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IDEA: An Alternative for Learning Problem Solving in the Course of Mechanics for Engineering Students at FICA

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Abstract

The objective of this study was to know the impact exerted by the implementation of a strategy known as IDEA in a collaborative learning framework for problem solving in the subject Physics I for engineering students in the School of Engineering and Agro-Livestock Sciences (FICA). Basically, the following research questions were to be answered; namely: Does the educational strategy IDEA help students to improve their performance in Physics problem solving (PS) at Physics I for the engineering courses at FICA? , and a second question: Does the problem solving capability depend on the conceptual knowledge?The design of this proposal stems as an alternative to the traditional method of transmission-assimilation with the aim of achieving a favorable impact and responding to the previously formulated questions. The results coincided a great deal with what was expected.

Keywords: problem solving, IDEA, Mechanicals Baseline Test, Force Concept Inventory, Control Group, Experimental Group

1. Introduction

Problem solving (PS) together with the particular language to be used in Physics implies for the student a great impact on the adaptation process to the engineering courses.

The lack of previous reflection when solving problems in Physics or, better expressed, the approach from a mere operational viewpoint, without a previous qualitative analysis, leads to sure failure. (Gil Pérez D., 1988).

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Redish E. (2003) selected five general principles that help us understand what happened in the physics classroom including PS:

a) "The constructivism principle: individuals build their knowledge by making connections to existing knowledge; they using this knowledge by productively creating a response to the information they receive".

"The student has the information, but it is inert and cannot be used or recalled except in very narrow, almost preprogrammed situations. To find out what our students really know, we have to find out what resources they are bringing and what resources they are using". Redish suggests give to the student problems more realistic, that can be directly related to their real world experience as a way to know if our students access the information in appropriate circumstances and do not providing too many physics clues specifying and accessing paths for them. It's also very important to give them the opportunity to explain what they are thinking in words.

b) "The contextual principle: what people construct depends on the context- including their mental states".Deep learningis enhanced by applying the concepts to different situations and contexts.

c) "The change principle: this principle deals with the dynamics of the mental state. It states that schemas are not only the way that we organize our interactions with the world, but they also control how we incorporate new information and experiences. .. It's reasonably easy to learn something that matches or extends an existing schema, but changing a well-established schema substantially is difficult. ..It's hard to learn something we don't almost already know. It is very difficult to change an established mental model."
Redishadds in one of his corollary, that doing many problems there is no guarantee that the students will link those skills into easily a structure that helps them to understand what is going on and how to use the basics concept appropriately.They will do many problems without thinking.

d) "The individuality principle: since each individual constructs his or her own mental structure, different students have mental responses and different approaches to learning. Any population of students will show a significant variation in large number cognitive variables".

e) "The social learning principle: for most individuals, learning is most effectively carried out via social interactions. This principle is based on the ideas of the Russian psychology Vigotsky (1978)". Peer interaction acts as a tool of great educational value because group discussion with your partner streamline the exchange of arguments and reasoning to achieve the necessary consensus. It has been proven that this tool, guided by the teacher turns out to be of enormous wealth. The social learning principle is relevant for us in this work like so the contextual principle.

Based on the previously considered principles and with the aim of achieving significant learning in PS in Physics, it is interesting to apply the IDEA strategy (Information, Development, Execution and Apprehension (Learning))so that it may represent an undoubtedly valuable shift in the traditional approach of the formulas application with its resulting data replacement and the true conceptual and procedural learning.

The IDEA strategy was implemented in a collaborative learning framework (Panitz E., s.f.)where interaction among peers was developed. This is a tool of great pedagogical value as group discussion or with a classmate speeds up the exchange of arguments and reasonings until reaching the needed consensus.

The problems to be solved in group with IDEA can be of different characteristics but, in this study, they presented, in general, aspects typical of context-rich problems. A context-rich problem (CRP)(Heller P., 1992)has some particular traits: it is fundamentally related to everyday situations; it is not easy to solve in an individual way; it usually has excess or little data, as with real problems; it includes words such as "you" so that the student may feel involved in it.

IDEA is based on recent educational research studies about PS. It has similar aspects to the methodology described by Polya(1945)in his book "How to solve it". Although Polya specialized in Math teaching, he proposed a method with the following phases to solve problems:

- Understand the problem.
- Devise a plan
- Execute the plan
- Look back to review the results

Similar steps to the ones developed by Polya are those taken with IDEA, coincidental with the word in Spanish (idea) and which is very frequent in youngsters when faced with a problematic situation: "I have no Idea"

This updated strategy was conceived and developed in the University Physics texts(Serway, 1999)

From a semantic viewpoint, each letter of IDEA (GOAL, in English) (Beichner J., 2014) is associated with a specific action to be taken by the student.

Inform yourself , Gathering information about the problem:(Idea or Goal)

At this stage, it is intended to identify the known from the unknown so that questions about the problem can be elaborated and to determine explicit and implicit information contained in the statement and to be able to get its relevant aspects.

It is at this moment when the student generates an internal space and establishes relationships between the problem and their personal knowledge.

Logical questions that should arise may be: What conditions does the problem present? What information is existent?

Develop a Plan, Organize an approach to the problem: (iDea or gOal)

Here, it is intended to establish possible qualitative solutions to the problem by setting analogies between the implied relationships. It involves making up a plan.

Do I need additional information apart from the one offered?

Questions about required knowledge and procedures: What new information do I need? What comes to my mind to find what I need? Can I resort to...? It is the modelling and formalizing phase.

Execute the plan, Analyze the problem: (idEa or goAl)

It is the materialization of the previous stage. Here, the procedure previously detailed is elaborated with coordinated mathematical and theoretical operations, leading to the answer to a problem.

Apprehend, Learn from your efforts: from the effort (ideA or goaL)

Is the obtained result reasonable? Does what was previously estimated coincide with the result? Were the units correctly taken into account? What any other reality element can I associate it with?

According to studies, the previously mentioned working methodology leads the student to the normal scientific endeavor and thus tends to shift from the traditional educational model that presents science as a static and closed content.

A consequence of this perspective is that it seems that students can solve more difficult problems than other students with the traditional approach and they seem to improve the reasoning skills and develop a deeper understanding of concepts and principles (Leonard W., 2002).

This study presents research results about the effectiveness of a strategy (IDEA) on the problem solving (PS) classes of Newtonian mechanics, energy, work and movement quantity in Physics I for a group of students in First Year of the engineering courses at FICA. These students constitute the experimental group in contrast to the control group that followed the traditional methodology in teaching.

The research attempted to find answers to these questions:

Does the educational strategy IDEA help students to improve their performance in the Physics problem solving (PS) at Physics I for the engineering courses at FICA?

Does the problem solving capability depend on the conceptual knowledge?

2. Research Methodology

The experience consisted in comparing quasi-experimental type groups and it was applied in Physics students at First Year in the engineering courses at FICA.

The design was pre-test/ post-test type with the control group. Two groups were designed: the Experimental Group receiving intervention and the Control Group serving as reference and receiving traditional training in the subject. At the Control Group, students were handed out a problem list (with an analogous structure to the one presented in Physics text books). Out of this list, between five and eight problems were selected to be solved in the classroom, one or two were explained by the teacher on the board and the rest were solved by students in class or at home.

The Experimental Group worked with the same problem list but some of them within a rich context. It occurred within a collaborative group framework.

A pre-test and post-test was implemented in both groups. The result was valued and analyzed in context of the changes occurred from the pre-test to the post-test in both groups. The sample was made up by students of the engineering courses attending Classical Mechanics (Physics I at FICA).

Two groups were established. The first: a Control Group with 30 engineering students at Physics I of the following courses; namely, Electromechanical Eng., Chemical Eng., Food Eng., Mechatronics Eng., Industrial Eng., Electronic Eng.. The second group: the Experimental Group with 30 students, from the same courses as constituted by the Control Group.

The distribution in each group was done at random. Subject repeaters (under the assumption that they are many) were proportionally assigned to both groups. Both groups, Control and Experimental, were assigned a weekly 180-minute session for problem solving, divided into two classes.

The topics developed were; kinematics of particle, dynamics of particle, statics of particle, work and energy, momentum and impulse and conservation of momentum.

The planned test period for the application of IDEA in PS was successfully implemented from August to October 2013, at four workshops with the previously mentioned topics but the strategy was continuously applied on other occasions with the remaining topics.

At the same scheduled practice time for all Physics students, a workshop was programmed approximately every fifteen days. Only the Experimental Group worked with IDEA. The other group used the traditional system. The problems for the Experimental Group were similar but not exactly the same. Some were context-rich problems. The difficulties presented were the same shown for other problems but within a different context. The measurement instruments analyzed were:

MBT (Mechanics Baseline Test)(Hestenes D., 1992)contains 26 questions covering kinematics concepts (linear and curvilinear motion), basic principles (Newton's Three Laws of Motion) conservation of energy principle, impulse-momentum, work and the special forces (gravity and friction).

The test was given twice (as pre-test and then as post-test) simultaneously to the Control and Experimental Groups. Authors of MBT were the same as FCI (Force Concept Inventory) but they developed this multiple choice test (MBT) which covers a wider variety of Newtonian Mechanics topics, not included in FCI.

FCI consists of 30 multiple questions assessing the concept of force through 6 dimensions; kinematics, Newton's Three Laws of Motions, types of forces and superposition principle. (Hestenes D. et al 1992). The test was given twice (as pre-test and then as post-test) simultaneously to the Control and Experimental Groups, on different dates from MBT.

3. Results

To answer the question whether the educational strategy IDEA helps students to improve their performance in Physics problem solving (PS) at Physics I of the engineering courses at FICA, post-tests and pre-test were compared (FCI, MBT) within the Experimental and Control Group and then the obtained normalized gain was analyzed.

Hake gain or normalized gain was used in order to quantify conceptual learning(Hake R., 1998).

MBT and FCI tests were applied at the beginning (pre-test) and at the end of the instruction (post-test). With the dataobtained, normalized gain was calculated, defined as (Hake, 1998):

$$g = (<post>-<pre>)/ (100-<pre>)$$

Where the sign <> indicates the average of correct answers of all the analysis group for the pre-test and post-test, respectively. Normalized gain (g) allows to compare the achievement score of the educational strategy in different samples, independently of the initial knowledge state. It is an intensive measurement of the obtained gain and it is very useful to compare; for example, secondary students with university students or from different institutions.

A zero factor (0% percent) would indicate that there was no knowledge change while a one factor (100% percent) would represent maximum learning.

In table I, statistical analysis can be seen (t-students) for a p-value < 0.05, for MBT and FCI:

Table 1. Statistical Comparison between the Control and Experimental Groups(MBT and FCI.)

Test	Grupo	MEAN PRE (sd)	MEAN POST (sd)
MBT	CNTRL (N=30)	23 (8)	30 (11)
	EXP (N=30)	25 (12)	53 (12)
FCI	CNTRL (N=30)	21(10)	30 (15)
	EXP (N=30)	22 (13)	51 (16)

Table 2: Gains Statistical Comparison for MBT and FCI

Grupo	MBT (Gain)	GAN FCI (Gain)
CNTRL	0.08	0.12
EXP	0.37	0.37

In figure 1, the results are shown for the Control Group of the pre-test and post-test applied to MBT (Mechanics Baseline Test), in relation to correct answers. Likewise, in Figure 2, the results are shown for the Experimental Group. And in Figure 3, for the same test, comparative results are shown of the post-test for the Control Group and of the post-test for the Experimental Group.

Figure 1: Comparison between pre and post-test for MBT Control Group (CNTRL)

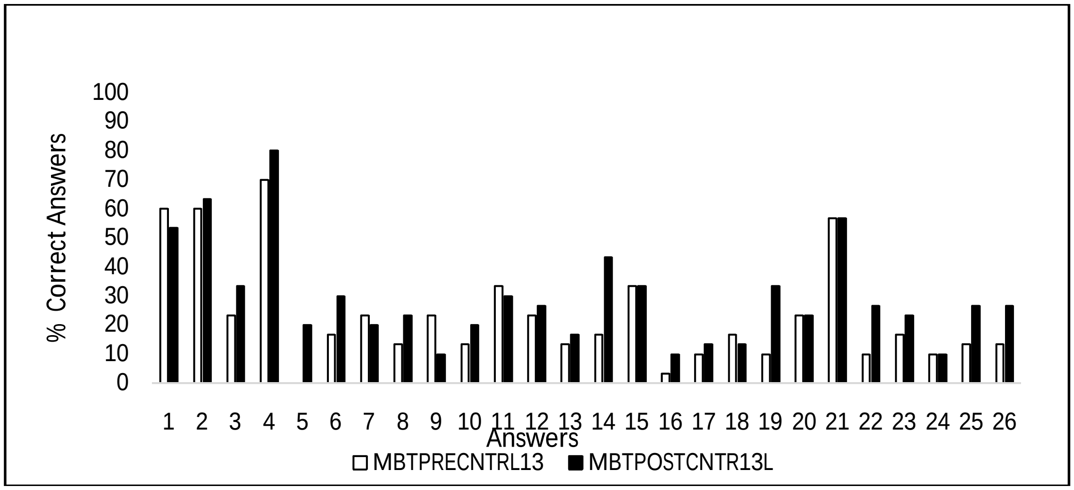


Figure 2: Comparison between preand post tests for MBT ExperimentalGroup (EXP)

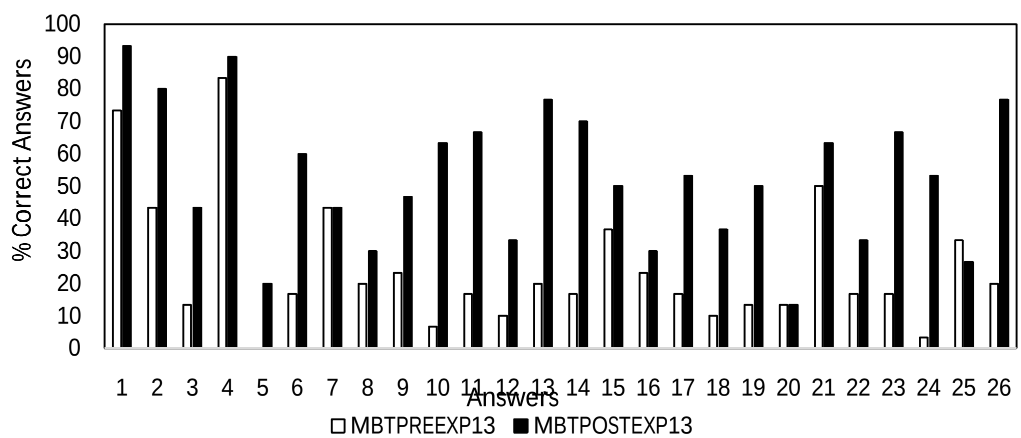
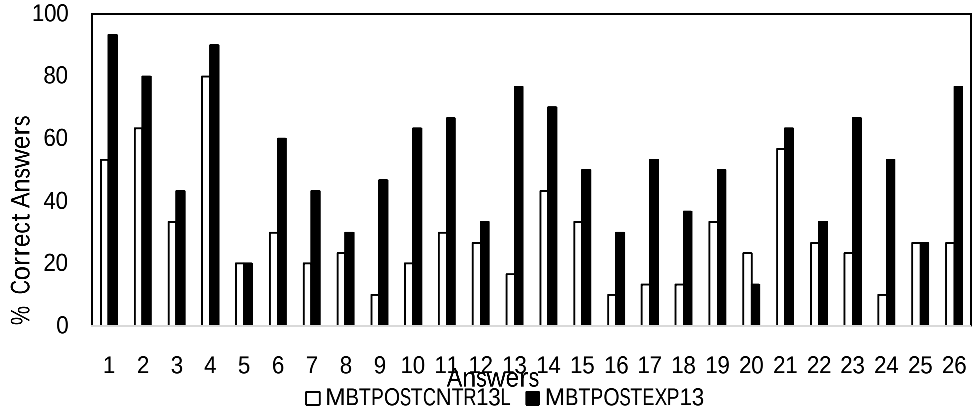


Figure 3: Comparison MBT POST between Control Group (CNTRL) and Experimental Group (EXP)



Next, in Figure 4, results are shown for the Control Group of pre-test and post-test applied to FCI (Force Concept Inventory), in relation to correct answers.

Likewise, in Figure 5, the results are shown for the Experimental Group. And in figure 6, for the same test, comparative results are shown of the post-test for the Control Group and for the Experimental Group.

Figure 4: Comparison between pre and Post-Test for FCI Control Group (CNTRL)

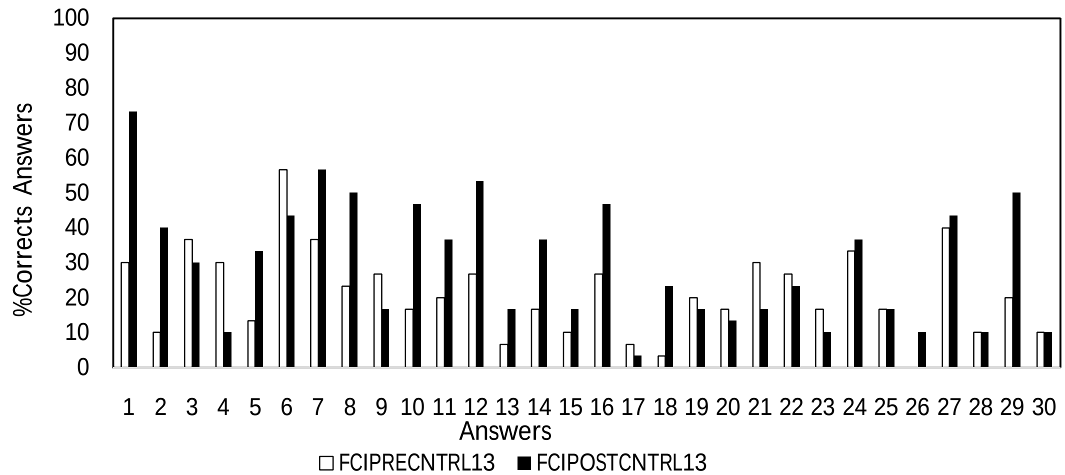


Figure 5: Comparison between pre and post text for FCI Experimental Group (EXP)

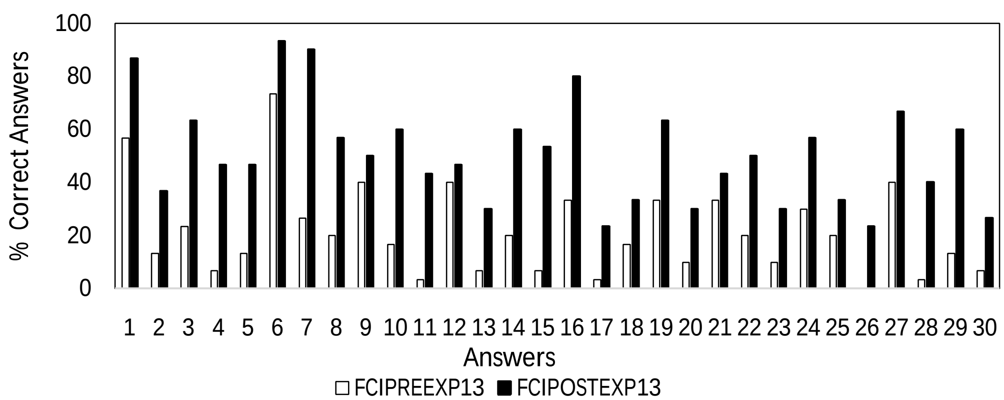


Figure 6: FCI Comparison within Control Group

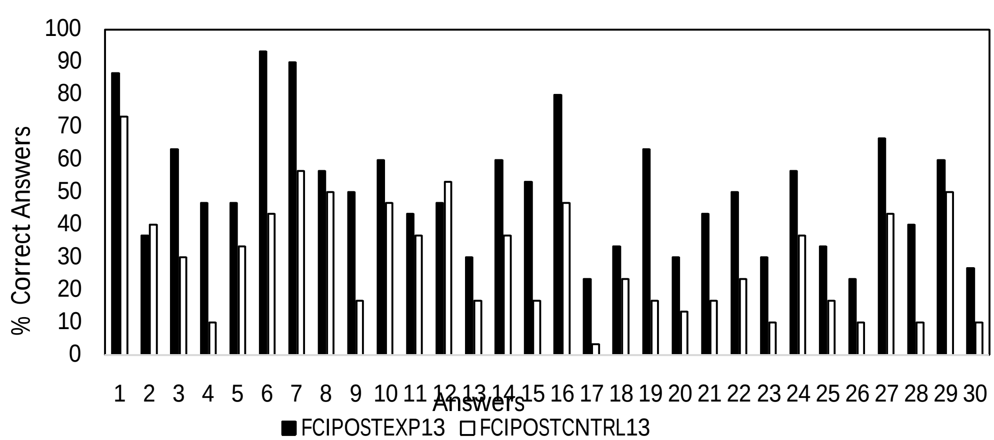


Figure 7: Gain Comparison MBTControl Group (CNTRL) and Experimental Group (EXP)

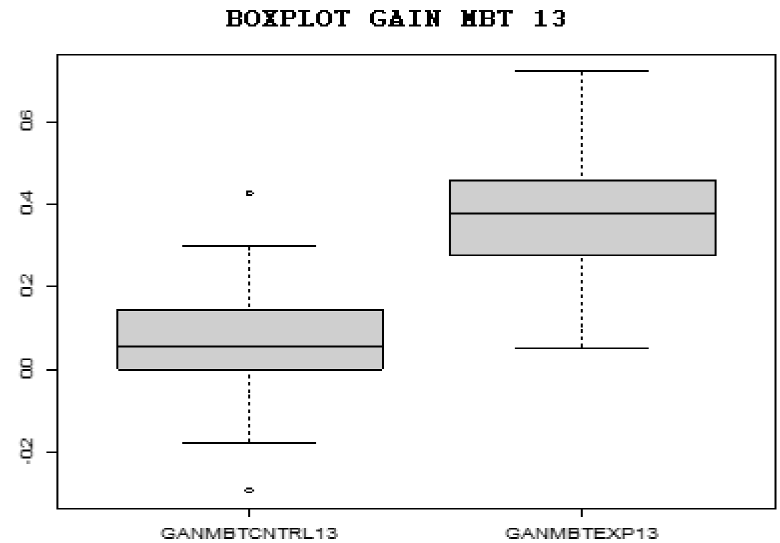
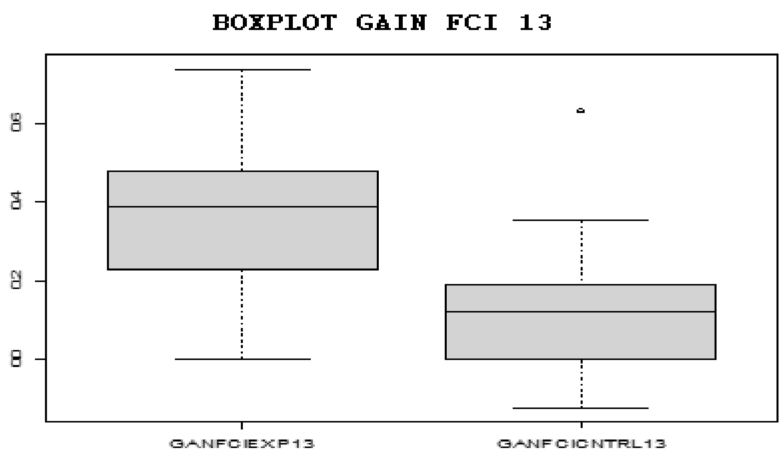


Figure 8: Gain Comparison FCI Control Group (CNTRL) and Experimental Group (EXP)



4. Discussion of Results and Conclusion

To answer the research question "Does the educational strategy IDEA help students to improve their performance in Physics problem solving (PS) at Physics I in the FICA engineering courses?", similarities and differences were compared between the Control and Experimental Groups through the MBT and FCI results analysis with an R statistical program (Computing, 2007).

With the respective and previous studies on normality and homogeneity of variance, test t was then applied.

Achievements were observed to be statistically significant, with visible differences between the Experimental Group and the Control Group MBT ($p< 0.05$), which explained the favorable impact exerted with the application of strategies such as IDEA.

In Table 1, for MBT, t.tests from the Control Group produced averages, about 30% for the Pre-Test and 23% for the Post-Test; while in the Experimental Group the averages were 25% for the Pre-Test and 53% for the Post-Test at the Control Group.

FCI analysis producedthese results: at the Control Group, 21 % for the pre-test and 30 % for the post-test, while at the Experimental Group, 22 % for the pre-test and 51 % for the post-test.

In table 2, Hake gains were compared after variances had previously been studied. An approximately 0,37(37%) MBT gain could be observed for the Experimental Group compared with a 0,08(8%) for the Control Group; which can be clearly seen in box-plot of Figure 7.

Figures 1, 2 and 3 are illustrative with regard to the comments previously specified. The correct answers for each question in each group are shown in these. The total assessed questions were 26 for MBT and 30 for FCI.

Figures 4, 5 and 6 present the correct answers percentages for FCI for each question in each group. The total assessed questions were 30.

The comparisons of Hake gains for the FCI represented a 0.37 (37%) for the Experimental Group and a 0.12 (12%) for the Control Group. This interpretation is added to Figure 8 about the FCI boxplot gains for both groups.

The other question sought to be answeredwas: Does the problem solving capability depend on conceptual knowledge? To answer this, it was necessary to determine if there existed any correlation between FCI and MBT. A statistical analysis between post experimental MBT (per students) and FCI post experimental (per students) revealed a 0.52 correlation, though moderate; which could indicate that there was a correlation between FCI and MBT. Thus, an affirmative answer wasgiven to the previous question on the need to rely on conceptual knowledge for PS. Hestenes et al report a 0.68 rate between FCI and MBT as a good correlation(Hestenes D. , Malcolm W., 1992). On the other hand, these authors suggest that the FCI should be within a 60% approximately as conceptual threshold necessary for PS. In this study, the result was around 51% (<60%), but we believe that this a deep-seated problem and more coincidental with the demanded level in the Spanish context in the 50%, as cited by Regales C. and Celemín M. (2008).With respect to MBT, it is asserted that it is not an easy test as several items require the execution of calculations and so serves as a means to assess SP skills. However, true difficulties seemed to emerge from conceptual deficiencies by students.

For example, a low score in question 5 at MBT reveals that the student is not able to understand the presence of normal acceleration. A low score in question 18 reflects difficulties with the second law of Newton; in questions 8 and 9 with curvilinear motion. Questions such as 20 and 22 were also difficult to understand as they are related to quantity of movement and kinetics energy.

At FCI, low scores, in question 13, reveals the belief of force persistence after contact, in 17 and 30 the idea that upward movement is determined by stronger force in that sense, in 23 the difficulties with inertia dissipation; in 25 and 26 problems with the second law of Newton and with action superposition.

In summary, although the analyzed sample size was not large, for this research in particular, the quantitative results were, in general, encouraging as they obtained gains that may not have been that high as reported by American literature(Crouch C. , Mazur E. , 2001)but nonetheless representative and important for our Argentinian social-educational reality(Benegas J., 2007).(Infobae, 2014)

To sum up, it is relevant to re-ask the question set out by Gil Pérez et al (1988)What do we, teachers, do to teach to solve problems? Or, more specifically, what is it that we do that most students are incapable of solving a problem when it is slightly different from the problems dealt with in class? This is a question leading us to reflect and think about the need to provide some strategy to deal with this problem. This research paper, part of the Master thesis of one of the authors, seeks to contribute to this reality and to continue analyzing variables impactingPS.

5. References

Beichner J., D. D. (2014, 11 23). GOAL-Oriented Problem Solving. Retrieved from https://lost-contact.mit.edu/afs/unity.ncsu.edu/lockers/ftp/beichner/RB/GOALPaper.pdf

Benegas J. (2007). "Tutoriales para Física Introductoria: Una experiencia exitosa de Aprendizaje Activo de la Física". Latin American Journal of Physics Education, 1, 32-38.

Computing, R. D. (2007). http://www.R-project.org.

Crouch C. , Mazur E. . (2001). Peer Instruction: Ten years of experience and results. Am. J. Phys. 69 (9), 970-977.

Gil Pérez D, Martínez Torregrosa, J. y Senent Pérez, F. (1988). "El fracaso en la resolución de Problemas de física: una investigación orientada por nuevos supuestos". Enseñanza de lasciencias, 6 (2),131-146.

Hake R. (1998). "Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics test data for introductory courses". Am. J. of Physic, 66(1),64-74.

Heller P., H. M. (1992). "Teaching Problem Solving trough cooperative grouping". Am. J. Phys, vol 60, 7.

Hestenes D., Malcolm W. (1992). "A Mechanics Baseline Test". The Physics Teacher 30, 159-166.

Hestenes D., Wells M. ,Swackhamer G. (1992). "Force Concept Inventory". The Physics Teacher,30, 141-158.

Leonard W., G. J. (2002). "Resolución de problemas basada en el análisis. Hacer del análisis y del razonamiento el foco de la enseñanza de la física". Enseñanza de las ciencias: revista de investigación y experiencias didácticas, 20,3,387-400. Citado por: Rodríguez M., Mena D., Rubio C., "Razonamiento científico y conocimientos conceptuales de Mecánica: un diagnóstico de alumnos de primer ingreso a licenciaturas en ingeniería" .FormaciónUniversitaria Vol. 3 Nº 5 (2010).

Panitz E. (n.d.). http://home.capecod.net/~tpanitz/tedsarticles/coopdefinition.htm. Retrieved from Colaborative vs Cooperative Learning: a comparison of the two concepts wich will help us uderstand the underlying nature of interactive learning.

Polya G. (1945). "How to solveit".Nueva Jersey: Princeton UniversityPress: Trad. española: "Cómo plantear y resolver problemas". (Trillas: México) (1965).

Redish E. (2003). Teaching Physics. U.S.A.: John Wiley & Sons.

Regales Covián E., Celemín M. (2008). Diez años de evaluación de la enseñanza-aprendizaje ,26(1). Enseñanza de lasciencias, 23-42.

Serway, R.,. (1999). Physics: for scientists and for scientist and engineers. N.Y.: Thomson Learning.

Vygotsky, L. S. (1978). Mind in Society: The development of Higher Psychological Process. Harvard University Press: M.Cole, v.John Steiner, S. Scribner and E. Souberman, eds (Harvard University Press 1978).

http://www.infobae.com/2013/02/16/696801-los-jovenes-eligen-carreras-alejadas-las-necesidades-del-pais

http://www.clarin.com/sociedad/formacion-universitaria-carreras-alumnos_0_1243675639.html