Applying the Agile Manifesto to a Project-Based Learning Experiment:

A Statistical Analysis

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***Abstract*— This work proposes the use of active learning in Electrical Engineering, as a complement to conventional teaching methods, where there is an unilateral knowledge transfer, and the instructor is the responsible for all steps of the process. In order to assess this approach an active learning methodology was proposed and applied at the Regional University of Blumenau (FURB), developed especially for non-integral courses, called Project-Based Learning Agile (PBL^A). The methodology has been applied for five semesters. The results were analyzed using partial least squares path modeling (PLS-PM) with fuzzy regression (in order to consider the uncertainties of the human condition) by means of a TS-qQP-PLS-PM algorithm. From the results analysis, it was possible to statistically understand how the learning process is connected to the PBL^A. The data analysis suggests that the educational process applied in this work is rooted in a humanist basis, formed by individual (self-esteem and self-realization) and social (cooperation) aspects, and the PBL^A, sustained by this humanization, serves as a basis for the Learning. Thus, the results suggest that humanization is an important part in the education process of a new electrical engineer.**

Keywords—Assessment tools; Knowledge transfer; Statistical analysis; Structural equation modeling; Project-Based Learning;

I. Introduction

It is important for the students to understand their connections to the world, and their role in society, in order to fit in a market where the traditional knowledge expected from an engineer, involving equations and mathematical concepts, is no longer a differential. Nowadays, several soft skills are expected from an engineer, including cooperation, leadership and creativity [1], [2].

Trying to keep up with this change, and bring out students' soft skills [3], active learning has gained strength in recent years [4]. It is a methodology where the students are not simple spectators, as they participate, experience and stare at their own epistemological trajectory.

There are several ways to implement active learning, among them there is the Project-Based Learning (PBL), which has been gaining ground, and being successfully applied in several fields [5]–[7]. It consists of a project based methodology where students must independently solve technical problems similar to those faced in their professional life. However, one of the difficulties found in PBL is the measurement of how knowledge is generated and disseminated.

Considering the aforementioned difficulties, this work proposes and describes a statistical analysis of knowledge construction, in the context of active learning in an electrical engineering major using Partial Least Squares Path Modeling (PLS-PM), a technique that has been expanding in social studies [8]

Due to the PLS-PM popularity it becomes interesting to improve the algorithm to extract more information from the studied population. In this way, in [8] a modification to the original algorithm was proposed using fuzzy possibilistic regression to handle data uncertainties in the presented results; However, this regression has been criticized in the literature [9].

This work proposes the expansion of the algorithm presented in [8] to a quadratic optimization model with a central tendency. The idea is to minimize the problems described in the literature referring to the purely possibilistic regression [9] - not to be related to the classical concepts of least squares regression – by means of a two stage regression.

The proposed algorithm is then used to evaluate the "Project-Based Learning Agile" methodology, which is an active learning methodology conceived aiming at part-time degree courses, where students reconcile full-time jobs with academic education. The basis for the statistical analysis is a survey answered by the students at the end of the project.

The remaining of the paper is organized as follows. Section II presents the background and characterization of the methodology, Section III presents the PLS-PM algorithm, Section IV presents literature revision of the fuzzy regression, Section V presents the proposed algorithm, Section VI presents the results and data analysis and Section VII presents the conclusions.

II. Background and Characterization

The project took place in the Department of Electrical Engineering and Telecommunications of the Regional

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University of Blumenau - Brazil (FURB) and had the involvement of the following courses: Power Electronics and Control and Servomechanisms. The project has been applied for five consecutive semesters since its implementation in 2014/2.

The two courses selected for the project have the following content as available by the university:

Power Electronics II – power semiconductors; DC-DC switched converters; DC-AC converters; basics of switching power supplies.

Control and Servomechanisms – system terminology and modeling; stability; transfer functions; performance indexes; Bode diagram; design and compensation using Bode plots; Nichols and Nyquist analysis; root locus analysis; design and compensation using root locus; proportional, integral and derivative compensation.

The integration between the two courses is important because it involves the students with the power electronics in a manner that they may be challenged in their professional life. Controlled converters are present in everyday life, and the research and development of new technologies related to them is a growing area.

The integration of the courses is also justified by the current syllabus. In Power Electronics II the converters are shown operating in open loop, just alerting the students to the fact that they can be controlled. In Control and Servomechanisms course, control strategies are presented in general terms and with no practical applications. Thus, the junction of the two lines of knowledge in a single design allows the students to have a more comprehensive learning process, focused on real life problems and applications.

Two main aspects were considered important in the implementation of the projects: team's formation (integration among students) and differentiation (the same project for all teams, but with different requirements to allow experience exchanging).

Students who were not in the two courses intersection set could be divided into two groups: one group of those who already attended one course and are attending the other one; and the second group would be those who are attending one course and would attend the other in the future. Only the second could create a problem in the project's process. So there was a recommendation that the group should have members of both courses to share experiences and knowledge. The idea was to mitigated the issue.

A. Project-Based Learning Agile

The part time profile of the Electrical Engineering major of FURB led to the creation of a new application model of Project-Based Learning. This, could be adapted to the student's profile, being dynamic and adaptive. Thus, its development was based on the principles of Agile practices.

The Agile manifesto [9] was used as a basis, which was adapted to better meet the expected requirements of such project, creating a methodology called Project-Based Learning Agile (PBL^A), according to the following principles:

Individuals and interactions over processes and tools
Working simulation over comprehensive documentation
Student collaboration over deadlines negotiation
Responding to change over following a plan

In the adapted manifesto (as in the original), even if there is value in the items on the right hand side (those not in bold), the highest value is given to items on the left hand side (bold ones).

The Agile manifesto principles are important to give the project a flexible content. It is important that a project that can quickly adjust along the way, to meet potential difficulties that arise during the progress of the courses that form the project.

Furthermore, the benefits of Agile even when not connected to a PBL have also been pointed out in the literature. In [10] the benefits of software development teaching using Agile are discussed. In [11] the use of the method in education is well explored, showing that in some cases it replaces traditional education even in projects considered as "common" in favor of using frameworks like Scrum and XP by the students.

The difference of this proposal is its goal. It does not aim to make the students to follow the Agile methodology within the PBL, but to use the principles of the manifesto for the creation of PBL. As a result, only the instructors have contact with Agile, making the methodology transparent to students.

III. Partial Least Square Path Modeling

The structural equation modeling (a second generation multivariate analysis) is a set of techniques that simultaneously allows the evaluation of the relationship between the observable variables (indicators) and the latent variables. This is done through the multivariate regression of the variables in which the operator wants to check the influence.

The role of one variable (if it influences and/or is influenced by another) must be defined through the theoretical analysis of the object of study [12], [13].

One of the approaches to structured equation modeling well known in the literature is the PLS-PM (Partial Least Squares Path Modeling) algorithm, which allows to estimate cause-effect relationships between latent variables while seeking to maximize the total variance explained from the variables. Its use is recommended in exploratory studies [13].

The choice by this method is adequate when the purpose of the research is between the need to test a theory and the objective to predict patterns, according to Fig. 1.

If the purpose of the research is justly predictive, the use of Artificial Neural Networks (ANNs) is more appropriate, on the other hand if the purpose of the research is purely confirmatory, the covariance based structural equation modeling methods are more adequate [14].

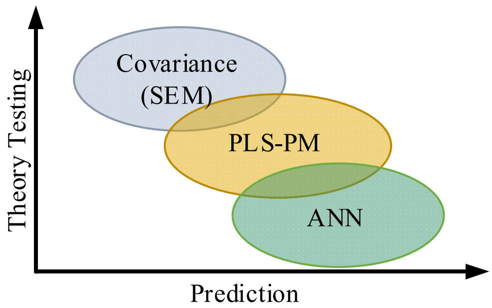

Fig. 1 - Approach based on the analysis objectives.

A. *PLS-PM Algorithm*

Each PLS-PM model consists of two sub models, one defined as inner model, also known as structural, and the outer model, defined as measurement. The structural model concerns the relationships between latent variables, while the measurement model refers to the relationships between a latent variable and its observable variables [15], [16].

Given *p* variables (questions of a questionnaire) measured by *n* observations (respondent individuals), it is considered that these variables can be divided into *J* blocks:

- **X** is the set of data containing the *n* observations and *p* variables. A matrix of dimensions' *n x p*.
- **X** can be divided into *J* mutually exclusive blocks, $\mathbf{X}_1$, $\mathbf{X}_2$, $\mathbf{X}_3$, ..., $\mathbf{X}_J$.
- The blocks $\mathbf{X}_j$ have *K* variables: $\mathbf{X}_{j1}$, $\mathbf{X}_{j2}$, ..., $\mathbf{X}_{jK}$.
- Each of the blocks $\mathbf{X}_j$ is associated as a latente variable LV_j. LV_j Being an unobserved abstract representation.
- The estimation of a latent variable, also defined as a score, is represented by $\widehat{LV}_j = Y_j$.

From the data set, weights ($\widetilde{w}_j$) are extracted from each of the indicators that are used later in the estimation of path coefficients (β_{ji}). It is considered the fact that all relations of the structural model are treated as linear, which can be expressed by equation (1)

$$LV_j = \beta_0 + \sum_{i \to j} \beta_{ji} LV_i + erro_j \quad (1)$$

Subscript *i* of LV_i refers to all latent variables (dimensions) that are supposed to predict LV_j. The coefficients β_{ji} are the path coefficients and represent the strength and direction of the relationship between LV_i and LV_j. β_0 is the intersection term and $erro_j$ refers to residuals.

The path coefficients are characterized by the coefficients of the ordinary least squares linear regression of Y_j on all Y_i related to it, as (2) and (3).

$$Y_j = \sum_{i \to j} \beta_{ij} Y_i \quad (2)$$

$$\beta_{ji} = (Y_i^{'} Y_i)^{-1} Y_i^{'} Y_j \quad (3)$$

Given these considerations, the algorithm is presented in Table 1.

TABLE 1 – PLS-PM ALGORITHM.

PLS Path Modeling with path scheme, standardized latent variable scores and OLS regressions [32].
Input: . $X = [X_1, ..., X_j, ..., X_J]$., with *J* blocks of variables;
Output: w_j, Y_j, β_{ij}, $\widehat{\lambda}_{jk}$;
initialize $\widetilde{w}_j$
for all $j = 1, ..., J$ **do**
$Y_j = \sum_k w_{jk} X_{jk}$
$e_{ji} = \begin{cases} cor(Y_j, Y_i) & LV_j \to LV_i \\ (Y_i{'}Y_i)^{-1} Y_i^{'} Y_j & LV_i \to LV_j \end{cases}$ *path scheme*
$Z_j = \sum_{i \leftrightarrow j} e_{ij} Y_i$
update $\widetilde{w}_j$: $\widetilde{w}_{jk} = cor(X_{jk}, Z_j)$
if $\lvert w_{jk}^{S-1} - w_{jk}^{S} \rvert < \Delta$
$Y_j = \sum_k \tilde{w}_{jk} X_{jk}$
$\beta_{ji} = (Y_i^{'} Y_i)^{-1} Y_i^{'} Y_j$
$\widehat{\lambda}_{jk} = cor(X_{jk}, Y_j)$
else
repeat until convergence
end if
end for

IV. FUZZY REGRESSION

The fuzzy regression was proposed in the literature as a way to consider the uncertainties of the coefficients of a linear regression, i.e.: to add the uncertainties of the human condition to an analysis [17]–[19].

This kind of analysis was initially proposed by [17] based on the concepts of fuzzy functions presented by [20] that aimed to take into account the natural uncertainties present in a certain phenomenon.

While for traditional linear regressions the deviation between the observed and estimated values were identified as errors in the observations, in [17] they assumed that these differences occur because of the diffusion or vagueness of the measured system. The fuzzy parameters of a linear system measured by the model proposed by the authors correspond to the system's possible distribution, being responsible for measuring its uncertainty.

A. *Possibilistic Regression*

By generating parameters corresponding to the distribution of possibility of a system, the model presented in [17] is known in the literature as possibilistic regression and has as general form the equation presented in (4).

$$\tilde{y} = \tilde{A}_0 + \tilde{A}_1 x_1 + ... + \tilde{A}_n x_n \quad (4)$$

Where $x = [x_0, x_1, ..., x_n]^T$ is a vector of independent variables and $\tilde{A} = [\tilde{A}_0, \tilde{A}_1, ..., \tilde{A}_n]^T$ a vector of fuzzy coefficients denoted in the form of a triangular by $\tilde{A}_j = (a_c, a_w)$, having its pertinence function described by (5).

$$u_{\tilde{A}_j}(a_x) = \begin{cases} 1 - \frac{|a_c - a_x|}{a_w}, & a_c - a_w \leq a_x \leq a_c + a_w, \ \forall j = 1,2,...,N \\ 0, & otherwise \end{cases} \quad (5)$$

Where a_c and a_w are respectively the center point and the maximum dispersion of the function, as shown in Fig. 2.

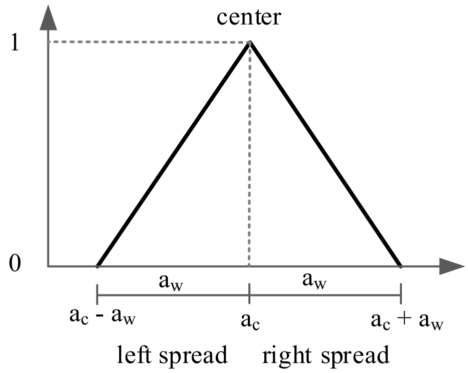

Fig. 2 - Triangular membership function.

Thus, the regression presented in (4) can be rewritten as in (6).

$$\tilde{y} = (a_{c0}, a_{w0}) + (a_{c1}, a_{w1})x_1 + ... + (a_{cn}, a_{wn})x_n \quad (6)$$

Or in the general formulation shown in (7).

$$\tilde{y} = (a_{c0}, a_{w0}) + \sum_{j=1}^{n} (a_{cn}, a_{wn})x_{ij} \quad (7)$$

Differently from the ordinary least square regression, the deviation between the data and the estimated model depends on the imprecision of the parameters and not on the measurement errors, in this case the model of [17] proposes that to minimize the uncertainty of the estimated model one can minimize the total spread of the system's fuzzy coefficients [21].

This spread may also depend on a degree of pertinence known as the "factor h", defined by the operator, which specifies the degree of feasibility of the system conditions [22]. The higher the degree of viability, the higher the spreading of the system, i.e., the factor h expands the confidence interval of the model. Fig. 3 illustrates the change in the lower and upper limits for h factors of 0.5 and 0.7.

Fig. 4 illustrates the behavior of the spreading of the system with the increase of the h factor, both to the right and to the left of the central part of the system. It is possible to perceive that its increase is directly proportional to the expansion of the limits, allowing the inclusion of more or less data (represented in the figure by the blue points) between the limits of the model. While the typical values are contained within the limits even with a reduced h factor, the outliers are included with the factor expansion.

From these considerations, in [17] possibilistic regression is reduced to a linear programming problem whose objective is to minimize the spread of the system, or its uncertainties, as presented in (8) subject to the constraints present in (9).

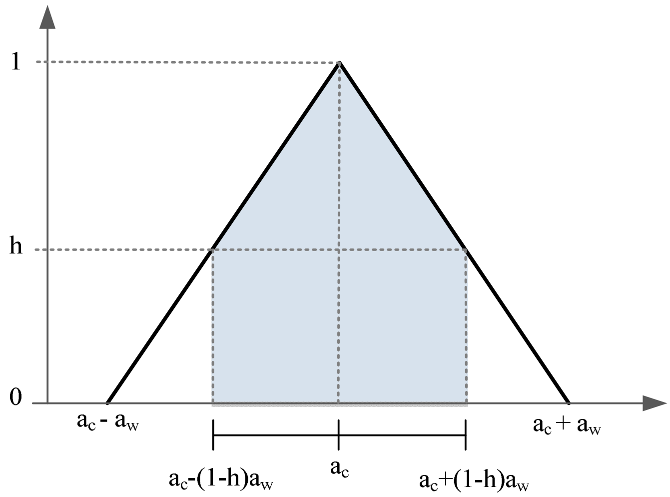

Fig. 3 - Triangular membership function with h factor interval.

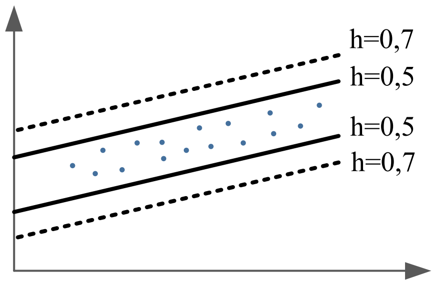

Fig. 4 - Increase of fuzzy interval with a higher h factor.

$$\min_{a_c, a_w} J = \sum_{i=1}^{n} a_{0w} + a_{iw}x_{ij} \quad (8)$$

$$s.t. \quad \left(\sum_{i=1}^{n} a_{ic}x_{ij}\right) - (1-h)\left(\sum_{i=1}^{n} a_{iw}x_{ij}\right) \leq y_j$$
$$\left(\sum_{i=1}^{n} a_{ic}x_{ij}\right) + (1-h)\left(\sum_{i=1}^{n} a_{iw}x_{ij}\right) \geq y_j \quad (9)$$
$$a_w > 0$$

However, although still present in the literature due to its ease of implementation and lower computational cost compared to improved models [21]–[23], the possibilistic regression using linear programming has received several criticisms, some of them are listed by [22]:

- The model presented by Tanaka resembles linear regression, but there is no evidence of how it relates to the classical concept of least squares [24].
- High sensitivity to outliers;
- Tendency to become multicolinear as more independent variables are collected;

In this matter, the literature has presented alternatives for the possibilistic regression using linear programming, such as: fuzzy regression using least squares [24], rigid fuzzy regression [25], piecewise fuzzy linear regression [26], [27], fuzzy regression with linear neural networks [28] and nonlinear neural networks [29].

The authors of [17] themselves continued to improve the model by means of a quadratic programming, which according to the author increases the tendency of the coefficients to become diffuse when compared to the initial model [18].

The possibilistic regression using quadratic programming starts from the quadratic minimization of the spreads of the function, as presented in (10).

$$\min_{a_c, a_w} J = \sum_{i=1}^{n} (a_{iw}{}^{t} \left| x_{ij} \right|)^2 \qquad (10)$$

The function can be rewritten as presented in (11), with the addition of a new term, where ξ is a sufficiently small positive number added to the objective function so that (11) is strictly convex. The constraints of the function remain the same, as shown in (12).

$$\min_{a_c, a_w} J = a_{iw}{}^{T} \left(\sum_{i=1}^{n} \left| x_{ij} \right| \left| x_{ij} \right|^{T} \right) a_{iw} + \xi a_{ic}{}^{T} a_{ic} \quad (11)$$

$$\begin{aligned} s.t. \quad & \left(\sum_{i=1}^{n} a_{ic} x_{ij} \right) - (1-h) \left(\sum_{i=1}^{n} a_{iw} x_{ij} \right) \le y_j \\ & \left(\sum_{i=1}^{n} a_{ic} x_{ij} \right) + (1-h) \left(\sum_{i=1}^{n} a_{iw} x_{ij} \right) \ge y_j \quad (12) \\ & a_w > 0 \end{aligned}$$

To allow an optimization capable of differentiating the possibility of left propagation of the possibility of right propagation, one can rewrite the quadratic possibilistic regression as in (13), subject to the restrictions presented in (14).

$$\min_{a_c, a_{wL}, a_{wR}} J = (a_{iwL} + a_{iwR})^{T} \left(\sum_{i=1}^{n} \left| x_{ij} \right| \left| x_{ij} \right|^{T} \right) (a_{iwL} + a_{iwR}) + \xi a_{ic}{}^{T} a_{ic}$$

(13)

$$\begin{aligned} s.t. \quad & \left(\sum_{i=1}^{n} a_{ic} x_{ij} \right) - (1-h) \left(\sum_{i=1}^{n} a_{iwL} x_{ij} \right) \le y_j \\ & \left(\sum_{i=1}^{n} a_{ic} x_{ij} \right) + (1-h) \left(\sum_{i=1}^{n} a_{iwR} x_{ij} \right) \ge y_j \quad (14) \\ & a_{wL} > 0 \\ & a_{wR} > 0 \end{aligned}$$

From this modification the optimization starts to consider a non-symmetric triangular membership function, as shown in Fig. 1.

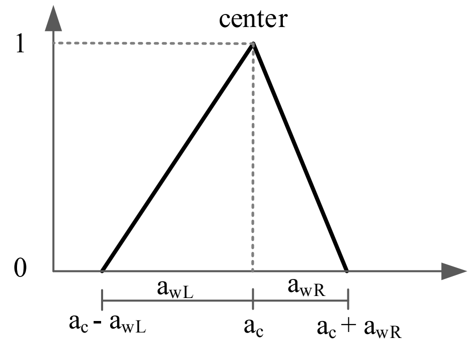

Fig. 1 – Non-symmetric fuzzy triangular membership.

B. Hybryd Regression

Criticism of the initial model presented in [17], including the uncertainty of how it relates to the traditional model of least squares regression [24] has led to the creation of hybrid models.

One of these hybrid models seeks to maintain the central tendency of the model, [30] introduced a two-stage fuzzy regression considered important by its results and low computational cost [23]. In the two-stage fuzzy regression, the central trends of the model are typically defined, typically by ordinary least squares, which are then used as known variables in the optimization.

Let a_c be a central trend vector previously defined, the two-stage fuzzy regression can determine the spreads as in (15) subject to the conditions presented in (16).

$$\min_{a_w} J = \sum_{i=1}^{n} a_{iw} x_{ij} \qquad (15)$$

$$\begin{aligned} s.t. \quad & \left(\sum_{i=1}^{n} a_{ic} x_{ij} \right) - (1-h) \left(\sum_{i=1}^{n} a_{iw} x_{ij} \right) \le y_j \\ & \left(\sum_{i=1}^{n} a_{ic} x_{ij} \right) + (1-h) \left(\sum_{i=1}^{n} a_{iw} x_{ij} \right) \ge y_j \quad (16) \\ & a_w > 0 \end{aligned}$$

This model can be expanded to use quadratic programming in order to increase the diffuse of the coefficients.

Rewriting (15) in its quadratic form it is possible to arrive at (17), very similar to the model of [18], however, without the need for addition since the vector ac is already defined in the first stage of the regression and does not need to be optimized, making the function naturally strictly convex.

$$\min_{a_w} J = a_{iw}{}^{T} \left(\sum_{i=1}^{n} \left| x_{ij} \right| \left| x_{ij} \right|^{T} \right) a_{iw} \qquad (17)$$

With two-stage fuzzy regression it is possible to maintain the original central tendency of the model, which can be replaced by other types of estimation (ridge, minimax), and minimize spreads based on these values to include the human uncertainties in the model.

V. Proposed Algorithm (TSqQP-PLS-PM)

Alternatives using possibilistic regression in the PLS-PM algorithm have been described in the literature in the form of Fuzzy PLS-PM (FPL-PM) in which the estimation of path coefficients was replaced by possibilistic regression using linear programming [31].

In this work, to consider the uncertainties of the human condition in the model to be estimated, it is proposed an adaptation to the PLS-PM algorithm based on the Fuzzy PLS-PM [21], where the path coefficients are now estimated by a quadratic programming model using strictly convex functions in order to maximize the identification of spreads in the model [19], taking into account also the influence of the central estimation of the model (least squares concept), in a quasi-possibilistic model.

Thus, the proposed algorithm modification is called TSqQP-PLS-PM (Two-Stage quasi-Possibilistic Partial Least Squares Path Modeling). The first step consists in defining the central trends by means of the regression by ordinary least squares, generating the β_c vector, as shown in (18).

$$\beta_{ic} = (Y_i^{'} Y_i)^{-1} Y_i^{'} Y_j \quad (18)$$

The coefficients of the β_c vector are used as input data in the constraints of the optimization of the path coefficients spreads, seeking to minimize the equation (19) subject to the constraints presented in (20).

$$\tilde{\beta}_{ij} = \min_{\beta_{wL},\beta_{wR}} J = (\beta_{iwL} + \beta_{iwR})^T \left(\sum_{i=1}^{n} \left| x_{ij} \right| \left| x_{ij} \right|^T \right) (\beta_{iwL} + \beta_{iwR}) \quad (19)$$

$$\begin{aligned} s.t. \quad & \left(\sum_{i=1}^{n} \beta_{ic} Y_{ij} \right) - (1-h) \left(\sum_{i=1}^{n} \beta_{iwL} Y_{ij} \right) \le Y_j \\ & \left(\sum_{i=1}^{n} \beta_{ic} Y_{ij} \right) + (1-h) \left(\sum_{i=1}^{n} \beta_{iwR} Y_{ij} \right) \ge Y_j \quad (20) \\ & \beta_{wL} > 0 \\ & \beta_{wR} > 0 \end{aligned}$$

The cost function of the TSqQP-PLS-PM is also kept quadratic to increase the tendency of the coefficients to become fuzzy [18]. In this case, since the vector is formed by constants, there is no need to adjust the cost function as previously, since it is already strictly convex.

VI. Results and Data Analisys

In order to assess the impact of the methodology for posterior use with the agent-based simulation, a survey first proposed in [32] was applied in the post-implementation phase of the projects. The idea is to measure the acceptance of PBL methodology and to identify possible skills developed by the students during the project.

As a way to operationalize the survey for the purpose of this work - to identify the elements that construct active learning in Electrical Engineering based on humanistic concepts - five dimensions were taken from the literature:

- PBL (composed by questions of prefix P_x)
- Learning (composed by questions of prefix C_x)
- Cooperation (composed by questions of prefix G_x)
- Self-esteem (composed by questions of prefix E_x)
- Self-realization (composed by questions of prefix R_x)

With the end of the project, the data analysis of the survey was made so that it was possible to assess the project's impact on the students. After five applications of PBL^A, 162 students' responses were collected.

B. Model Hypotheses

During the model conception, the classical education literature have been considered, and hypotheses have been raised to understand the importance of the human aspect in the educational process.

In order to measure the impact of the humanization on the proposed methodology and, consequently, on learning, the relevant dimensions of human relations (self-esteem, self-realization and cooperation) were grouped into a new dimension called "Humanization".

The new created dimension is based on the literature regarding the humanization of engineering education and the 21st century required skills [2], [33], [1], [34]. Its creation considers intrapersonal and interpersonal skills, and seeks to understand how both influence student training.

It is considered that humanization exists at a level of abstraction beyond those that builds the individuality and the cooperation and serves, for the purposes of this work, as a way of grouping skills non-technical [2], [1].

After the assumption of such higher order construct, it is possible to infer the hypotheses regarding the constructs defined in the survey [32]. According to [12], the hypotheses of quantitative origin are predictions made by the researcher regarding the expected relationships between variables, and their confirmation depends on the statistical procedure employed by the researchers on the population of a study.

With the objective of understanding the formation of knowledge with the application of a PBL methodology, taking into account the humanization of the process, hypotheses to investigate these relationships are suggested. The hypotheses formulated and their rationale are presented below:

Hypothesis A: Humanization is a common factor of self-esteem;

This presupposition seeks to understand the question of the student's personal satisfaction with himself in the humanistic aspect of teaching [35]–[37].

It is assumed that individuality is an important aspect in the training of the engineer, responsible for helping or not his learning process, supported by aspects related to self-esteem, self-actualization and emotional background of the student.

Hypothesis B: Humanization is a common factor of self-realization;

This assumption examines the student's relationship with his or her tendency to develop their growth capacities [35], [38], [39]. This hypothesis has another aspect concerning the assumption of the importance of individuality in the formation of the engineer.

Hypothesis C: Humanization is a common factor of cooperation;

This assumption is based on the transversal competences of the 21st century, which value cooperation as an integral part of the modern world [1], [3].

In addition, it is also based on the ideas of [40] and [41], authors that address the fragmentation of the world's existing knowledge, and the importance of integration for the society progress.

Hypothesis D: Humanization has a positive influence on PBL;

Humanization as the foundation of the PBL is based on the concepts presented by [42], who cites the importance of an engineer involved with humanitarian and social aspects, who is integrally involved in the community in a manner that the knowledge he acquires is useful.

This hypothesis also seeks in [33] his confirmation, an author that addresses the importance understanding the student's own role on the word before the learning. This aspect was also shown in the Maslow's pyramid [43] with the assumption that knowledge will only be acquired if all human needs are satisfied. For [34] the complementation of the technical and human aspects is fundamental on the training of a student for the society.

Hypothesis E: PBL positively influences learning;

On the assumption that deals with the positive influence of learning in the PBL, it is possible to resort to all the authors that have already applied the methodology in the Electrical Engineering context [32], [44]–[47], [4], [48], [49], [5], [50].

Relating to these hypotheses, it is suggested that the proposed and applied PBL has its roots in a humanist basis, formed by individuality (self-esteem and self-realization) and by cooperation among students, and thus sustained by this humanization, PBL serves as the basis for learning.

The hypotheses have been analyzed using the TSqQP-PLS-PM algorithm, and are shown in Table I, defining the fuzzy path coefficient interval between each connected latent variable. Other pertinent information about the model are also shown in Fig. 5.

Hypotheses	Interaction	Central Tendency	Range
H_A	Self-esteem → Humanization	0.874	[0.874; 0.894]
H_B	Self-realization → Humanization	0.866	[0.859; 0.866]
H_C	Cooperation → Humanization	0.753	[0.753; 0.782]
H_E	Humanization → PBL	0.735	[0.735; 0.761]
H_D	PBL → Learning	0.729	[0.729; 0.785]

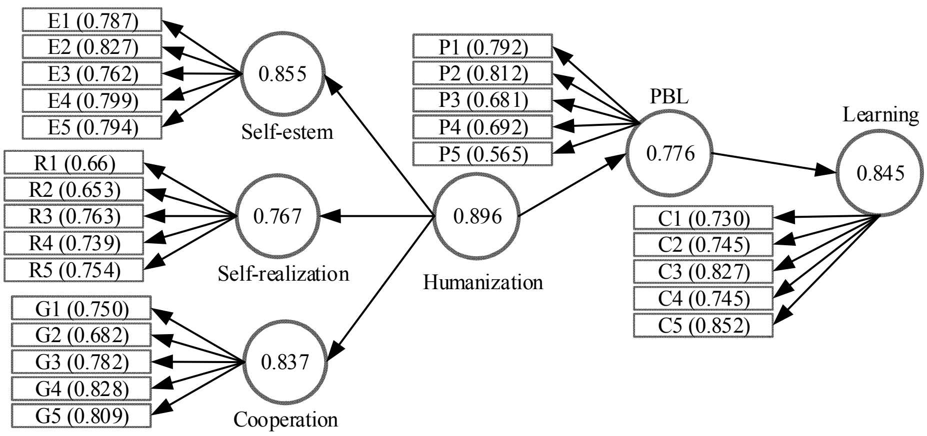

Fig. 5 - Analyzed model based on the literature hypotheses.

The directions of the arrows between circles indicate which latent variables are having their influences checked on each other.

- The loads of each manifest are presented in the rectangles;
- The results of the ρA [51] are presented within the circles for each dimension;
- The values shown in the connection arrows between the circles (dimensions) are the paths coefficients, i.e., they show how a latent variable influences another. For this relationship to be meaningful it must have a value greater than 0.2, where 0.25 is considered weak; 0.5 is considered moderate, and 0.75 is substantial [12].

Also, to illustrate the effects of the fuzzy regression on the last part of the TSqQP-PLS-Algorithm, **Fig. 6** shows the lower and higher limits of the influence of PBL on Learning.

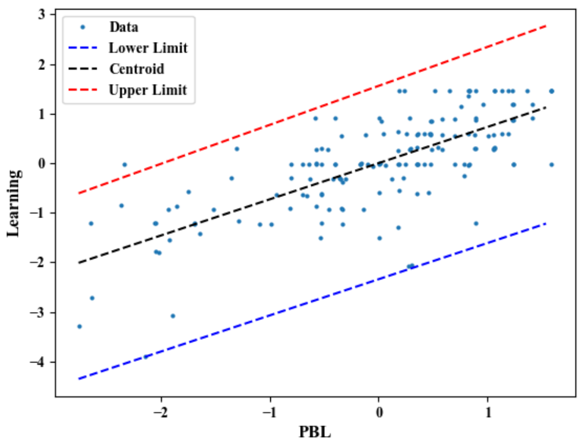

Fig. 6 - Effects of the fuzzy limits on the data lines.

The results were validated using the methodology proposed by [52], evaluating the indicators reliability (indicators with loading bigger than 0.7), the internal consistence reliability (indicators of a same dimension share a high correlation) and the discriminant validity (indicators are better represented by the dimensions they were allocated). Also the results were tested with and Bias-Correct and Accelerated bootstrapping process [53].

After assessing the results generated by the PLS-PM it was possible to see the positive influence of the individual (self-esteem of 0.874 and self-realization of 0.866) and social (cooperation of 0.753) aspects in Humanization which had a high influence on PBL (0.735).

Finally, PBL also showed significance influence on Learning (0.729). Thus, representing this analysis in a simple way, the "PBL supporting pyramid" (Fig. 8) is proposed. This pyramid has foundations based on the Humanization (wrapped in the skills of the 21st century) [3] as a basis for building the Learning and the final project edification.

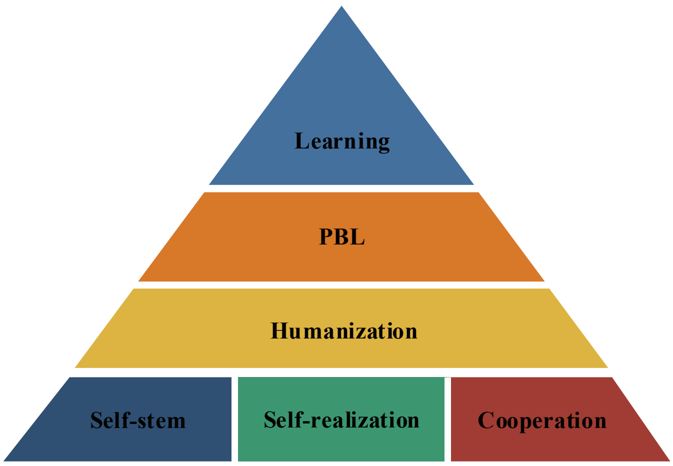

Fig. 7 - Pyramid of the knowledge formation in PBL.

VII. CONCLUSION

This paper proposed and evaluated a new methodology of active learning called PBL^A (Project-Based Learning Agile) by means of a modified structural equation modeling to handle the uncertainties of the human condition.

The methodology was implemented in a part time Electrical Engineering major, where students conciliate full-time jobs with academic education. It sought to establish the validity of this teaching model as a complement to contemporary education trends in higher education. To evaluate the methodology a survey was applied to a total of 162 students. Despite its experimental character as a process analysis tool, it had its reliability and validation considered as acceptable.

The experiment took part in a period of five consecutive semesters and at the end, the project has been incorporated into the practice of the of Electrical Engineering major at FURB. The application perceptions changed significantly. In the beginning, there was a "quite unsafe" perception, from both, students and instructors. At the end of the experiment, there were students waiting to engage in the project and looking forward to develop it, many already insisting to rethink their classes schedules in order to attend the two courses simultaneously.

As the project involves students, this work proposes an expansion to previously proposed algorithms in the literature to be able to include as diffusion of the human condition in the data shown to the modeling operator, through a quadratic fuzzy regression, which aims to maximize performance scattering by optimization.

The modified algorithm is able to approximate the central tendency of the traditional model, moving the reins to pure possibilistic regression.

Through the questionnaire analysis it has been possible to statistically understand how the knowledge is formed in a PBL application. The data analysis suggests that the educational process applied in this work is rooted in a humanist basis, formed by individual (Self-stem and Self-realization) and social (Cooperation) aspects, and thus supported by this Humanization; PBL serves as a basis for Learning.

The results presented in this study suggest that even if it is possible to focus only on the technical aspects, Humanization is an important part in the education process of a new electrical engineer.

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