical model, that accompa- nied by a complete survey for educators (see section 3), al- lows us to define an index of use and appropriation of ICT by teachers. Our model is based in the UbiTag learning framework, and on three principal dimensions: Technology, learn- ing and change management [31].The model is represented in figure 1 and the mathematical approach of the model yields two fundamental premises: first, the model favors the bal- anced development of all dimensions, meaning that the de- velopment of ubiquitous learning is founded in an equilib- rium growth of these dimensions. Second, the model requires all variables to have positive values, because any zero in the second variables make the value of the higher variable equals zero, which implies that focus the intervention in only one dimension will not generate an innovation culture[2].

2. We refer to the main dimensions (technology, learning and management) as the secondary variables and to the ubiquitous learning as the higher variable.

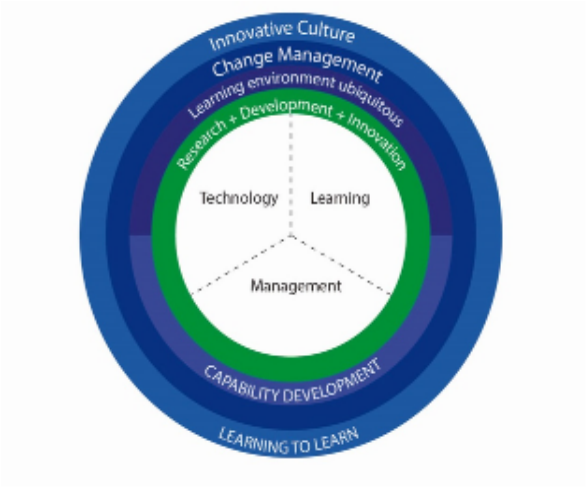

Figure 1. UbiTAG model.

Therefore, in our theoretical framework, a school teacher uses efficiently ICT if he develops simultaneously the following three dimensions: First of all, the technological infrastructure dimension, that must be oriented to the service allowing integration between the administrative and academic areas with information technology solutions [16]. Then, the principles for technology architecture are: availability, scalability, performance, fault tolerance, interoperability, mobility and security. Second, the learning dimension composed by knowledge and skills which are expected to possess teachers to create a culture of learning and innovation through the use of ICT. The most desirable skills are: technological, communicative, ped- agogical, management, research skills and socialization. Finally, the change management dimension, that includes factors which build a culture of intelligent use of ICT in educational institutions. Building institutional culture is made by radical changes in the organization, which is structured in three stages: induction, intervention and institutionalization [14]. These changes are supported by interventions in infrastructure, institutions and technical changes (hard interventions); but also interventions in motivation, abilities and attitudes (soft interventions) [7].

METHODOLOGY

Instrument of use and appropriation of ICT

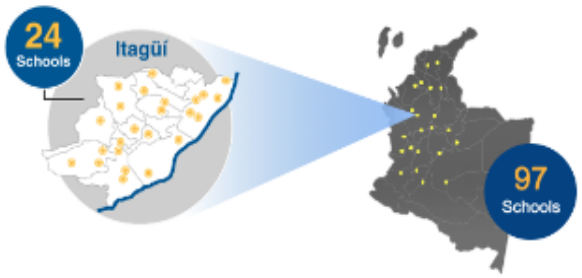

Figure 2. School's sample

KMO	0.926
Barlettt test of sphericity	0.000
Determinant of the matrix correlation	0.000

Table 1. Validation test.

The instrument measures schools teachers selfperception about the following aspects: knowledge, pedagogical use of ICT and intentionality of knowledge; access and quality of ICT infrastructure at home and school; as well as institutional aspects and educational community that affect the use and appropriation of ICT. These aspects are including in the three dimensions of our theoretical model explained above.

The survey is answered by a stratified random sample of school teachers from 121 public schools in Colombia, where 24 schools[3] have been intervened by a program called Plan Digital TESO. Therefore, we have three comparison groups: the treatment group at baseline (2013) and follow up (2015), and a control group of 97 public schools distributed in five departments in Colombia (see figure 2).

Exploratory factor analysis (EFA)

We use EFA to identify the underlying factors that explain the higher proportion of variance of the original variables. Since the instrument has dichotomous and ordinal variables, assuming normal distribution of the variable may lead to statistically erroneous results. As it was argued by [19], both the number of factors and the estimation of factor loadings would be biased. Therefore, following [12, 20], the correct approximation is to assume that the discrete variables come from a continuous underlying variable X*k. If the observed variables are divided in categories 1, ..., k, it is assumed that they result from dividing the continuous underlying variable X*k into a set of thresholds.

To obtain an unbiased estimation of the correlation between two categorical variables X_1 and X_2 one must find the correlation between the continuous underlying variables

X^*_1 and X^*_2. This type of estimation is called polychoric correlation [19]. Once we guarantee the unbiased estimation of matrix correlation, we perform the KMO test, Bartlett test of sphericity and the determinant of the matrix correlation. Table 1 shows the results, the estimated value of KMO is 0.926 indicating the statistical evidence of a high level of common variance in the set of variables. The Bartlett test of sphericity rejects the null hypothesis of identity correlation matrix, confirming the existence of lineal combinations, further the determinant of the matrix correlation equals zero.

We estimate the EFA using the principal factor method, and then we use the Kaiser rule to extract 6 factors (see figure 3). Table 2 shows that our 6 factors explain 92% of the original variance. we also execute an oblique varimax rotation, since it is probable that factors are correlated [3, 6]. Only correlation coefficients greater than 0.3 will be taken into account since these values are considered signicant [24].

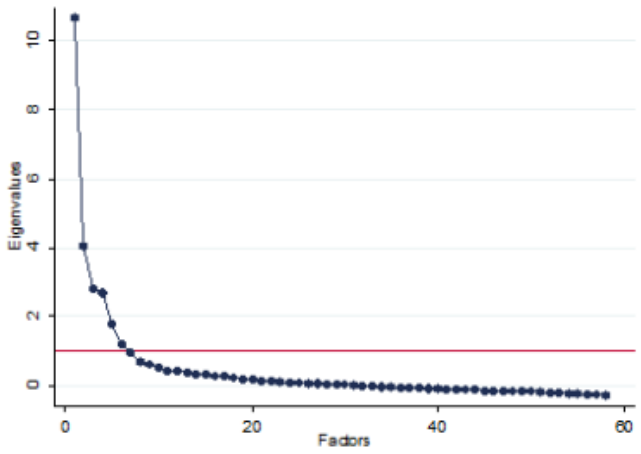

Figure 3. Scree plot

Factor	Eigenvalue	Explained variance
1	12.15	0.46
2	3.14	0.13
3	2.94	0.11
4	2.51	0.09
5	1.87	0.07
6	1.44	0.05
Total		0.92

Table 2. Proportion of variance explained.

Figure 9 in the Apendix 1 shows the resulting constructs with their respective significant factor loadings. The learning dimension is represented by the first two factors, where the first one includes the communicative, pedagogical, management and research skills. We call this factor knowledge intentionality. The second factor includes the technological knowledge.

Following our theoretical model, factor 5 represents school management, and factor 6 represent the technological dimension. Factor 3 includes the variables related to the use of ICT inside the classroom, and factor 4 measure teachers perceived benefits of using ICT.

We use all 6 factors to build the multivariate index of use and appropriation of ICT by teachers, thus it includes the three dimensions of our theoretical model. We aggregate the vari- ables using a simple average of the factors because we want to value all constructs with the same weights. The measure of the indexes is rescaled from 0 to 10 to make easier its interpretation.

Finally, figure 4 show the distribution of the multivariate in- dex with the range from 0 to 10. The value of this index represents the use and appropriation of ICT given the percep- tion of teachers and the relative values of the other teachers that filled out the survey. It means that the method provide a relative measures related to the sample and does not allow us to extract absolute values.

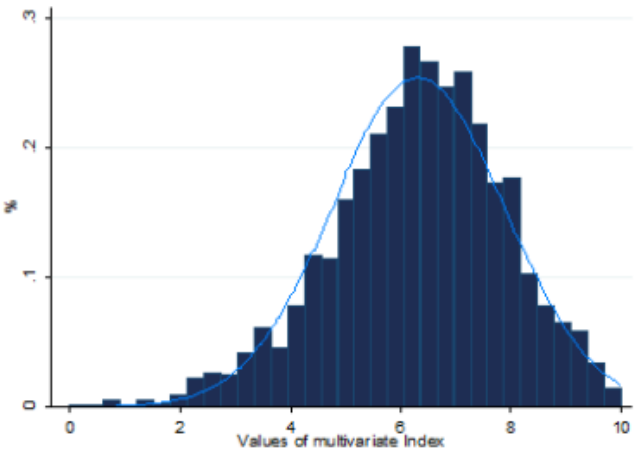

Figure 4. Distrubtion of the multivariate index

GENERAL RESULTS: PLAN DIGITAL TESO

To test the strength and effectiveness of the multivariate in- dex of ICT use we compare the distribution of teachers belonging to TESO before and after the intervention, 2013 and 2015 respectively. In addition, we compare the distribution of teachers under treatment, teachers from TESO schools, with teachers from other schools in Colombia. Figure 5 shows the empirical distribution functions of the multivariate index for the teachers of TESO digital plan 2015 in contrast to the other groups.

Results show better levels of use and appropriation of ICT for TESO teachers in 2015 in all quantile distributions. Additionally, the distribution of TESO teachers has a more homogeneous behavior. After a non-parametrical test[4] that confirms the differences in the distributions; we perform a difference in means to determine the direction of this change. Results are conclusive in terms of use and appropriation improvements by teachers belonging to TESO in 2015 in comparison with baseline, and control teachers. This finding suggests evidence for the positive effect of the intervention of the theoretical model and the intervention TESO.

Although the multivariate index allow us to determine the progress in the use and appropriation of ICT by teachers, it is important to determine which components are affecting more the improvement of this index.

Specifically, we observe that the differences between the distribution functions of the three groups are lower in the learning construct, than in the other two dimensions. In the technology dimension, we observe a higher difference between TESO 2013 and 2015, in comparison to the control group. This is explained by the fact that TESO made a lot of progress in making all existing technology available to school actors, and it provides a personal computer to each teacher. Finally, mayor differences are observed in the management dimension. The better values of the distribution function in the management dimension for teachers in TESO 2015 is due to the perception that both, the existence of normative documents and the organization of the school, strengthen the pedagogical use of ICT in an adequate institutional environment.

Even though the empirical distribution functions in all cases have higher values for TESO 2015 than for the TESO 2013 and the control group, further research, as confirmatory factor analysis (CFA), is advised to confirm the exploratory findings presented in this article.

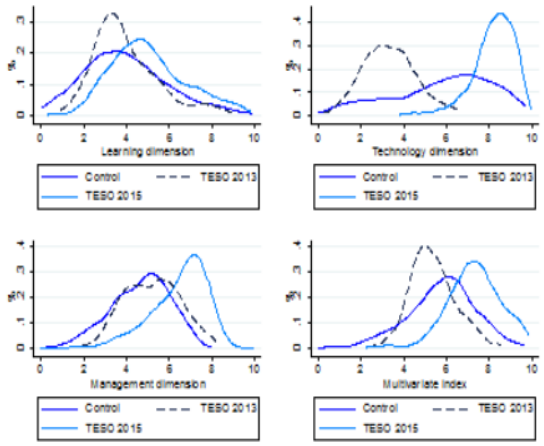

Figure 5. Comparison of the distrubtion of the multivariate index by dimension

The last hypothesis is the principle of equilibrium: values of the three dimensions of the theoretical model have to be more concentrated in the group of teachers with better use and appropriation of ICT. Previously, we showed that teachers from TESO 2015 had the best level of ICT use, thus if the hypothesis of our model holds, the concentration of learning, technology and management constructs values should be the highest. Figure 10, shows the concentration of TESO 2015, TESO 2013 and the control group. The figures 6, 7 and 8 shows the highest concentration for TESO 2015. The distribution of the treatment group are more concentrated and centered in comparison compared with teachers at baseline and in the control group. However, a weaker development in the learning dimension is observed, which is caused by the intervention plan that generates a further development of technology, management, knowledge, and use of ICT in the first phase. In a second instance, the intervention developes knowledge intentionality that causes the unbalance between dimensions.

4. KolmogorovSmirnov test, which quantify the distance between the empirical distributions functions, under the null hypothesis that the distributions are equal. We reject the null hypothesis of equality in the distributions.

Figure 6. Comparison of the distribtion of the UbiTAG dimensions. Plan DIgital TESO 2013

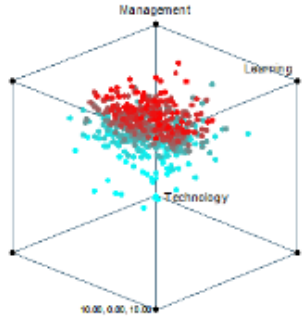

Figure 7. Comparison of the distribtion of the UbiTAG dimensions. Plan DIgital TESO 2015

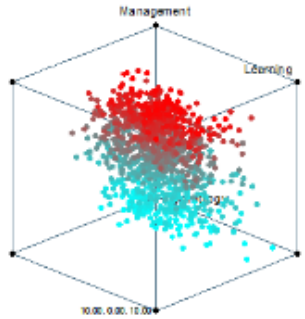

Figure 8. Comparison of the distribtion of the UbiTAG dimensions. Control group

UbiTAG Model. Results show a statistically significant positive progress for the density function of the multivariate ICT use index for the intervened teachers between 2013 and 2015, for each dimension and the aggregate index. Treatment group of teachers have also statistically higher distribution of the multivariate index than the control group. As a result, we conclude that the proposed index shows internal consistency for different samples. Finally, the evidence supports the hypothesis of the UbiTAG theoretical model, which proposes that the three dimensions must improve evenly to ensure that the level of use and appropriation of ICT by school teachers also improves.

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APPENDIX 1

Instrument of use and appropiation of ICT

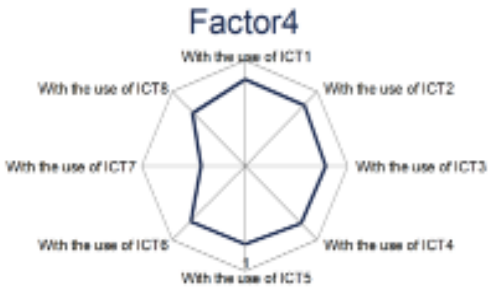
Variable	Explanation
Knowledge1	Use of computer and basic resources
Knowledge2	Use of educational technology resources such as educational websites and software
Knowledge3	Strategies and methodologies of the ICT in education. Eg. Activities, Didactics, assessment, projects
Knowledge4	Critical processes and ethical sharing
Knowledge5	Use of internet communities and learning environments on internet
Knowledge6	New technologies impact in actual society
Knowledge7	ICT use for school management
Knowledge8	Learning environments design
Knowledge9	ICT use to solve special educational needs of people with disabilities
Benefit1	Better cultural knowledge
Benefit2	Manage better my time
Benefit3	Better professional development
Benefit4	Better independence and autonomy
Benefit5	I do not see any benefit
Benefit6	I do not see benefits
Benefit7	Better academic performance
Benefit8	Better communication with friends
Benefit9	Better communication with teachers
Benefit10	Better communication with directors
Negative1	Digital divide and economic differences
Negative2	Digital divide, individualism and withdrawn
Negative3	Exposes Negative risks to physic and psychological integration of a person
Negative4	It does not have a negative effect
Negative5	Digital divide, individualism and withdrawn with partners
Negative6	Digital divide, individualism and withdrawn with family
PC availability Internet	Computer availability with internet at school
PC availability School	Computer availability with pedagogic use
Connectivity	Connectivity in educational institution
Software	Pedagogic software availability
Hours by week	Daily average browser duration
PC Internet	Computer availability with Internet outside the educational institution
Computer Internet	Computer availability outside educational institution
Internet	Internet access outside educational institution
Idle.	Idle. availability outside educational institution
Information use	Instructor uses internet to inform
Communication use	Instructor uses internet to communicate
Working-Study use	Instructor uses internet to work or study
Research	Instructor uses internet to research
Entertainment	Instructor uses internet to entertain
Meet. people	Instructor uses internet to meet people
Planning Use	ICT frequency to prepare to form
Class use	ICT frequency to prepare for class
Planning1	Consult different sources
Planning2	Experiences exchange with local colleagues or from another institution
Planning3	Find didactic materials (Simulations, interactive activities) that allows the topic learning
Planning4	Consult experts in working subjects
Planning5	Research and assign spaces and virtual communities in order to promote students interaction through ICT with each other
Planning6	Produce its own didactic material
Planning7	I do not use technology resources to plan my class
Objective1	Develop competences related with curriculum
Objective2	Develop competences for the media use (search, process, share information)
Objective3	Develop values with activities in group
Objective4	Take digitally correspondence through multimedia, games and simulations
Objective5	Train to publish their own contents
Objective6	Train to participate in collaborative work
Objective7	Accompany work done by their in virtual environments (Blogs, etc.)
Objective8	Teach how to learn
Objective9	Develop leadership processes with ICT
Objective10	I do not use ICT with my students
Strategies1	Work production and presentations without internet (Microsoft Word, Excel, Power Point, etc)
Strategies2	Free exploration activities where students create original objects
Strategies3	Guided activities and internet didactics
Strategies4	Software use with pedagogical objectives (Students with programming skills or use html, scratch, Java, ActionScript, ect)
Strategies5	Prototype creation or virtual models
Strategies6	Participation in the design or content production in websites
Strategies7	Correlation activities, collaboration and project development in virtual communities. (Social networks, ect)
Strategies8	Publish and find ideas or opinions ideas and creation in Internet (Wikis, blogs, Scratch community, etc)
Strategies9	I do not use a computer as pedagogical resource

Assessment1	Increase learning level of the group for its discipline
Assessment2	Increase of dialogue
Assessment3	Increase of students interest for research
Assessment4	Students have improved their capability in use of ICT
Assessment5	Students have higher capacity to create contents in multiple media
Assessment6	My students have learned to manage their own knowledge
Assessment7	Change in their way to assess the students performance
Assessment8	I do not use to many technologies in my practice
Assessment9	I do not pedagogic use of technologic resources
Assessment10	Change the way my students have learned to manage their own knowledge
Change1	Change in the class time (longer or shorter class time)
Change2	Change in the way to group students (Student groups with different ages)
Change3	Change in students mobility (Activities outside the classroom with mobile device)
Change4	Boss development of collaborative work
Change5	Boss pedagogic development in teachers
Change6	It does not have generated any change described above
ICTLIPP	About presence of ICT in the Institutional Educative Plan
Planning1	Number which is used to evaluate plan about the pedagogic use of ICT in school. It is done through usual planning
Planning2	Number which is used to evaluate plan about the pedagogic use of ICT in school. It is done in collaborative works
Planning3	Number which is used to evaluate plan about the pedagogic use of ICT in school. It is done in meetings
Planning4	Number which is used to evaluate plan about the pedagogic use of ICT in school. It is done in spontaneous way
Planning5	Number which is used to evaluate plan about the pedagogic use of ICT in school. It is not done.
Planning	Scale of means, importance of institutional planning about the ICT pedagogic use
Assessment1school1	Number which is used for evaluate assessment about the ICT use - It is done through usual planning
Assessment1school2	Number which is used for evaluate assessment about the ICT use - It is done in collective work schedule
Assessment1school3	Number which is used for evaluate assessment about the ICT use - It is done in specific meetings
Assessment1school4	Number which is used for evaluate assessment about the ICT use - It is the first time that has been done
Assessment1school	Scale of means, importance of institutional assessment about the ICT pedagogic use
Organization	The organization of the school that favors the pedagogic use of ICT
Community1	About of ICT use in school for the community - Area is educative community
Community2	About of ICT use in school for the community - Educative community does not use ICT
Community	Areas of ICT for educative community
With the use of ICT1	I use the ICT in class in creative way
With the use of ICT2	I use the ICT to explain in an easier way
With the use of ICT3	I use the ICT to be closer to students
With the use of ICT4	I use the ICT to offer a more attractive and motivated course
With the use of ICT5	I use the ICT to have different educative resources that allows to develop my class
With the use of ICT6	I use the ICT and I feel more motivated to develop professionally
With the use of ICT7	I use the ICT and I feel more motivated to work with my colleagues
With the use of ICT8	I use the ICT and I use more motivated to support educative interinstitution processes

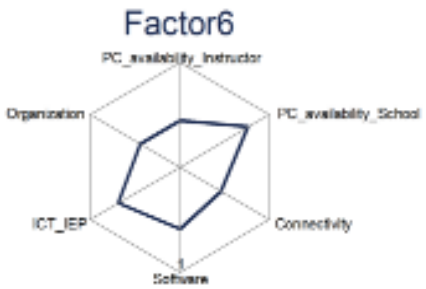

Factor1
Changes4
Planning5
Objective4
Assessment7
Objective5
Assessment6
Objective6
Assessment5
Objective7
Assessment4
Objective8
Assessment3
Objective9
Strategies3
Strategies4
Strategies7
1
Strategies6
Strategies5


Factor2
Knowledge1
Knowledge9
Knowledge2
Knowledge8
Knowledge3
Knowledge7
Knowledge4
Knowledge6
1
Knowledge5


Factor3
Planning1
Changes5 (negative)
Planning2
Assessment9 (negative)
MD_Objetivo1
Assessment3
Objective2
Strategies9 (negative
Objective8
1
Strategies3
Objective10 (negative)


Factor4
With the use of ICT1
With the use of ICT8
With the use of ICT2
With the use of ICT7
With the use of ICT3
With the use of ICT6
With the use of ICT4
1
With the use of ICT5


Factor5
Planning
1
Community
Assessment_school


Factor6
PC_availability_Instructor
Organization
PC_availability_School
ICT_IEP
Connectivity
1
Software

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