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Relationship between the ergonomic state of the classroom measured in energy units and the well-being of students observed by non-invasive instrumentation

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Abstract

This work aims to measure the ergonomic level of a classroom by means of the quantification of two readily measurable variables. The central hypothesis is that the greater the ergonomic level of the classroom, the higher the well-being of the students and, consequently, the less of total environmental adjustments that must be done to achieve a comfortable situation. Previous research put forward that when human beings are faced with non-pleasing environments, immediately emerges a state of restlessness, which is behaviorally manifested by postural changes and surrounding observation assessing both the sources of discomfort and the potential resources to avoid them. This fact is mainly attested by the movements of the head, the part of the body that concentrates all the sensory system, and the rest of the body. Regarding that the well-being experienced by a student in a specific learning environment is reflected in the body of the individual, we choose to measure these movements as a proxy variable of the ergonomic level of the classroom. A second variable can be measured during the first few minutes of the class by recording the distance displacement of objects and the modification of other aspects of the classroom made by the students to get a better condition to be in it. We choose the net amount of energy required to do these changes as another proxy variable to estimate the ergonomics of the classroom. This second variable is measured once the students are free to make adjustments in the classroom quantifying the energy used for this purpose. These observations are plotted on a Cartesian plane revealing a clear correlation between energy and movements, confirming that both variables are quantitative indicators of the ergonomic state of the classroom, the main artificial ecosystem of learning.

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1. Introduction

Ergonomics (from the Greek word *ergon* meaning work, and *nomoi* meaning natural laws), in its broadest sense, is understood as the science of work. As such, it has addressed both to improve environmental conditions and to increase productivity in several human activities [1]. The teaching-learning process is not an exception and it is clear that the more comfortable is the classroom, the greater is the well-being of whom is learning there [2].

This well-being would be reflected in the physiology of the human being, situation that can clearly be seen when such environmental conditions become more pleasant and when simultaneously one has the opportunity to equip appropriate instrumentation to capture changes in the individual [3]. With current technology such physiological changes can also be observed using non-invasive instruments such as electroencephalogram, eye tracker, face reader and galvanic skin response sensors. Therefore, these physiological records would also be a sort of quantitative measures of the ergonomics of classroom.

On the other hand, the ergonomic state of the environment (classroom in this case) can also be measured in terms of energy by quantifying the efforts that people (students in this case) must do for adapting, adjusting, tailoring or accommodating their actual environment to other more pleasant [4]. Today, technology allows us to calculate the effort done by people by changing their surroundings. This effort can be quantified through the movement of objects of the surrounding and the force used to achieve such shifts.

So, this paper displays a method to find the relationship between two variables which stand for the ergonomic of a classroom: one of them scored by physiological non-invasive devices that represent the restlessness and the other one through the energy consumed by the effort involved in altering the environment in order to reduce the discomfort that this space causes.

If there is correlation between these two variables, any of them can be taken as a quantitative *proxy* indicator of the ergonomic of a classroom and in turn be correlated with other variables of the teaching - learning process such as academic performance.

2. State of Art

2.1. An overview

There is unanimity in accepting that well-being produces a pleasant feeling and that such emotions facilitate better performance in any kind of task. Thus, during this century and coming from a business scope, appears the concept of "Great Place To Work" and from a pro-nature scope, the idea of "Green Ergonomics" to refer to several initiatives to improve the environmental conditions at work [5].

Since work is universally defined as the ability to create changes, several disciplines have concurred to make their contribution to improve and thus facilitate these changes. Ergonomics is one of those disciplines that have focused on measuring indicators of comfort validated one way or another through physical aspects [6]. A basis for this exploration may be some marketing studies that show how pleasant is a new manufacture or service by records of the behavior of the human body [7]. Such advances may be used as analogies with different components of the classroom, modeled this space as an artificial human ecosystem.

Another technology has also emerged for the purpose of determining the ergonomics according to neurological behavior variables. This technology, which emerges from marketing [8] and medicine [9], offers interesting applications such as measuring heart rate, limb movements and brain activities by means of electroencephalograms, galvanometers and other biometric tools. Because of the easy handle, small size and low price, there are many devices in the global market for measuring student's physiological responses in the classroom without perturbing the lessons.

On the other hand, there are useful advances in the determination of human metabolism, so that the quantification of tasks in energy units can be performed by examining those nourished databases and knowing how much work or energy involves performing any task [10]. Indeed, the occupants in a given environment can achieve better comfort, i.e. thermal and light through adjustment to their personal environmental condition in the form of taking on/off clothing, drinking hot/chilled water, opening/closing windows, shifting the sun shadow and switching on/off fans, heating or air conditioners, etc [11].

This thermodynamic, physiological and ecosystem connotation has not been regarded previously and, therefore, this study acquires a novelty which can be framed in a discipline now called Educational Ergonomics where its main goal was settled many year ago: "The main challenge in the science of human learning is to understand the requirements of educational design at all level"[12].

From the literature summarized above, it follows that it is possible to indirectly measure the states of comfort from the environment through physiological non-invasive instruments. Besides, the discomfort caused by environmental factors has energy equivalence because to change the environment, it is necessary to do some work and that work can be calculated [13].

2.2. Key facts

With the evidence examined, one can conclude the following facts in a sequential order which roughly follows:

- Comfortable environment is a key variable in human activities.
- Education as human activity needs that its productive factors contribute to get better comfort level of the environment.
- Classroom is one of these productive factors in educational contexts and that can be altered by the students who learn there.
- Most measures of the level of comfort (or synonyms) of the classroom, rely on questionnaires.
- Notwithstanding the usefulness of these questionnaires, current technology offers other ways to measure the discomfort that the classroom has.
- Since the level of discomfort or comfort of a student is manifested in his or her behavior, it is possible to measure it by means of direct observation and the use of non-invasive sensors.
- Because otherwise the same student attempts to decrease the discomfort by altering the classroom, it is also possible to measure the discomfort through the efforts that he made to achieve this goal.

These seven key facts besides the assumption that feeling of each student has a sort of influence on the state of his/her body, allow us to fine-tune the central hypothesis and configure a simple and inexpensive experiment.

3. Hypothesis review

One hypothesis states that the well-being, as the physiological response of students in the classroom, may be observable using physiological devices. Since these teaching-learning scenarios in their broadest sense are not ideal, there are always sources of discomfort for humans which, in one way or another, will be attempted to cancel.

Whether it succeeds or not, a second hypothesis states that the effort, real or potential, to nullify all sources of discomfort on the part of students in their classroom, is measurable as work for getting a better environmental condition. Therefore, the lower energy demands for such purpose, the greater is the well-being experienced.

So there are two ways to measure the ergonomic of a classroom: the first one is by means of the energy demanded for getting better this space, and the second one is by means of the restlessness experienced in the space. Both would be correlated.

4. Method

4.1. The experimental scenario

It was chosen a classroom that had no new elements that could distract the normal development of the lessons and lectures. In that classroom were arranged twelve work places for twelve students. Each work place comprised one fixed desk and one rolling chair. Under each desk, it was attached a small distance meter pointing to the respective rolling chair (Fig 1).

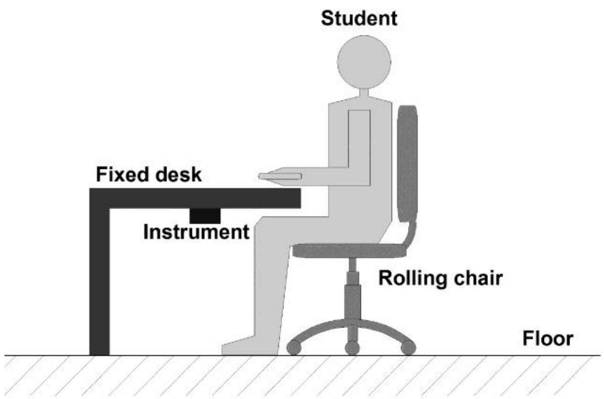

Fig. 1. Work place

The curtains, doors, windows and furniture among other equipment were also arranged to be moved by the students and thus alter the acoustic, thermal and lighting of the classroom conditions. The possibility to modify these three variables was considered important because they are the common concern of architects and engineers [14].

4.2. Measuring the restlessness

Due non satisfactory environmental condition, we suppose that each student get restlessness which generates some movements of his body. Because this human body lies on the rolling chair, the free movements were scored by the distance meter which performed angular sweeps. There is a sketch of the device used in Fig 2: a sort of small ultrasonic sensor which rotates in horizontal plane by a motor in which it is jointed.

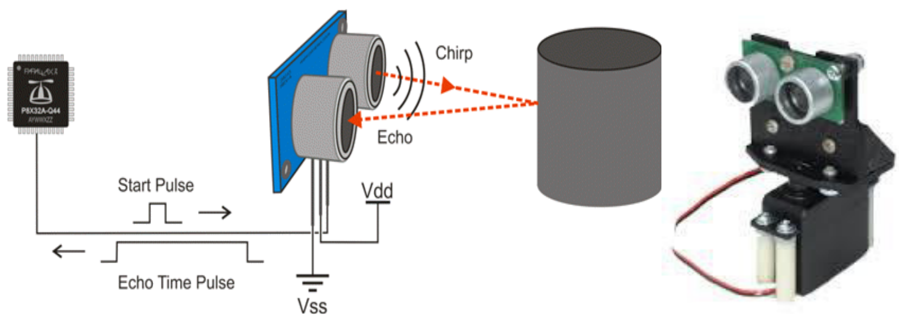

Fig. 2. Ultrasonic sensor for performing angular sweep

Despite the existence of various instruments in the market to observe the sitting posture [15], it was preferred the ultrasonic sensor of the Fig 2, which programmed by mean of a microprocessor, resulted in a cheap, simple, non-invasive and easy to use system.

4.3. Calculating the energy

The lesson was interrupted at 120 seconds and students were asked to modify the classroom for their convenience. The movement of objects (curtains, furniture, doors and other) from an uncomfortable position to another more comfortable, is the expected response from students [16].

The work used in these amendments was calculated multiplying the force applied to each environmental element by the displacement achieved.

4.4. Trials and Plotting

The experiment regarded six different trials in which willfully were set unwanted acoustic, anatomic and light conditions. For example an open window allowed the entry of noise from the street and another window with extended curtain avoided the passage of natural light. Also the seat of the chair was left too low or high. Even a tower of a PC was left on the teacher's desk to block the view on the blackboard. Furthermore, this blackboard was located at a height lower than normal. These results are summarized in Table 1.

Table 1. Trials

Trial	Movements due restlessness (*cm*)	Energy for changing the uncomfortable situation (*kJ*)
One	56	12
Two	103	20
Three	140	23
Four	196	30
Five	260	36
Six	300	42

Ordered pairs of these six trials are shown in the Cartesian plane of Fig 3. The x-axis shows the discomfort generated by the ergonomic position of the classroom, measured by the sum of movement of all students during the first 120 seconds. The y-axis shows the total energy that the students used to override such sources of discomfort after these 120 seconds. In practice, the restless behavior was observed predominantly during the first two minutes.

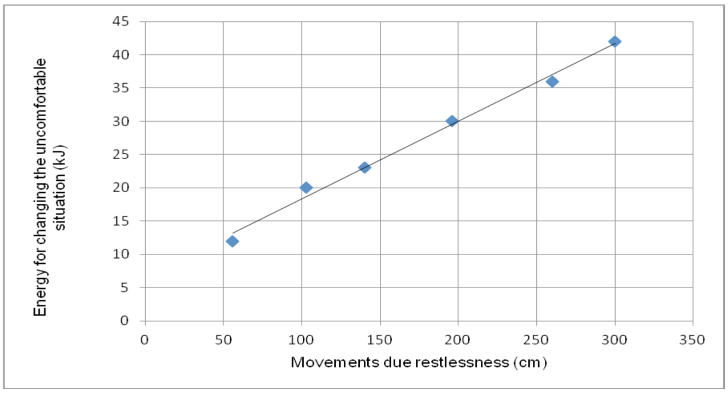

Fig. 3. Graph of observations

As the graph shows, there is an almost linear correlation between the two variables (R^2= 0.9925). However, because it does not have more than six trials we cannot confirm the hypothesis forcefully. On the other hand, we can say that both variables are related in the way that it was intuitively thought before the present work.

Finally, it is important to note that a comfortable classroom does not generate concern and therefore does not distract students from their lesson. Neither this unsatisfactory state requires that students spend part of their energy in environmental adjustments in detriment of devoting the same energy to the lesson.

6. Conclusions

The welfare felt by students due to the comfort state of the classroom has been a topic of interest in both educational and ergonomic fields. However, a quantitative ecological view as presented in this paper can provide arguments for the holistic design of teaching-learning process.

Due to logistical constraints, within the vast range of non-invasive instruments for measuring the human behavior, in this study we use the remote distance meter of angular sweep. Because its price, weight and size; this simple artifact can be used in similar studies without disturbing the behavior that is being measured.

About the energy, the other leading variable of this study, we preferred take it as the work done and calculate it by multiplying the force by the amount of movement of an object. This magnitudes are easy measurable by traditional methods in the classroom by dynamometers and measuring tapes.

Once plotted the ordered pairs, it was noted that the body movements that reveal the concern caused by a living ergonomic conditions are directly correlated with the efforts to improve such conditions. Thus, both variables are proxies of the ergonomic of the classroom.

Although this study is exploratory, the results are encouraging, motivating the use of inexpensive and non-invasive technology to quantify phenomena hitherto described only qualitatively. Moreover, this study provides a more ecosystemic vision than traditional, thereby facilitating a more constructive way to conceive the classroom as a vital space of teaching-learning process.

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