Study of connectivity in student teams by observation of their learning processes

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We can’t solve problems by using the same kind of thinking we used when we created them.

Albert Einstein

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Abstract. A registration procedure based data tracking classroom activities students formed into teams, which are immersed in basic learning processes, particularly physical sciences is presented. For the analysis of the data various mathematical tools to deliver results in numerical indicators linking their learning, performance, quality of relational nexus to transformation their emotions. The range of variables under observation and further study, which is influenced by the evolution of the emotions of the different teams of students, it also covers the traditional approach to information delivery from outside (teaching in lecture) or from inside each team (abilities of pupils) to instructional materials that enhance learning inquiry and persuasion.

1. Introduction
This study is centered on the interaction processes at the level of students inside the classroom. Since through these is one of the essential pillars of the learning process and achievement of the same goals and that is connectivity.

A significant proportion of human activities is built, in first approximation, driven by certain horizon of expectations fed back by margins of predefined prediction, generating a "world of homogeneity" [1, 2], linear reductionism of life and actions of people that is very suitable and functional in Economy and its definition of quality [3, 4]. But its application in Education is valid in a restricted domain, it is not true that more infrastructure buildings, more computers, more information technology and communication [5, 6], more Internet [7], etc., provoke, in direct proportion, most significant learning [8], since they depend on the relational forms among people [9, 10, 11]. The educational system is highly complex [12, 13, 14] because of the fundamental variables that characterize it, especially in learning are interrelated [15, 16, 17], which is the basis of all real human system.

Behaviors displayed by teams of students learning processes are observed, studying codifiable dimensionalities formed by their emotions, inquiries skills, persuasive, search for internal and external information. In its analysis, nonlinear dynamic elements that reveal how they influence and how they
can get to promote or restrict the process towards achieving meaningful learning teams students are employed. For this purpose the following objectives:

• Specify a set of significant variables that account for the dimensionalities involved in performing a teaching track and record them in real time.
• Validate measurement instruments, according to the universal sample of study, statistical distribution for \( t \) – student, sample correlation coefficient of Pearson [18] and index Cronbach [19]
• Use initial conditions for the induction of emotional transformation.
• Apply mathematical methods of analysis databases: Time series of Fourier, Fast Fourier Transformation (FFT) and Cross Correlation Function, non linear dynamics [20]
• Build graphical representations of the variables in both two-dimensional and three-dimensional form.
• To characterize the transitions between dynamic and numerically obtain connectivity giving relational bonds and emotional transformation of students in each team which directly affects the quality of their learning.

2. Emotion

The set of emotions or moods that holds a person or a group of them and that allows the interactions among them by the atmosphere or environment to which the person is incorporated, we will call emotional field, like a field of physical forces, whose name explained by the fact that emotions have the capacity to mobilize people. Emotions play a critical role in learning [21, 22, 23] that students acquire and the actions to be taken for it. This follows the statement by Humberto Maturana, when he says that [21]: When we talk about emotions, they are different domains of possible actions on people and animals, and the various bodily dispositions that constitute and perform. (...) There is no human action without emotions that melts as such and makes possible an act. (...) Is not the reason that leads us to action but emotion.

3. Characterization of each dimension is measured by teams inside the classroom

Conduct likely observational follow [11, 12, 24, 25, 26] were coded.
Variable Y is essential in this work which corresponds to emotions, has been divided into: Positivity (POS.) when positive acts as support and understanding in the team and Negativity (NEG.) manifest if it manifests in the form of negative acts such as disapproval, sarcasm or cynicism.
Variable X has been divided into: Inquiry (INQ) that relates to use didactic elements [27] of the experimental activity and Persuasion (PER) if discussion components are used in favor of the point of view of someone on the team getting others to understand and take that view.
Variable Z is composed of External Information (EI) which is linked to whether the information is directed outward or from outside the team and classroom. Internal Information (II) refers to the (s) person (s) dealing topics appealing to resources within the team: students with mathematical skills, another one in physics, etc..

4. Research Methodology

The sample is composed of 160 students (40% female and 60% male) Risk Prevention Engineering and Industrial Processes Engineering at Inacap IP (Professional Institute) Campus Santiago Sur. These students are a segment who finished high school with no prerequisite university selection test and a significant proportion of them, make up a human group of first generation family in accessing higher education.

They are divided into five courses of physical mechanical issue, leaving one the courses as a control, but all observational monitoring. Each class has an average of 32 students who are divided, for specific laboratory sessions, in two of 16 students working conforming 4 teams with 4 students each, planning to exploit the potential of cooperative learning (and also the parity gender). The temporal tracking matrix team of students is divided into intervals of 9 minutes (attentional optimization criterion) to complete the 90-minute class [23]. Emotions in the micro-scale (micro human emotions and micro expressions), whereas Gottman [24] uses times of the order of 1 second in scale coding.
specific affections of 20 categories to explore possible emotions that can come to express a couple
during a conversation, is beyond the range of this study.
Each dimensionality involved in the study (X or Y or Z) is recorded by one person, psychologist or
trained professional. To illustrate the dual polarity scale for the variable Y (t) (= Positivity / Negativity
(t)) is shown, and subsequently graph:

Scheme Nº1. Points out the domain dual polarity and scale coding, in its dual polarity, Positivity.

Table Nº1 presents the behavior to be followed in time and taxonomy of coding.

Figure 1. It represents the behavior in time, t, of the variable Y (defined as quotient Positivity / Negativity). The first maximum of the curve is produced by applying the initial condition at 36
minutes:

The same treatment is performed to the X and Z allowing ultimately build the other Tables of Values
and their respective graphical representations variables. By transforming the data into time Fourier
series [28], the observed interaction between team members detected processes of mutual influence or
interlaced between the team members behavior. This is the environment of the control parameter, r,
and essential in the learning process of arduous monitoring and quantification, based on behaviors
within teams of students, enhancing or impeding progress towards the achievement of an educational
objective [29, 30]. Each temporal Fourier series [28], consequent with the non-linear mathematical
model, has the algebraic form:

$$\frac{dx}{dt} = a_0 + \sum_{i=1}^{\infty} (a_i \cos \omega t + b_i \sin \omega t); \quad \frac{dy}{dt} = b_0 + \sum_{i=1}^{\infty} (c_i \cos \omega t + d_i \sin \omega t); \quad \frac{dz}{dt} = c_0 + \sum_{i=1}^{\infty} (e_i \cos \omega t + f_i \sin \omega t)$$
By adapting a series of continuous time Fourier experimental curve of the form $Y(t)$ versus $t$, $\frac{dY(t)}{dt}$ versus $t$ (similarly for $X(t)$ versus $t$, $Z(t)$ versus $t$, $\frac{dX(t)}{dt}$ versus $t$ and $\frac{dZ(t)}{dt}$ versus $t$) graphs are obtained:

![Fourier Analysis](image1)

**Figure 2.** The black line is the variation in the time dimension (= Positivity / Negativity). The other is as Fourier fitting curve. On the right graph the dark line is the rate of change of $Y$ in time $t$.

5. Initial Conditions

By using initial conditions [28, 31], once perceived homogeneity of the initial emotional field of students (which may contain behaviors of stagnation, indifference, anxiety, etc.), and a new emotional disposition occurs that drives toward the objectives presented. The type of initial condition depend on the level of complexity of content, how feasible is contextualize, the nature of the difficulty that the student has [32], etc., which gives it a high complexity [20, 33].

Initial conditions were applied at 36 minutes into the laboratory session 90 minutes because, in general, students are not adequately prepared their working guidelines. The teacher should invest time in introducing them to the activity of the day (time is important to the achievement of the objectives). The difficulties arising from the work of each team, the initial perception of the environment of emotional field indicate the type of initial condition that breaks the symmetry generating an environment of new emotional field that provides the impetus to start efforts toward the goal.

Was verified in this study the effectiveness of initial conditions such as:

demonstrative experiment limited to a fraction of time over the school period class, scheduled laboratory session within the course, subject to independent laboratory but it is the counterpart to the theoretical practice course with intersecting optimizing and improving content objectives learning, practical sessions and according professional profile is intended for the student, short videos (10 or 15 minutes) structured in a simple and accessible narrative oriented to specific thematic content, brief presentation of any specific item by a teacher researcher charismatic and empathetic (testimony), etc..

6. Results

6.1. Data analysis and graphics.

From the graphs constructed and based on the domain of behaviors experimentally verifiable, according to the ranges defined for $X$, $Y$, $Z$ [10, 11, 25], follows:

1. Learning objectives are achieved if the variables of inquiry / persuasion balanced manifest. The experimental work presents a physics lab, for the inquiry, behaviors concatenated in a measurement process, a second behavior does not occur if you have not met before. Therefore it is essential that the activities related to each behavior that is contained in persuasion stimulate inquiry.

The graphs show that the domain of persuasion experimental sessions work necessarily entails a dissipation of effort generating a "damping" in the way $e^{-\frac{t}{t}}$ that drags the other variables ($Y$, $Z$).
When monitoring X (t), for different dynamic arises from its graphics a 'resonant' effect for teams that achieve learning objectives and resulting chaotic attractor dynamics type. This effect involve functional on X (t) is well described by exponential forms $e^{\lambda g(t)}$ of positive type and determines an increase in the time of X (t). The reinforcement or encouragement among students of the team, is based on the generation of emotional field, and positive elements such as humor, empathy, self-generation of confidence, etc..

2. Although the variable Y, emotions, involving the ratio of positivity and negativity with behaviors associated with numerator and denominator is what drives the process, if not properly channeled connectivity inter alumni team also tends to "damp" dissipating such a decay to a negative exponential function of time, $e^{-\beta h(t)}$.

When generating the initial condition, induces a new emotional atmosphere what provides stimulus and energy to the educational goal. It is observed from the graphs that high performing teams are able to manage in the long term this "emotional" energy. Not so average performance teams and under which, despite having reached an "excited state" and associated energy, similar to the case of high performance not well "used" in time spreading inter and extra equipment seriously affecting the achievement educational goals (creating a climate where disorder prevails, work dispersion, jokes, little commitment to the rigor of measurements, etc.).

The positivity / negativity ratio is a major influence in the numerator. If very dominant positivity students too condescending teams between them become so neither facilitates the achievement of goals (Gottman in his study of proposed marriages lasting relationships for over 5.8 as appropriate [25].

3. Internal information / External information.

This variable has teams in laboratory work in physics a unique characteristic. From the observed, which exhibit more commitment to the objectives are oriented towards working within the team (internal information) and search for answers within. But this is not a general feature in the teams in this study, which is reflected in the final graphical results. The more data that is recorded is the
external orientation, i.e. seek answers outside the team and in the particular teacher. While this statement is speculative, perhaps this has to do with an educational deformation tends to imitation or repetition (or rudely told to "copy" the work of the other teams or follow patterns of authority), in the context in which observations are made. Then the key factor in why internal information / external information are the denominator dominates for defined behaviors. This determines a damping effect on all experimental dynamic.

For other lab sessions, under reference experimental - theoretical model implemented and shows the behavior of the four variables (X, Y, Z, t), can be prepared to perform the activity in order to reduce errors and increase efficiency. The teacher should read the "resume" (emotional and yield) of each student in order to rigorously select the suitable initial condition, a task that can implement any experienced teacher. This would allow, prior, identify and characterize the optimal initial condition and that time, anticipating the possible scene and conflict.

6.2. Graphical representation of the different dynamics.
The graph described by the variables X, Y and Z for high performance teams determines a dynamics called chaotic, as shown in figure [20, 34]:

Average performance teams show numerical values for inquiry / persuasion (X) and positivity / negativity (Y) well below unity and decreasing. This means that in the case of variable X, the denominator are dominant teams incurring the persuasive type behaviors when in fact what is required in the measurement process is laboratory investigation of phenomena with capacity data recording instruments measure. Inside teams, an emotional field is generated with negativity domain behaviors apathy disorder, deny conflicts, etc. Not so for the internal information / external data showing a clear tendency to seek answers outside or inside the team.
The graph below shows how the variables X, Y, Z are combined to give rise to the dynamics of fixed point [20, 34]
If teams exhibit a low performance, working procedure is characterized by the search for solutions without validation analysis thereof. Learning is minimized because through copying results to other teams of students or improvising solutions is very hard to occur a meaningful learning as a team and as personal contribution of its components. The graph below shows how the variables X, Y, Z are combined to generates the dynamics of the weak point. [20, 34]:

The projection of three-dimensional curves as each XY, XZ, and YZ allows getting in graphical form the centroids associated with the outbreaks of the attractors that keep trajectories within limits [10]. The numerical values indicate that each variable influence has on the other. This macroscopic view of nonlinear dynamics indicates the way in which relational links or connectivity (r) between members of the team is manifested.

7. Time Fourier series and Moving Averages
Using time series and moving averages of the data, an average value of the quotient convergence Positivity / Negativity, P / N is obtained for each case, which is a fundamental parameter for the characterization and classification of work dynamics:

\[
\left( \frac{P}{N} \right)_{\text{WEAK}} \rightarrow 0.375, \quad \left( \frac{P}{N} \right)_{\text{MEDIUM}} \rightarrow 1.95, \quad \left( \frac{P}{N} \right)_{\text{CHAOTIC}} \rightarrow 5.25
\]

8. The cross-correlation function
Given two functions f(t) and g(t) the cross-correlation function [20] is given by:

\[
C_{f,g}(\tau) = f(t) * g(-t) = \int_{-\infty}^{\infty} f(t) g(t + \tau) \, dt
\]

The cross-correlation function can be interpreted as a measure of the coincidence between two images, for various amounts of shift. It is possible to measure the ties through the discretized cross-correlation
function applied to all time series data [35] that were generated from work, each team of students, for X, Y, Z. This function provides a measure of how strongly and how long it takes the particular conduct of a person, in time, to connect with the conduct of another person.

The graphs for each dynamic deliver an accurate descriptive picture from the pattern of behavior of teams from the correlation. The emotional field mediates the other variables, but, in itself, depends on the context of experiential reference (culture, values, social relations, economy, family, etc.) where students are inserted, and this framework and narrative, extra classroom and student teams, also plays a role in the achievements of the teams. If the educational institution has failed to structure emotional field conditions which prevail in the values and principles (honesty, nobility, generosity, solidarity, etc.) this will influence negatively the performance and "procedures" to achieve the goals by the students affected indicators. So excess positivity or negativity was reflected even in the teams 'best' performance. Tables of values follow:

**Table 2.** Tables of cross correlation values, C.

|                  | Chaotic case | Attractor mean Case | Attractor Weak Case |
|------------------|--------------|---------------------|--------------------|
| Cxy              | 0.44         | 0.16                | 0.13               |
| Cxz              | 0.24         | 0.28                | 0.23               |
| Cyz              | 0.27         | 0.29                | 0.32               |

Since Cxy represents the influence between the variables of Inquiry / persuasion with Positivity / Negativity in the chaotic case "borders" 50% while in the remaining two cases is less than 20%. Similarly it observed in the groups of low and average yield, the greater the influence of negativity in positivity / negativity ratio and internal / external ratio Orientation, seeking a way to balance showing a tendency to get solutions by whatever means.

**9. Graphical representation of the cross-correlation**

Plotting the cross-correlation function in time the value of maximum travel (vertical axis of the coordinate system) arises for each graph XY (t), XZ ((t) and YZ (t). The calculation for the influence of Y (t) on X (t) was presented for the three dynamics studied:

- **Case 1.- Chaotic attractor**
  - Graphics for cross-correlation with chaotic dynamics calculating the maximum connectivity value: $0.81 \times 36 = 29.16 \approx 29$

- **Case 2.- Medium tractor**
  - Graphics of the cross-correlation for the dynamics of the fixed point calculating the maximum connectivity value: $0.56 \times 36 = 20.16 \approx 20$

- **Case 3.- Weak attractor**
  - Cross-correlation graphs for dynamic weak point with calculating the maximum connectivity value: $0.45 \times 36 = 16.2 \approx 16$

**Figure 9.** Graphics of the cross-correlation for the dynamics.

**11. Graphic Connectivity versus performance**

Connectivity can be defined as the ability the team members show to expand their actions with the actions of others and to expand their own actions from the actions of others [36, 37]. So in particular
for the relationship - influence of Y on X according to the different dynamics: Figure 10 gives the connectivity by calculating the centroid, cross correlation [23], the theoretical recursive method as MatLab [38] applied nonlinear model [34, 39, 40] and averaged value:

![Figure 10. Graphic of Connectivity versus levels of school performance, the latter understood as significant learnings.](image)

From the observation of the interaction [24] the dimensions of the model, the information work of teams of students [41] is extracted. According to the central hypothesis of this study is that to be mediated by the quotient Positivity / Negativity, the variable Y of emotions, is tested quantitatively, from the graphs in time, its influence and interdependence in Nonlinear way what directly affects the performance of the teams.

12. Conclusions

The approach used gives a quantitative numerical vision that allows qualitative conclusions regarding the observed performance of equipment and how emotions are crucial in achieving the learning objectives. Using time scales graduated at intervals of 9 minutes is appropriate because the emphasis is on how the process leads to the goal and the way in which the evolution of the observed variables (X, Y, Z) lead to meaningful learning This process is not instantaneous. It is unlikely that there is an understanding of concepts or instruments relating to physics in 1 second.

The transition between those low, medium and chaotic dynamics is given by the parameter r, connectivity, while its values for each case in the order 16, 20 and 29 respectively, which is verified by the experimental methods of the centroid and the correlation crusade confirming theoretical modeling of the nonlinear Lorenz equations. These numerical values are indicative of meaningful learning teams, revealing, in the order given, if it is low, medium or high. They confirm and justify that whoever drives the transformation and transition between dynamic is the evolution of the emotional field.

A more rigorous understanding of quality [42] in its relationship with significant learning as appears linked to the quotient Positivity / Negativity as demonstrated by the time series, the values of convergence are in good numbers defined (0.375 (weak), 1.95 (medium), 5.25 (chaotic)) indicating which is the dominant factor of the fraction. This allows building a domain of validity for the quality of the educational process which directly affects perception, integration and continuity of pupils in their learning and assessment made of the same. This is crucial in this study from the point of view of avoiding permanent abandonment or desertion of the various professions studying by young.

In the segment of students tested, many are imbued with an emotional dynamic that, most of the time; it feeds on some negativity and fatalism [43]. Yet their attitude is clearly aspirational in the sense of set goals to help them out of this emotional potential well.

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