Analysis of the Success Factors of the Quality of E-learning in the Medical School in a Neutrosophic Environment

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Abstract

The COVID-19 pandemic has affected the presence of students in the classroom, especially in medical schools where the practice is essential to gain skills. Virtual teaching or e-learning has emerged as the answer to that problem in this environment. Despite its many advantages, this process has faced different problems that have been overcome thanks to success factors. Considering the need to search for quality in medical schools in Ecuador, a study was carried out on those applied factors that have contributed to guaranteeing the quality of the teaching-learning process. That is the main objective of this research, supported by the bibliographic search and Plithogeny. It can be concluded that the highest level of impact has been made possible by the combination of the correct use of Information and Communication Technologies with adequate teacher training.

Keywords: e-learning; b-learning; medicine;success factors; Plithogeny.

1. Introduction

Nowadays, it is straightforward to master different areas from the comfort of your home. An example of them is the virtual classroom, through which the teacher can keep students informed of tasks or schedule changes. This has been possible with the development of the internet and other technologies and the tendency to be connected all day. It can be said that there is no longer an excuse for not being aware of what is happening in the world[1]. Just by having a computer or any other technological device you can be connected and learn many things on the internet. Incorporating educational technologies in their teaching-learning processes and their practices both inside and outside the classroom has been promoted mainly in higher education.

Thus, the change from face-to-face to online education became necessary to reduce student dropouts, using new information and communication technologies [2]. This phenomenon is known as distance education, also called e-learning, Tele training, digital learning, or network learning. In recent years, with profound technological advances and the universalization of devices, verifying that distance learning is reaching high levels of success, not only in its didactic quality but also in user satisfaction, could mean that it will be prioritized over other teaching modalities more linked to the traditional educational model, totally in-person, or a combination of both [3], [4].

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Information and Communication Technologies (ICT) within the educational teaching process is an essential tool for developing new pedagogical models in distance training. One of the most used tools for this process is Moodle (Modular Object-Oriented Dynamic Learning Environment) as it is free software, easy to install and use. That is why students and institutions preferably use this system [3]–[5]. However, with the increase in the development of science and technology, keeping abreast of advances becomes a challenge for professionals who mainly use their time to practice their specialty, leaving aside their continuing education .

An ethical imperative and a commitment of the universities of these times is the permanent observance of quality as the basis of their harmonious development and guarantee of the training of professionals [3]. Technology is used in the teaching-learning process to contribute significantly to the universities to achieve the role of agent and agency of the scientific and technological development of the countries [5]. However, this must be accompanied by the training of university teachers as a strategy for universities to improve educational quality [6], [7].

The evaluation of virtual learning cannot be understood as a mere translation or transposition of the internal content of a computer to the mind of the student and from this to the computer but as a process of personal reconstruction of the student, where the assimilation process transits by the internal cognitive structure of the learner. This is a process where the student develops diverse learning strategies, reaches greater motivations, guarantees the mastery of more specific and elementary knowledge, in turn, metacognitive abilities to solve problems, and better design their goals and expectations [3], [6].

It is necessary to establish relationships between teachers and students and between themselves. That is why blended learning or b-learning, a face-to-face and virtual modality, is the most appropriate response [7], [8]. For that reason, it is said that it represents a challenge for university authorities, especially in medical practice, teachers and students, due to the considerations and requirements for its development: internet availability, an adequate environment, academic and technological support, management of virtual platforms, syllabus adapted to it. In other words, there are limiting factors in the use of the media in educational practices that can be summarized as [8]:

- Difficulties related to the characteristics of the available means.
- Difficulties related to Teachers.
- Difficulties related to the educational system and teaching centers. [8]

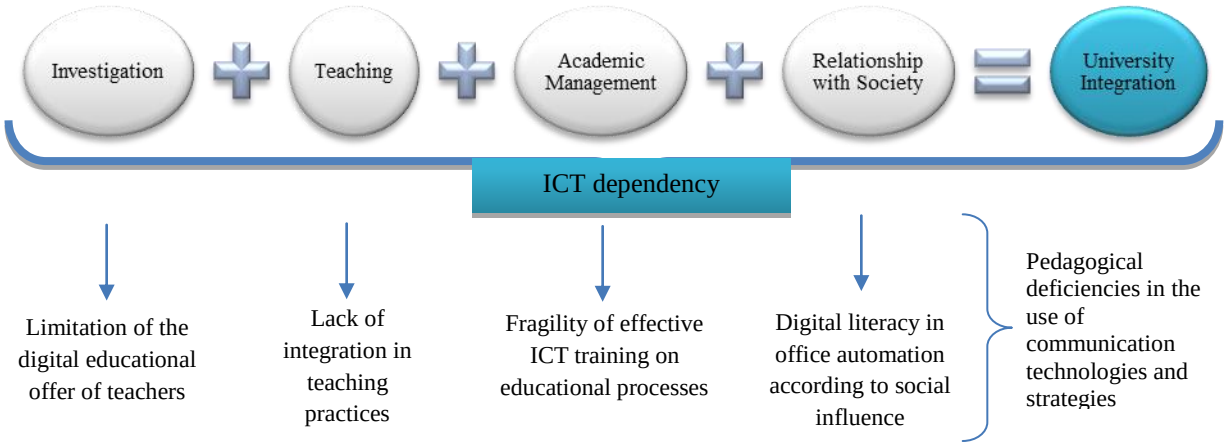

Figure 1: Main limitations in Ecuadorian institutions.

Due to the heterogeneity of the perception of the phenomenon of e-learning and b-learning among students and teachers in the specific case of Ecuador, it's necessary to carry out a study on that topic. Especially in

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the field of medicine, where there are few studies of this type in the context of Latin America, given that cultural factors vary from one country to another and among university students, this is no exception. Where social influence also plays an important role [4], [5]. Interactivity and distance interactions support online education pedagogy and are identified by researchers as keys to success. Educational strategies with a constructivist approach are necessary to produce knowledge in virtual learning environments [7], [9].

With the arrival in 2020 of COVID-19, virtual learning becomes the method to conceive the continuity of education as similar as possible to face-to-face. However, it is a change that was taken abruptly, and with almost no preparation; hence, it does not correspond to an online learning system or at least does not respond to the online learning or teaching-learning model. Furthermore, there arises the internal questioning of each teacher without being able to guarantee quality cognitive, social and didactic learning. It was widely noted how teachers faced this unprecedented challenge without having sufficient digital skills. However, once again the vocation and the desire to serve led to the search for a way to learn and empower the digital tools necessary to face this transformation of the teaching-learning processes during a voracious pandemic [3], [10].

Considering what has been analyzed so far, it is necessary to study the behavior of virtual learning in other centers, determining its success factors to guarantee and maintain the quality of the process and then determine which of these has had the highest level of success by consulting experts. The preceding becomes the objective of this research because if these factors are determined, they can be implemented objectively, optimizing the resources of the institutions. Similarly, the effectiveness required by medical students can be obtained, as one of the most affected schools by the incidence of the pandemic and the isolation caused, thus making it impossible to practice teaching as a way to acquire skills.

We will then proceed to the bibliographic review and the processing of information through multi-criteria decision methods. The latter in their neutrosophic extension due to the benefits that this science offers in decision-making in an environment of neutralities that may exist in the consultation of experts, due to the subjectivity that this confers on the process. For the development of the study, mathematical modeling for decision-making was applied from neutrosophic logic to plithogenic logic. Plithogeny advocates the connections and the unification of theories and ideas in varied fields of science, being an extension of the classical set, fuzzy set, fuzzy intuitionist set, and neutrosophic set [11].

From now on, the investigation will consist of sections to explain the methods and techniques to obtain and process information, the presentation of the case study, the results obtained, their discussion, the conclusions, and the bibliographical references used.

2. Methods and techniques

2.1 Methods to obtain the information

The following section describes the theoretical and empirical methods used throughout the research to meet the specific objectives. The methods used are listed below:

- Inductive-deductive: to verify the factors raised regarding the research topic in addition to structuring the research profile for its application.
- Analytical-synthetic: to compare all the phenomena involved in the research
- Historical-logical and descriptive-systematic: to analyze the problem situation of the research. It is intended to make a current observation of the phenomena for their interpretation.
- Surveys and interviews will be applied to the sample made up of the target population and selected experts. Questionnaires were prepared aimed at obtaining information about the real problem and issuing possible solutions to obtain valid conclusions and support the results.

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Sample:

$$n = \frac{N}{(E)^2(N-1)+1} \quad (1)$$

Where: n = sample size, N = Population or Universe, E = 0.1% margin of error

2.2 Information processing methods

Neutrosophic sets in the literature by Florentin Smarandache since fuzzy intuitionistic sets could only handle incomplete information, but not the indeterminate and inconsistent information, which commonly exists in fuzzy systems. The term neutrosophy means knowledge of neutral thought, and this neutrality represents the main distinction between fuzzy logic and fuzzy intuitionism [12]. In neutrosophic sets, the indeterminacy is explicitly quantified through a new parameter I. True membership (t), indeterminate membership (I), and false membership (F) are independent of each other, and the sum between them satisfies the inequalities $0 \leq T + I + F \leq 3$. In fuzzy intuitionistic sets, the uncertainty depends on the degree of membership and the degree of non-membership [13]. In neutrosophic sets, the indeterminacy factor (I) is independent of the true and false values. There are no restrictions between the degree of truth, the degree of indeterminacy, and the degree of falsehood [14].

If U is a universe of discourse, a Neutrosophic Set (NS) is characterized by three membership functions, $uA(x), rA(x), vA(x) : X \rightarrow \,]0-, 1+[$, which satisfy the condition $0 \leq -\inf uA(x) + \inf rA(x) + \inf vA(x) \leq \sup uA(x) + \sup rA(x) + \sup vA(x) \leq 3+$ for all $x \in X$. $uA(x), rA(x)$ and $vA(x)$ are the membership functions of the veracity, the indeterminacy, and the falsehood of x in A, respectively and their images are standard or non-standard subsets of $]0-, 1+[$.

When approaching the perspective of indeterminacy and contradiction, as is the case with Gödel's incompleteness theorem, he states that any proposition in a mathematical axiom system will present a degree of truth (T), falsehood (F), and indeterminacy (I). Neutrosophy, therefore, establishes a unique solution for the existence of paradoxes in philosophy [15].

Plithogeny is the genesis or origin, creation, formation, development, and evolution of new entities from dynamics and fusions of multiple contradictory and/or neutral and/or non-contradictory previous entities. Plithogeny advocates the connections and unification of theories and ideas in varied fields of science. "Knowledge" is taken as "Entities" in various fields, such as social sciences, technical sciences, theories of arts and letters [16].

Plithogeny is the dynamics of various types of opposites, and/or their neutrals, and/or non-opposites and their organic fusion. Plithogeny is a generalization of dialectics (dynamics of a type of opposites: <A> and <antiA>), neutrosophy (dynamics of a type of opposites and their neutrals: <A> and <antiA> and <neutA>) , since plithogeny studies the dynamics of many types of opposites and their neutrals and non-opposites (<A> and <antiA> and <neutA>, <B> and <antiB> and <neutB>, etc.), and many non-opposites (<C>, <D>, etc.) all together. As an application and particular case derived from plithogeny, the plithogenic set is an extension of the classical set, fuzzy set, fuzzy intuitionist set, and neutrosophic set, and has multiple scientific applications [16].

So, (P, a, V, d, c) is called a plithogenic set

a) Where "P" is a set, "a" is an attribute (multidimensional in general), "V" is the range of attribute values, "d" is the degree of membership of the attribute value of each element x to the set P for some given criteria ($x \in P$), and "d" means "d_F" or "d_{IF} " or "d_N" when it is a fuzzy degree of membership, an intuitionistic fuzzy membership or a neutrosophic degree of membership, respectively, of an element x to the plithogenic set P
b) "c" means " c_F" or "c_{IF} " or "c_N", when it is a fuzzy attribute value contradiction degree function, intuitionistic fuzzy attribute value contradiction degree function, or neutrosophic attribute value degree of contradiction function, respectively.

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The functions $d(\cdot,\cdot)$ and $c(\cdot,\cdot)$ are defined according to the applications that the experts need to solve. Then, the following notation is used: $x(d(x,V)), \text{where } d(x,V) = \{d(x,v), \text{for every } v \in V\}, \forall x \in Pv_D$. The attribute value contradiction degree function is calculated between each attribute value concerning the dominant attribute value (denoted by v_D) in particular and other attribute values.

The function of the degree of contradiction of attribute value c evaluated between the values of two attributes is used in the definition of plithogenic aggregation operators (intersection (AND), union (OR), implication ($\Longrightarrow$), equivalence ($\Leftrightarrow$), inclusion (partial order), and other plithogenic aggregation operators that combine two or more degrees of attribute values based on a tnorm and a tconform. Most plithogenic aggregation operators are linear combinations of a fuzzy t-norm (indicated by) with a fuzzy tconorm (indicated by), but nonlinear combinations can also be constructed [17]. If the t-norm is applied on the value of the dominant attribute denoted by, and the contradiction between $\wedge_F$ and $\vee_F$ is, then it is applied on the value of the attribute as follows:

$$[1 - c(v_D, v_2)] \cdot t_{norm}(v_D, v_2) + c(v_D, v_2) \cdot t_{conorm}(v_D, v_2), \quad (2)$$

or, using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \wedge_F v_2) + c(v_D, v_2) \cdot (v_D \vee_F v_2) \quad (3)$$

Similarly, if the $t-conorm$ applies to the value of the dominant attribute denoted by v_D, and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then it applies to the value of the attribute v_2

$$[1 - c(v_D, v_2)] \cdot t_{conorm}(v_D, v_2) + c(v_D, v_2) \cdot t_{norm}(v_D, v_2) \quad (4)$$

or, using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \vee_F v_2) + c(v_D, v_2) \cdot (v_D \wedge_F v_2) \quad (5)$$

The plithogenic neutrosophic intersection is defined as:

$$(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = (a_1 \wedge_F b_1, 1/2\,[(a_2 \wedge_F b_1) + (a_2 \vee_F b_2)], a_3 \vee_F b_3) \quad (6)$$

The plithogenic neutrosophic union is defined as:

$$(a1, a2, a3) \vee p (b1, b2, b3) = (a1 \wedge D\ b1, \tfrac{1}{2}[(a2 \wedge D\ b2) + (a2 \vee D\ b2)], a3 \wedge D\ b3) \quad (7)$$

In other words, what applies to membership, the opposite applies to non-membership, while in indeterminacy the average between them is what applies. Plithogenic neutrosophic inclusion is defined as follows:

Since the degrees of contradiction are:

$$c(a_1, a_2) = c(a_2, a_3) = c(b_1, b_2) = c(b_2, b_3) = 0.5,$$

$a_2 \geq [1 - c(a_1, a_2)]b_2$ o $a_2 \geq (1 - 0.5)b\_2$ o $a\_2 \geq 0.5b\_2$ applies, while $c(a_1, a_3)c(b_1, b_3) = 1$.

The opposite is true for $a_1 \leq b_1$therefore $(a_1, a_2, a_3) \leq_P (b_1, b_2, b_3)$ if and only if

$a_3 \geq b_3$, therefore $(a_1, a_2, a_3) \leq \_P (b_1, b_2, b_3)$ if and only if $a_1 \leq b_1$, $a_2 \geq 0.5b\_2$, and $a_3 \geq b_3$.

For the elaboration of a single decision matrix, the median of the plithogenic numbers is calculated for each combination, for all specialists. The median is calculated using the following formula:

$$median^m{}_{(i=1)}\{PN_i\} = (median^m{}_{(i=1)}\{T(PN_i)\}$$

$$median^m{}_{(i=1)}\{I(PN_i)\}, median^m{}_{(i=1)}\{F(PN_i)\}) \quad (8)$$

Where PN_i are plithogenic numbers, $T(PN_i)$ are their true components, $I(PN_i)$ are their indeterminate components and $F(PN_i)$ are their false components. In other words, Equation 7 means that the median of a set of plithogenic numbers is defined as the plithogenic number of the medians of its components.

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plithogenic number were introduced because the measurement of uncertainty of data needs to be handled with more attribute value to raise accuracy level [18].

2.3 Methodology based on plithogenic sets

- Determine the success factors
- Apply questionnaires
- Process information by determining the factor with the highest level of influence by weighting the criteria using the linguistic terms shown in Table 1, since it is more appropriate to evaluate a numerical scale because human beings deal better with natural language than with numerical scales:

Table 1: Plithogenic linguistic expressions

Linguistic Expression	Plithogenic number (T, I, F)
Very poor (VP)	(0.10, 0.75, 0.85)
Poor (P)	(0.25, 0.60, 0.80)
Moderately poor (MP)	(0.40, 0.70, 0.50)
Medium (M)	(0.50, 0.40, 0.60)
Moderately good (MG)	(0.65, 0.30, 0.45)
Good (B)	(0.80, 0.10, 0.30)
Very good (VB)	(0.95, 0.05, 0.05)

3. Results

According to the bibliography consulted [3]–[10], [19]–[29], in the case of medicine, blended-learning is the best option as a form of distance education. Questionary was developed based in success factor in [30]. Among the success factors described in the use of this type of education to guarantee its success and quality are the following:

A. ICT exploitation
   - A1) Use of interactive platforms and multimedia
   - A2) Group chats and discussion forums
   - A3) Virtual classrooms
   - A4) Satisfaction surveys

B. Support in teaching resources
   - B1) Case discussion and problem-based learning
   - B2) Tutorial Videos and Guides
   - B3) Concept/Mind Maps
   - B4) Self-evaluation
   - B5) Collaborative and autonomous learning

C. Adequate teacher training
   - C1) Proper use of ICT (devices, office automation, social networks, platforms).
   - C2) Implementation of resources for teacher-student feedback.
   - C3) Efficient use of teaching resources to optimize the teaching-learning process.
   - C4) Provide adequate bibliography.
   - C5) Innovate in the form of assessment to ensure continuity of learning.

D. Student skills and abilities
   - D1) Attitude in knowledge feedback
   - D2) Aptitude for self-learning
   - D3) Skill in the use of ICT (devices, office automation, social networks, platforms).
   - D4) Appropriate technical support

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D5) Correct intention while using ICT

For data processing in a plithogenic environment, the groups among themselves will be chosen as attributes. Which will be subjected to evaluation by experts using table 1. The sample calculation according to equation 1 was as follows:

MAXIMUM ALLOWED ERROR MARGIN	10.0%
POPULATION SIZE	27
Size for 95% confidence level	21
Size for 97% confidence level	22
Size for 99% confidence level	23

Figure 1: Calculation of the Sample

21 experts were chosen for the conformation for the plithogenic analysis of the multi-attribute of dimension 4 and cardinality (4x5x5x5), which is established by pairs. The degrees of contradiction between the pairs were the following:

- ✓ $c_D(A1, A2) = c_D(A1, A3) = c_D(A1, A4) = 0.25$
- ✓ $c_D(B1, B2) = c_D(B1, B3) = c_D(B1, B4) = c_D(B1, B5) = 0.2$
- ✓ $c_D(C2, C1) = c_D(C2, C3) = c_D(C2, C4) = c_D(C2, C5) = 0.2$
- ✓ $c_D(D2, D1) = c_D(D2, D3) = c_D(D2, D4) = c_D(D2, D5) = 0.2$

Being the dominant values are:

A1) Use of interactive platforms and multimedia.
B1) Case discussion and problem-based learning.
C2) Implementation of resources for teacher-student feedback.
D1) Attitude in knowledge feedback.

The evaluation of the pairs by the experts is set out below:

Table 2: Evaluations given by the experts

	Success factors	Medians
ICT exploitation	Use of interactive platforms and multimedia	[0.575,0.35,0.525]
	Group chats and discussion forums	[0.725,0.225,0.325]
	Virtual classrooms	[0.8,0.1,0.3]
	Satisfaction surveys	[0.575,0.35,0.525]
	Median	**[0.65,0.2875,0.425]**
Support in teaching resources	Support in teaching resources	[0.65,0.25,0.45]
	Case discussion and problem-based learning	[0.8,0.175,0.25]
	Tutorial Videos and Guides	[0.575,0.35,0.525]
	Concept/Mind Maps	[0.5,0.4,0.6]
	Self-evaluation	[0.65,0.25,0.45]
	Collaborative and autonomous learning	[0.65,0.25,0.45]

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	Median	**[0.65,0.25,0.45]**
Adequate teacher training	Proper use of ICT (devices, office automation, social networks, platforms).	[0.725,0.225,0.325]
	Implementation of resources for teacher-student feedback.	[0.8,0.1,0.3]
	Efficient use of teaching resources to optimize the teaching-learning process.	[0.8,0.1,0.3]
	Provide adequate bibliography.	[0.575,0.35,0.525]
	Innovate in the form of assessment to ensure continuity of learning.	[0.65,0.25,0.45]
	Median	**[0.725,0.225,0.325]**
Student skills and abilities	Attitude in knowledge feedback	[0.575,0.35,0.525]
	Aptitude for self-learning	[0.65,0.25,0.45]
	Skill in the use of ICT (devices, office automation, social networks, platforms).	[0.725,0.2,0.375]
	Appropriate technical support	[0.575,0.35,0.525]
	Correct intention while using ICT	[0.5,0.4,0.6]
	Median	**[0.65,0.35,0.525]**

Plithogenic neutrosophic union between attributes according to equation 6 is defined as:

Table 3: Plithogenic Neutrosophic Binding

Support in teaching resources Student skills and abilities	[0.4225,0.34375,0.23625]
Support in teaching resources Adequate teacher training	[0.47125,0.265625,0.14625]
ICT exploitation Student skills and abilities	[0.4225,0.3690625,0.223125]
ICT exploitation Adequate teacher training	[0.47125,0.28859375,0.138125]

As can be seen, the experts agree that the success factors that have had the highest level of impact on the medical career in Ecuador, result from the combination of the correct exploitation of ICT with the adequate training of the teacher. Therefore, educational institutions need to improve their strategy, so it is recommended to choose to improve teaching and academic management from these two aspects.

4. Conclusions

The objective proposed in the research was achieved since:

- The behavior of virtual learning of the medical school in other centers was studied, determining the success factors and;
- those that have developed the process with the required quality were determined

The use of Plithogeny allowed to find accurately and quickly which combination produces a higher level of synergy between these factors. In this way, it can be implemented objectively to achieve the optimization of the resources of the institutions. The utility of Plithogeny is exposed as a form of analysis of the origins of problems where subjectivity is a high determinant.

With good use of ICT and adequate teacher training, it will be possible to obtain the effectiveness required by medical students, as one of the most affected schools by the incidence of the pandemic and the isolation caused, thus making teaching practice impossible as a way to acquire skills

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