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Compensatory fuzzy logic model for impact assessment when implementing ICT in pedagogical scenarios

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Abstract. A Pedagogical Scenario is the place where different events take place and serves as an essential framework for the teaching-learning process. It is the space organized and structured in such a way that facilitates access to knowledge, through the generation of activities and relationships that motivate learning. Pedagogical scenarios can be designed or predicted. The aim of this article is to evaluate the impact of the implementation of Information and Communication Technologies (ICT) in pedagogical scenarios, using compensatory fuzzy logic. The compensatory fuzzy logic has operators of conjunction, disjunction, negation among others that facilitate the solution of problems because it allows mathematically modeling the experience of experts in natural language and on the other hand it allows to decide which is the most convenient evaluated scenario.

Keywords: Compensatory Fuzzy Logic, pedagogical scenarios, ICT, mathematical operators, natural language

1 Introduction

Today's higher education is related to the education, training and preparation of man/woman for life from a social constructivist point of view, as well as the training of professionals capable of facing the challenges and transformations that are manifested today in the different branches of science and who are responsible for solving the problems that arise in the sphere of production and services. In this sense, the new pedagogical scenarios that are presented in the current educational system play a fundamental role[1], as are the technologies that have transformed the current learning environment and influenced the traditional process of teaching educators under a new dynamic, updated and innovative practice of university education [2].

Pedagogical scenarios today require a preparation in terms of technology, especially in computing and communication, to achieve satisfactory results in the training of professional skills. To achieve this objective, it is necessary to face an essential problem that lies in the preparation of students according to the performance of their work as a professional future, for which it is essential to appropriate an accumulation of skills that will allow them to face with quality the productive process, which has as a precedent an undergraduate training in tune with current transformations and that is materially evidenced in the conception of solutions with quality and scientifically justified.

With regard to pedagogical scenarios and, in particular, educational models according to, it defines them according to the transversal content that the educational models should have in themselves, and especially the teachings present in all parts of the curriculum of the different educational phases, that is, common themes to all the areas directed to the integral formation of the student and to the preparation of the same to be integrated into society. In the document itself, the author refers to transversal contents in education and specifically those related to training in the use of new information and communication technologies.

In the development of educational theories and models, of pedagogical scenarios that promote the creation of learning environments and communities supported by Information and Communication Technologies (ICT), important efforts have been made, which have included guidelines for the design, implementation and evaluation of educational materials, didactic units, activities and learning objects mainly applied to education mediated by technology, in this sense when in daily coexistence there are inadequate patterns in human behavior, it is necessary to unlearn incorrect patterns, reconstruct the pieces of behavior and relearn other patterns of new learning as in the case of information and communication technology [3].

Today's knowledge society, driven by scientific progress in a globalizing socioeconomic framework and sustained by the widespread use of diverse information and communication technologies, brings about changes that affect all areas of human activity. These effects are manifested in a general way in work activities and in the world of education, the way of teaching and learning, the infrastructures and means we use for this, the organizational structure of centers in general and schools in particular based on their culture.

Based on the foregoing, it should be noted that it is necessary to introduce ICT in pedagogical scenarios, to strengthen the teaching-learning process so that its presence in the system does not constitute a factor of addiction and dependence. In this context[4], they identify difficulties in introducing ICTs in the pedagogical environment and in turn in the new cultural context, highlighting the presence of technocratic, reformist and holistic pedagogical scenarios.

Regardless of the difficulties in introducing ICTs into educational environments, as in other fields of human activity, their use, as referred to [5], has social, economic or political consequences, but different from one culture to another. Therefore, this transformation of implementing technology into a useful and applicable environment is a process that has to be carried out both on a social and institutional level, as well as on a personal level, in order to seek and find that real utility that technology can bring as an added value in the teaching-learning process.

The use of ICT in pedagogical environments becomes an indispensable tool, where they can perform multiple functionalities, however, in pedagogical environments where the use of ICT constitutes a threat the functionalities to be performed are lower, but the tendency to technology addiction is also lower.

In accordance with the above, this study evaluates pedagogical scenarios in higher education, using compensatory fuzzy logic, in order to support decision-making regarding the impact of the implementation of ICTs in the pedagogical scenarios of higher education.

The analysis carried out leads to the risk of addiction to technology in students. To this end, the level of learning obtained in students must be observed, with the use of technology and without its use. The corresponding results give an account of academic performance, which is a factor to be taken into account in this evaluation.

In order to obtain measurable results, all categories of ratios of the teaching-learning process, whether or not ICTs are implemented in pedagogical scenarios, should be used to appreciate the impact of this process. The lack of generic indicators that demonstrate the impact of the pedagogical scenarios, before and after applying ICT, becomes a barely confusing problem in the teaching-learning process, which makes it difficult to evaluate the pedagogical scenarios of higher education efficiently.

Faced with the situation described and with the use of traditional techniques to measure the impact of implementing ICT, it is not possible to obtain an adequate evaluation, since traditional techniques do not provide an appropriate solution, sometimes the information obtained with such techniques is imprecise or missing, a situation that needs to be resolved with other advanced techniques, such as the use of Compensatory Fuzzy Logic, this technique deals more solidly with linguistic terms and in particular the use of mathematical logic operators. It provides linguistic models that express, through logical propositions, the translation of ambiguous phrases in a colloquial style as they refer to[6] .

2. Preliminaries

In this section, we briefly review compensatory fuzzy logic concept. Afterwards, we present compensatory fuzzy logic operators.

2.1 Compensatory Fuzzy Logic

Compensatory Logic is a favorable field of application for decision support applications, with a high practical capacity. It composes a new multivalent system, which breaks with traditional Mathematics, in order to achieve a better semantic behavior than that of classical systems [7, 8].

Essentially, Compensatory Fuzzy Logic has among its properties, that it is sensitive to changes in the basic predicates, interpretable according to categorical scales of truthfulness, it contributes to the compensation of the values of the basic predicates with others, it is not associative [9]. It offers new operations to implement logical operators, among others: conjunction and disjunction, which facilitate a logical system of simultaneous modeling in the deductive and decision-making processes, since it simultaneously takes into account statements that may be contradictory. [10]

Compensatory Fuzzy logic offers a suitable working scheme that combines the advantage of implementing uncertain concepts with the possibility of handling sentences in natural language [11]. The modeling of vagueness is achieved through linguistic variables, which allows to take advantage of the knowledge of experts. The linguistic variables in Compensatory Logic have their foundation from the linguistic terms that are obtained, in the present work the foundation to be used with linguistic terms is based on the values of truth and their respective categories, this are shown in Table 1.

Truth value	Category
0	False
0.1	Almost false
0.2	Pretty fake.
0.3	Something false
0.4	More false than true
0.5	As true as false
0.6	More true than false
0.7	Something real
0.8	Quite true
0.9	Almost true
1	True

Table 1: Values of truth

2.2 Compensatory Fuzzy logic Operators

A Compensatory Fuzzy Logic system is a quartet of operators: a conjunction, a disjunction, a negation and a strict fuzzy order that satisfies the axioms of compensation, commutativity, strict growth, veto, fuzzy reciprocity, fuzzy transitivity and the Morgan's law [12].

In this work Geometric Mean Based Compensatory Logic (GBCFL) is used due to the robustness and relative simplicity of its main operators [13].

In GBCFL conjunction is defined as follows:

$$c(x_1, x_2, \dots, x_n) = (x_1 x_2, \dots, x_n)^{\frac{1}{n}} \tag{1}$$

Disjunction is defined as the dual of the conjunction:

$$d(x_1, x_2, \dots, x_n) = 1 - [(1 - x_1)(1 - x_2) \dots (1 - x_n)]^{\frac{1}{n}} \tag{2}$$

The fuzzy negation defined as is:

$$n(x) = 1 - x \tag{3}$$

and the fuzzy strict order is:

$$o(x, y) = 0.5[c(x) - c(y)] + 0.5 \tag{4}$$

With compensatory fuzzy logic we can express an "appealing" sensibility and attaint more reliable operators according to the way that human make decisions in real world [14].

2.0 Model for impact assessment when implementing ICT in pedagogical scenarios

The model for impact assessment when implementing ICT in pedagogical scenarios, supported by compensatory fuzzy logic, follows the steps shown in Figure 1.

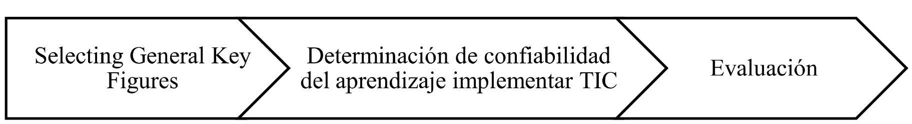

Figure 1: Stages of the model for the evaluation of the impact of the implementation of ICT in pedagogical scenarios, supported by the compensatory fuzzy logic. Source Prepared by the authors

The detailed description of each of the steps of the model are:

a. Stage of selection of the general key figures; all the key figures are specified with express indication of their calculation form and the range of the final results (absolute or relative as appropriate). For this purpose, a selection of ratios from a series of available indicators is made, in which the forms of calculation and their interpretation are made explicit. It is based on a previous analysis, which consists of hierarchical segmentation, based on the search for relevant factors that contributes to the identification of the variables that have the greatest impact on the classification of pedagogical environments, through the use of data mining techniques [14].

b. Stage of determining the reliability of learning, when implementing ICT, in pedagogical scenarios; indicators are selected to measure the reliability of learning, when implementing ICT, in pedagogical scenarios. Then, the propositional form of each predicate that intervenes in learning is detailed, by implementing ICT in pedagogical scenarios, which facilitates determining the reliability of learning with the use of technology.

c. Evaluation stage: The academic results are taken from a student cohort that has incorporated the use of ICT into the curriculum, and compared against another student cohort that has not incorporated ICT into the curriculum; the evaluation is carried out according to the rank of promotion indicator. For their score, the value of the promotion indicator is labeled.[15]

3 Results

According to the stages proposed in the model represented in Figure 1, the following results are obtained:

a. Stage of selection of the general ratios

At this stage the indicators are separated into four groups to be measured, they are:

- General indicators of the teaching-learning process
- Indicators specific to learning using ICTs
- Indicators of knowledge management with the use of ICTs
- Reliability of the knowledge managed with the use of ICTs

The defined indicators have been classified according to the students' learning when using ICT, standing out:

- The availability of skills for access to information and for the use of any technological resource.
- Cognitive abilities to transform information into knowledge.
- Ability to use languages and expressive forms to relate and disseminate information through any medium and communicate with other subjects.
- Interiorization of criteria and values for the ethical use of information and knowledge.

The student cohorts have been classified according to their professional competence. The groups to be measured are ordered according to the future decisions of the students' professional development. The groups A, correspond to the competences still unknown (A: Unknown), those corresponding to group C, are the students prepared to work in entities or companies; (C: Entities), those of group E, are the students who wish to work freely; (E: Free) and those of group O, are the students who wish to work in public institutions; (O: Public).

The ratios obtain rank that are calculated, with express determination of the reported data, according to the promotion variable in student cohorts. They are expressed in percent. Table 2 shows the indicators to measure the reliability of learning, when implementing ICT, in pedagogical scenarios.

Code	First name	Values
R1	Type of activity	Availability of skills for access to information and for the use of any technological resource, cognitive abilities to transform information into knowledge, ability to use languages and expressive forms to relate and disseminate information through any medium and communicate with other subjects. Interiorization of criteria and values for the ethical use of information and knowledge.
General indicators of the teaching-learning process		
R2	Percentage of total promotion	[0;1]
R3	Number of suspensions	[1;8844]
Indicadores propios del aprendizaje al utilizar TIC		
R4	ICTs as components of institutional culture	[0,38;88,74]
R5	Availability to involve the ICT in the formative task of the students	[18,86;884,46]
R6	Availability for the strengthening of technology and research habit through its insertion	[17,36;909,51]

R7	Investments in relation to the insertion of ICT in the teaching-learning process	[3,04;99,07]
R8	Surplus capital required to insert ICT in the teaching-learning process	[-10,34;778,01]
R9	Availability in relation to enforceable commitments of educational institutions to insert ICTs in the teaching and learning process	[1,09;958,65]
	Indicators of knowledge management with the use of ICTs	
R10	Knowledge management when using ICTs in relation to knowledge management without the use of ICTs	[-0,22;98,99]
R11	Unfavourable academic results in relation to the use of ICTs	[-269,6;283,29]
R12	Expenditure related to the teaching-learning process with ICT	[0;97,78]
R13	Expenses of Exploitation of technology in relation to the learning of the students	[1,2;687,39]
R14	Total expenditure related to the use of ICT in the teaching-learning process	[-0,22;785,17]
R15	Outcome in relation to the use of ICT in the teaching-learning process	[-651,66;554,43]
	Proposed indicator (Reliability of the knowledge managed with the use of ICT)	
R16	Reliability = Number of suspensions	[0,0000076;1,65]
R17	Difficulty = Difficulties with student cohorts in relation to the promotion of students with ICT insertion	[20,03;545,85]

Table 2: Range of key figures. Source Own preparation.

b. Stage of determining the reliability of learning by implementing ICT in pedagogical scenarios.

The indicators to measure the reliability of learning, when implementing ICT, in pedagogical scenarios are shown in Table 3, of these indicators is detailed its propositional form involved in the model

Criterion: Difficulty B(x)	
Difficulty index, B(x)	Quotient between students with difficulty in promoting and the technologies used
Criterion: Promotion C(x)	
Promotion index, C(x)	Quotient between quantity of promoted and technology used
Criterion: Financial solvency to insert ICT D(x)	

Financial solvency index to insert ICT composed by:	
a) Efficient ICT information management index, E(x)	Quotient between students promoted when managing information and ICT used
b) Favorability index of academic results in relation to ICT use, F (x)	Quotient between academic performance and ICT used
c) Promotion results index, G(x)	Quotient between the indices of the promotion and ICT results used
(d) Response capability index, H (x)	Quotient between ICT employment availability and economic solvency

Table 3: Selection of indicators of reliability of learning, when implementing ICT, in pedagogical scenarios. Source Prepared by the authors.

Detail of the predicates used:
A(x): x is a student cohort with ICT included that has a promotion and is considered reliable.
B(x): x has a low level of difficulty in learning with ICTs
C(x): x has a low level of promotion
D(x): x has financial solvency to insert ICTs
E(x): x has efficient ICT information management
F(x): x has unfavorable academic performance in relation to the use of ICTs
G(x): x has a good result in promotion results
H(x): x has a high responsiveness

The expressions for the determination of learning reliability, when implementing ICT, in pedagogical educational scenarios, totally subjective and that can vary according to the criterion of the experts, were defined by a group of experts specialized in the insertion of ICT in the process of teaching - learning of pedagogical scenarios. The expressions obtained were:

$$A(x) = B(x) \wedge C(x) \wedge D(x) \qquad (5)$$

$$D(x) = H(x) \vee [G(x) \wedge E(x)] \vee [F(x) \wedge (H(x) \vee G(x))] \qquad (6)$$

Where a - H(x) is the negation of indicator truth value, ∧ identifies the calculation through the operator and ∨ performs the calculation through the operator or.

The proposed model for impact assessment when implementing ICT in pedagogical scenarios
is shown in Figure 2.

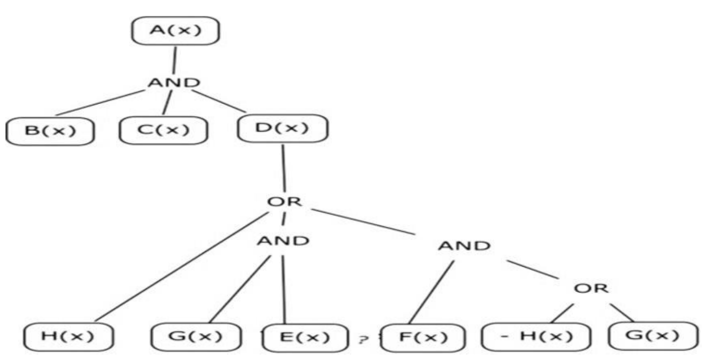

Figure 2: Proposed model for impact assessment when implementing ICT in pedagogical scenarios. Source Prepared by the authors.

Based on the model proposed for impact assessment when implementing ICT in pedagogical scenarios, the propositional form of each predicate involved in learning is detailed, when implementing ICT in pedagogical scenarios, which facilitates determining the reliability of learning with the use of technology.

Predicate D(x) corresponds to the sentence "The financial solvency to insert ICT is obtained through the high capacity of response, related to the good result in the promotion results and the efficient management of information with ICT, or of unfavorable academic results in relation to the use of ICT together with a low level of response or a high result in the promotion results" and implies the disjunction H(x) and other two compositions of predicates.

Predicate A(x) corresponds to the sentence "A student cohort with ICT included that has a good promotion is considered reliable if it has a low level of difficulty in learning with ICT, a low level of promotion and a good financial solvency to insert ICT" and implies conjunction of prepositions B(x), C(x) and D(x).

The linguistic labels defined in three levels, as the functions associated with the predicates of the ratios defined from the analysis of the graphical representation of the data were established as:

A(x)→ Student cohort with ICT included that has a promotion and is considered reliable has defined the linguistic scale: high, medium and low.

B(x)→ Difficulty in learning with ICT, has an associated function a sigmoidal membership function, through the scale: high, medium and low.

C(x)→ Promotion has a sigmoid function associated with it, using the following scale: high, medium and low.

D(x)→ Financial solvency to insert ICT, has defined the linguistic scale: high, medium and low.

E(x)→ Information management with efficient ICT, has an associated trapezoidal membership function, by means of the scale: very efficient, efficient and scarcely efficient.

F(x)→ Unfavorable academic results in relation to the use of ICT, has an associated trapezoidal membership function, through the following scale: high, medium and low.

G(x)→ Good result in promotion results, has an associated trapezoidal membership function, through the following scale: high, medium and low.

H(x)→ Response capacity, has a sigmoid membership function associated with it, by means of the following scale: very adequate, adequate and scarcely adequate.

They were not assigned membership functions[7] to the propositions of A(x) and D(x), because they are the result of the composition of other predicates, we worked with the labels according to the results obtained and the range of values they can take.

c. Evaluation stage

At this stage, they take the academic results of a student cohort that has incorporated the use of ICT into the curriculum, and compare it against another student cohort that has not incorporated ICT into the curriculum; the evaluation is carried out according to the rank of promotion indicator. For its score, the value of the promotion indicator is labeled. The results are shown in Table 4.

This type of analysis presents the value corresponding to the ratio that gives rise to the basic propositions [B(x), C(x),E(c),F(x),G(x) and H(x)] and the linguistic label corresponding to the proposed compensatory fuzzy model.

Criteria	Predicted	Indicator value	Linguistic expression	Truth value according to Table1
Difficulty	B(x): x has a low level of difficulty in learning with ICTs	0,1	Quite difficult	0.19
Promotion	C(x): x has a low level of promotion	0,04	Almost absolutely unsafe	0.11
Financial solvency to insert ICT D(x)	E(x): x has efficient ICT information management	283,72	More inefficient than efficient	0.41
	F(x): x has unfavorable academic performance in relation to the use of ICTs	-0,30	Average academic results	0.50
	G(x): x has good promotion results	-651,66	Absolutely bad.	0
	H (x): x has a high responsiveness	0	Almost absolutely unresponsive	0.10

Table 4: Analysis of the impact assessment model when implementing ICT in pedagogical scenarios. Source Prepared by the authors.

For the analysis of the results obtained in Table 4, the values of a given student cohort were taken, which gave a low reliability in the promotion results without inserting ICT, with which, in terms of this attribute, the result is quite insecure. Result obtained by calculating$A(x) = B(x) \wedge C(x) \wedge \{[H(x) \vee (G(x) \wedge E(x))] \vee [F(x) \wedge (-H(x) \vee G(x))]\}$, being obtained:

$A(x) = 0.2 \wedge 0.1 \wedge \{[0.1 \vee (0 \wedge 0.4)] \vee [0.5 \wedge (0.9 \vee 0)]\}$

$A(x) = 0.2 \wedge 0.1 \wedge [0.1 \vee 0 \vee (0.5 \wedge 0.684)]$

$A(x) = 0.2 \wedge 0.1 \wedge (0.1 \vee 0 \vee 0.585)$

$A(x) = 0.2 \wedge 0.1 \wedge 0.28$

$A(x) = 0.18\ (low\ reliability)$

This result shows that student cohorts with ICT insertion have high reliability in promotion results with respect to student cohorts without ICT insertion in their curriculum.

Conclusion

In order to measure the evaluation of the impact of the implementation of ICT in pedagogical scenarios, a relative study was carried out of the demand for preparation in terms of technology, especially in computer science and communication, which is needed in the educational system, in order to obtain a professional with greater preparation for professional performance.

The use of compensatory fuzzy logic is proposed to measure the linguistic terms of the evaluation of the impact of the pedagogical scenarios, given that in this technique the operators of human thought ( ) are better modeled with other probabilistic techniques.

A model was developed for the impact assessment of implementing ICT in pedagogical scenarios that consist of three stages, which were developed to then obtain the results of the model.

It is demonstrated through the proposed model, based on compensatory fuzzy logic, for evaluating the impact of implementing ICT in pedagogical scenarios, that these scenarios have greater reliability in learning than pedagogical scenarios with student cohorts, which did not insert ICT in their curriculum. Future work will concentrate on developing a compensatory neutrosophic model.

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