Incidence of Lamy's Theorem in static learning: Balance of forces

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Abstract. This research is within the thematic area education, especially within Didactics of physics, which is based on the existing problems in the teaching and learning of physics both at the level of secondary education and higher education. This research is based on meaningful learning theory raised by Ausubel, which provides valuable elements for the teaching of physics, with higher levels of understanding of the information and resistant to oblivion. The objective was to determine the incidence of the theorem of Lamy in the learning of the equilibrium of three forces, applied to the students of exact sciences of the Universidad Nacional de Chimborazo. It is considered a quantitative correlational research with a quasi-experimental design. The method used was the hypothetical deductive because it allowed to observe the phenomenon, consider a hypothesis for the explanation of the same. By the test of normality of the data is used evidence not parametric and, considering the statistical test of Wilcoxon resulted in a significant difference, between the application of the theorem of Lamy and the analytical method of decomposition of forces in problem solving on equilibrium of three forces.

1. Introduction

Studies show that in addition to the intrinsic complexity of the mathematics and physics, one of the main causes of apathy that have students towards Physics is the usual training system that usually lead teachers to practice, resulting in many cases of desertion or the choice of other races. The attitude of the students within the classroom is memorization, leaving aside the reasoning and provoking anxiety called the number, creating a false impression of having understood the contents proposed for the study of physics, which generates disadvantages in the ongoing development of learning during the following academic content. This, in addition to also exist in the classroom students who are an eminence solving theoretical problems of physics and any other subject, but in reality they do not know what real meaning has studied. On the other hand, according to the results obtained from the Secretariat of the career of exact sciences of the Universidad Nacional de Chimborazo, students obtained low scores of the test that was applied to all students who belong to the network of mathematics and physics, it is evident that students do not possess minimal knowledge both in mathematical physics at the level of basic education High school and higher.

In the teaching of physics and in particular the static, are commonly taught its foundations and fundamental concepts for understanding analysis. It is very common to confuse the physics as an
application of the mathematical equations and not as a science that deals with observation and knowledge of nature.

As researcher and also teacher of the third semester of exact sciences have seen the little domain presenting the students with regard to basic concepts, difficulty understanding trigonometric functions, application of science, field of study, in addition, lacks domain geometric causing difficulty in understanding it, as Physics makes use of geometric shapes for the representation of problem situations. The above difficulties are modelled in this study, in order to find alternative solutions that allow students significantly improve the problem mentioned above, using strategies appropriate for the resolution of problems and give you treatment that facilitates the mathematical approach that physics is often prioritized both the mathematical calculation as the analysis and interpretation of the results obtained during each problem solved.

On the other hand according to data provided by the National Institute of educational evaluation (Ineval) knowledge test disciplinary master 2016 - Ecuador, 84770 applicants who aspire to enter to the public teachers were evaluated, obtaining a basic score that falls on the proposed scale greater or equal to 600 points and less than 800 points evidenciando unable to reach excellence [1].

Worth mentioning as we are training future teachers of the Ecuadorian education, they need both cognitive and methodological tools enabling it to communicate successfully in the world of physics and solve the problems that warrant their use but understanding it. This research focused on the application of the theorem of Lamy to facilitate the study of static in the resolution of environmental problems, it was intended to awaken the interest of students to address issues that are closely linked with mathematical demonstrations. As well as providing future teachers of the career of Sciences of a methodological strategy for the learning of static with a view to the development of competencies in students; in which strategies become tools to break the pattern of one-way knowledge-centered learning, for flesh give step to a participatory approach, based on the model competency-based, and the exchange of experiences, where student expose their experiences, lessons learned, following a critical posture, support and encouragement to creativity, to meet the different situations that arise in the educational context from a perspective of psychology in order to develop a competent teaching, and students prepared for today's world.

Finally this research generates good academic performance of the student, and thus set aside the traditional education, which is not involved in their learning, is simply a being that it is limited to watching and listening; and consequently the learning of physics is not only to approve it, but to be applied in everyday life and allow learners actively develop in the process teaching and learning.

The question that arises then is focused to conduct research so it will be present in each one of the processes it. To what extent Lamy's theorem contributes to the improvement of the learning of the students for the resolution of environmental problems related to the static?

2. Theoretical framework
To carry out the investigation was necessary to perform a literature review about the proposed theme, which allowed to take into account the investigations or work late to it, here is a summary of the research. At the international level the thesis "study of the static of solids applying methodological strategies that facilitate understanding in problem solving in students of 10th grade C of the Institute Licenciado Miguel Larreyagna San Juan de Rio Coco, matrix during the second half of 2014" [2], focused on the implementation of methodological strategies to facilitate the study of the static of solids in the resolution of environmental problems It was intended to awaken the interest of students to address themes that are closely linked with mathematical demonstrations and that therefore they are apathetic to face these situations. Based on his work the researcher managed to develop three methodological strategies taking into account the context, the characteristics of the selected group, the subject of study, the level of depth that was intended to achieve, selecting activities that facilitated the coordination of elaborate organizing properly every teaching moment methodological strategies for students.
Research "Proposal of teaching of balance of rigid body by the action of forces coplanar with the use of the plane geometry in static, of the University course Pascual Bravo" [3]. The methodology consisted of knowing first know the student, emphasizing the concepts of physics you must strengthen before passing to static, link what you know with the new concepts and through class work to build the concept of what you should learn. With these experiences are new skills that will be carried to new contexts and situations. The investigator concludes that the exploration of knowledge tests, construction of free-body diagrams is achieved see difficulties in the management of interpret the laws of equilibrium in physics. To sense that a single force exercised balance, shows that they make no difference between the first and the second law of Newton.

At the local level there are no researches related to the proposed research topic.

The theorem of Lamy, was enunciated by the French religious Bernard Lamy (1645-1716), which States the following:

When a rigid body in balance is subject to the action of three concurrent forces, each module is directly proportional to the sine of its respective opposite angle.

\[
\frac{F_1}{\sin \alpha} = \frac{F_2}{\sin \beta} = \frac{F_3}{\sin \gamma}
\]  

[4]

This theorem is a consequence of the law of Sines, applied after forming the triangle of forces.

Learning should develop mainly in productive and meaningful ways that revitalize the study methodology, in order to reach Metacognition, i.e. to apply knowledge to solve problems for life. The skill is the expression of know-how in students, which characterizes the domain of action. The knowledge, skills and attitudes, constitute the main guide of the educational process. Within the teaching process learning is important to develop critical logical thinking of the students that are evident in the approach to skills and knowledge to interpret and solve problems of everyday life.

This research is based on the Polya model, for the resolution of problems, namely: identifying relevant concepts, the problem, run the solution, and evaluate the response.

3. Methodological framework

He was a descriptive-comparative study with a quasi-experimental design, where the same Group learned how to solve problems of balance of forces using the analytical or method known as vector decomposition, which is that usually apply the teachers in the classroom and the other learned to solve problems by using the theorem of Lamy.

The method used was hypothetical-deductive, as the imagination of the researcher rather than the inductivismo works with the experimentation to find empirical conditions suitable for the validation of the hypothesis.

Population was constituited by 70 students of the career of Sciences exact of the Faculty of Sciences of the education, human and National University technologies of Chimborazo, which through sampling non-probability of intentional type, will chose the representative sample for research being 14 students of the 3rd semester of exact sciences. The criterion for the selection of the sample was held because the subject to be treated is found in the silabo this semester.

The implementation of the proposal was carried out in 8 sessions with a duration of two hours, at the seventh session applied testing related specifically to the theme of balance of forces.

The following describes the procedure followed by the students for the solution of problems related to the balance of forces using vector decomposition method and the theorem of Lamy and shown in detail because solving a problem following protocol.

For example, consider the wooden packing 75 kg shown in the spatial diagram of the figure. It rested between two buildings and is now raised to the platform of a truck that will remove it from there. The package is supported by a vertical cable attached in A two strings that pass over pulleys fixed to buildings in B and C. You want to determine the voltage at each of the strings AB and AC. [5].

3
Problem of mechanical engineering, which is derived from a real physical situation, the methods of analysis are applied to a system of forces acting on a particle. [5]

Based on the Polya model for problem solving, they proceeded in the following manner:
Identify the relevant concepts. This problem concerns the conditions of equilibrium of a particle, this is must know the conditions that should be considered that a body is in balance. That is, when a particle is in equilibrium, the resultant of all forces acting on the particle must be equal to zero.
Pose the problem. To solve the problem should draw a diagram of free body showing particle in equilibrium. Since discussed tensions in the strings, the free body diagram must include at least one of these tensions and if possible to both.

Run the solution: Lamy theorem and the analytical solution by decomposition of forces was used for the solution to this problem. The forces exerted by the two strings are not known, but are equal in magnitude to the tension in the rope AB and AC cord.

Method N°1. Application of theorem of Lamy

\[
\frac{T_{AB}}{\text{sen}120^0} = \frac{T_{AC}}{\text{sen}140^0} = \frac{736\text{N}}{\text{sen}100^0}
\]

\[T_{AB}=647\text{N} \quad T_{AC}=480\text{N}\]
Method N° 2. Analytical solution or vectorial decomposition. The equations of equilibrium should be considered

\[ \sum F_x = 0 \]
\[ T_{AC} \cos 30^0 - T_{AB} \cos 50^0 = 0 \] \hspace{0.5cm} (1)

\[ \sum F_y = 0 \]
\[ T_{AC} \sin 30^0 + T_{AB} \sin 50^0 - 736N = 0 \] \hspace{0.5cm} (2)

We solve \( T_{AC} \) from equation 1

\[ T_{AC} = \frac{T_{AB} \cos 50^0}{\cos 30^0} \] \hspace{0.5cm} (3)

Replacing (3) into equation (2) is obtained:

\[ \frac{T_{AB} \cos 50^0 \sin 30^0}{\cos 30^0} + T_{AB} \sin 50^0 - 736 = 0 \]

\[ T_{AB} \left( \tan 30^0 \cos 50^0 + \sin 50^0 \right) = 736N \]

\[ T_{AB} = 647 \text{N} \] \hspace{0.5cm} (4)

Replace (4) into equation (3) and get

\[ T_{AC} = \frac{647 \text{N} \cos 50^0}{\cos 30^0} \]

\[ T_{AC} = 480 \text{N} \]

Evaluate the response: it corroborates what manifested itself by identifying the problem, that is, a particle is in equilibrium, the resultant of all forces acting on the particle must be equal to zero.

\[ \sum F_x = 0 \]
\[ (415.69\hat{i} + 240\hat{j}) + (-415.88\hat{i} + 495.63\hat{j}) + (0\hat{i} - 736\hat{j}) = 0 \]

To this end, the techniques and instruments used to obtain data were:
The written test that was applied to the 14 students of the 3rd semester of the Race of Exact Sciences, the same that consisted of 10 items related to the subject of balance of force, the test was scored on 10 points.

In addition, an observation sheet was applied in order to corroborate that with the application of Lamy’s Theorem in solving problems related to the equilibrium of three concurrent forces, the student was able to pass from the simple to the complex.

It should be mentioned that before applying the instruments these were validated as well as the degree of reliability was known using the Cronbach alpha coefficient.

For the verification of the hypothesis: The Lamy theorem significantly influences the learning of static: Balance of forces in the 3rd semester students of the Exact Sciences career of the National University of Chimborazo, worked with a confidence level of 95% and a significance level of 5%; We verified the normality of the data with the Shapiro Wilk test because it was applicable to samples smaller than 50, obtaining a value that denotes the use of non-parametric tests, for that reason the Wilcoxon distribution
was selected, taking into consideration the criterion: if the Probability obtained P-value $\leq \alpha$, reject $H_0$, otherwise $H_a$ is accepted, the SPSS software was used for the analysis of the data.

4. Analysis and discussion of results
As a general criterion, George and Mallery state that the Cronbach alpha coefficient calculated to be acceptable must be greater than 0.90 [6]; The alpha obtained was 0.894, so the instrument applied had a high degree of reliability. (See table No. 1)

| Cronbach's alpha | Cronbach's Alpha based on the elements tipificados | Strength n |
|------------------|-----------------------------------------------|-------------|
| 0,90             | 0,894                                         | 10          |

The results tab of the observation (see table No. 2) applied 14 students of the career of Sciences shows the influence of the application of the theorem of Lamy in the resolution of problems related to the balance of force, of which which deduces:

✓ Better understanding in the resolution of problems, related to the balance of forces
✓ Appropriate application of the steps for solving problems linked to the balance of forces according to indicators of achievement established for study.
✓ Correct graphic and geometric representation of problem situations proposed during class.
✓ Reduction of the time in the resolution of problems, with a good quality of answers to problems.

94% of students were able to move from the simple to the complex in the resolution of problems, using the theorem of Lamy.
80% of students using the theorem of Lamy, resolve problems in less than the set time.

| METHOD 1. Vector decomposition | METHOD 2: Lamy's theorem |
|-------------------------------|-------------------------|
| YES                           | YES                     |
| NO                            | NO                      |

| 1. Identifies the physical magnitudes existing in the problem | 80% | 20% | 85% | 15% |
| 2. Makes the graphic representation of the problem | 91% | 9% | 93% | 7% |
| 3. Determines if the data are insufficient to solve the problem | 81% | 19% | 90% | 10% |
| 4. Identifies the formulas useful for solving the problem | 75% | 25% | 91% | 9% |
| 5. Run in detail each operation | 70% | 30% | 95% | 5% |
| 6. Shows that the response corresponds to what is asked in the problem | 78% | 22% | 92% | 8% |
| 7. He was able to move from the simple to the complex, using each method | 65% | 35% | 94% | 6% |
| 8. The time to resolve the problem was less than the stipulated time | 63% | 37% | 80% | 20% |
As evidenced in table N° 3, significant is the difference between the averages of the methods applied for the resolution of problems of equilibrium of three forces, the average obtained using analytic or known as vector decomposition method was of 5,821 and using the theorem of Lamy Gets an average of 8.15.

| Method 1: decomposition of forces | N  | Minimum | Maximum | Media  | Desv. tìp |
|----------------------------------|----|---------|---------|--------|-----------|
|                                  | 14 | 5       | 7.50    | 5,821  | 0.77      |

| Method 2: Lamy theorem           | N  | Minimum | Maximum | Media  | Desv. tìp |
|----------------------------------|----|---------|---------|--------|-----------|
|                                  | 14 | 7       | 9       | 8,150  | 0.75      |

The hypothesis testing was carried out in SPSS software. (See table N° 4). Taking into account the statistical decision described above for the acceptance or rejection of the hypothesis, it found that the p-value retrieved 0.001 is less that the 0.05 significance level is therefore rejected the null hypothesis and accepted the alternative hypothesis, this is: Lamy theorem significantly influences learning balance of forces in the students of 3rd semester of exact sciences of the Universidad National de Chimborazo. This verifies the hypothesis. Resulting analysis to the application of the theorem of Lamy in trouble help effectively to the understanding of the static

| Tabla N°4. Contrasteb Statistics |
|---------------------------------|
|---------------------------------|
| Method 1 – Method 2             |
|                                |
| Z                              | -3.296*                       |
| Sig. Asintòt (bilateral)       | 0.001                         |

5. Conclusions
With respect to the analysis of the results achieved demonstrate that for solving problems where three forces are involved, method 2 referred to the theorem of Lamy is achieved best quality learning compared to the analytical method that is the breakdown of forces.

On the other hand has been observed that students show greater interest and motivation for learning in statics, using the theorem of Lamy in the resolution of problems related to the context.

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