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The Effect in the Action of the Professor and the Problems in the Development of Abstract Reasoning in Future Teachers

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Abstract Abstract reasoning is an important ability to understand science and mathematics concepts. The aim has been to increase this ability by means of mathematic problems and cooperative learning. This experiment has been carried out with six groups: the students have to do some mathematics problems. In the control groups, there was no aid from the professor, and in the experimental groups the professor solved any existing doubt. A pretest and posttest was done in order to consider if the professor's teaching had caused any difference. The results showed that the problems produced a gain and the intervention of the professor increased the gain in the experimental groups.

Keywords: *future teacher, logical reasoning, mathematics problems, gain, TOLT*

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1. Introduction

Educational institutions which have been encouraged to carry out a series of reforms in education, state that professors should stimulate students reasoning, particularly verbal reasoning [1,2].

In education, exists an increasing interest in the development of argumentative competency indeed [3]. In fact, this capacity precedes symbolic reasoning, since students use symbols as their cognitive development is growing [4].

As the tasks suggested, by the professor, are more open to the student's creativity, they indirectly make easier the capacity to argue. Since students don’t have just to apply a process, but to conceive that process. This is very common in the learning process based on both research or discovery [5,6].

In the field of mathematics, it is required that, without being a natural language, there are some indications such as: their symbolic aspect, which facilitates the interpretation of constituting a language. The features of this mathematic and verbal language are noticed in some aspects regarding the vocabulary, the expression and the psycho-pedagogic implications. Thus, the start must be assumed from natural expressions known by the children, using in general terms a basic vocabulary, not specifically mathematic. Since, psycho-educational consequences derived from the grade of precision-abstraction of the issues, exercises and problems that the student is going to find. And, their positive or negative effect regarding comprehension will depend on the verbal level that has been chosen. Therefore, it is essential to choose those words which are more suitable to express the concepts [7].

As far as mathematic competency is concerned, PISA (2013) [8] defines it as the capacity to formulate, interpret and use mathematics in different contexts. It tries to describe the capacities to reason mathematically speaking and using concepts, procedures, data and mathematic tools in order to explain and predict different phenomena. There are three essential dimensions of the mathematic competency: processes, content and context.

Processes describe what the individuals do to correlate the context of the problem with mathematics, as well as the underlying capacities to these processes. PISA (2013) differentiates three types of processes:

- Mathematic formulation of the situations;
- Use of mathematic concepts, data, procedures and reasonings;
- Interpretation, implementation and evaluation of the mathematic results.

The mathematic capacities which underlie these processes, interpretation, application and evaluation of the mathematic results, are: communication, mathematization, representation, reasoning and argumentation, design of the strategies for solving problems, use of operations and symbolic language, and use of mathematic tools.

Mathematic content is understood as the comprehension of mathematic knowledge and the capacity of implementing those processes, and it has been established considering the demands of historic development, the coverage of the mathematics’ area and the reflection on the main dimensions of the schools’ curriculums. Thus, the set of mathematic contents, that guided the elaboration of the questions PISA 2012, was based on the following categories: change and relationships; space and form; quantity; uncertainty and doubt.

There are different contexts in which the evaluation questions are inserted: personal, professional, scientific and social contexts. This contextual variety has been included so that an assessment, at the age of 15 years old, provides an earlier evidence in the way people will be able to respond to the great variety of situations. Those that they might find in the future and in which mathematics are implicated.

As educators in general, and teachers of Sciences and Mathematics in particular, our main concerns are mental block and failure, which are suffered by many students in these subjects. Therefore, it is advocated for methodologies and teachings based on individual reasoning, knowing that the construction of knowledge is enabled by means of one's own experience. Thus, more abstract approaches are reached and a more formal thought is used.

Having said that, are those methodologies and teachings taught and learned at university?

On countless occasions, the majority of teachers often forget that science and mathematics are simply mental activities created according to the physical world. However, students are supposed to learn those concepts without previous experiences; only by means of initiating them into complicated abstractions which, for hundreds of years, have been extremely hard to achieve by humankind itself.

The National Association of Education, in a statement of 1961 entitled The Central Objective for Education, said: "The aim which conducts and strengthens all of the other objectives of education, the common thread of education, is the development of the capacity for thinking" [9]. One of the most representative functions regarding the problem solving, lies in helping the students to get as closer as possible to this central objective. Nevertheless, teachers have a lack of a strong theoretical knowledge that leads them to manage with the resolution of problematic situations as a routine matter. But only, in order to accomplish the intended solution, and regardless of the process of problem verification, which needs the teacher's endorsement of the strategy. These intentions (about how to work in these areas), are enclosed in the curriculums.

Regarding problem resolution, which is the main focus of mathematic activity, teachers must have an extraordinary command of basic capacities: reading comprehension, reasoning about what is contemplated, establishing a plan to face a solution, verifying the solution if it is found and knowing how to communicate the result.

2. Teacher's Training and Good Samples

Therefore, this lack of a strong theoretical knowledge leads teachers to manage with the resolution of problematic situations as a routine matter, in order to accomplish the intended solution. And which result, depends on the imposition of the place in the topic's progression; instead of the confirming evidence of the problem, which is based on the teacher's endorsement of the strategy. So, these problematic situations, that appeared in some workbooks or in the chosen course books, differ significantly from their experiences and concerns. Indeed, any occasion of imaginative participation which could arise from the classroom is left on the sidelines. Consequently, motivation which serves to refresh their necessities; and security, which allows the possibility of making a mistake as a means of investigation in the learning process, are dismissed because of the absence of fields with possibilities of creative action.

The reflection about mathematic structures, that is used, implies a very specific language full of technical terms and with a high burden of abstraction. As a result, there will be students unable to reach this level of reality, even if they are in possession of a superior intelligence. Because, the problem is an imbalance between the spontaneous/natural framework of the individual and the methodology followed in the mathematic training.

This current period is characterized by an extensive field of mathematic applications to any daily activity: not only agriculture, stockbreeding, biology, engineering, demography, medicine, sociology and politics but also technology in industrial, commercial and administrative activities.

In fact, it is unarguable that the current technique has been reached thanks to the intercession of this branch of knowledge, and that mathematic knowledge is used in one or another case, at every turn. Undoubtedly, the construction of surrounding reality is always imbued with mathematics. Besides, mathematic training provides that students are accustomed to overtake the actual reality; in order to translate it into a new polished and more abstract language, which confers an ability of an incredibly powerful reasoning [10].

The degree of abstraction of many of the mathematic concepts, which are employed in the use of science, complicates their learning and usage. Moreover, the fact that hierarchic structure of some concepts prevails over the basis of others, and seriously hinders the learning process. Mainly, considering that concepts of high range are not transmitted merely by definition., because a concept is not definable by itself, even though it can be illustrated with examples. Undoubtedly, the use of examples is, the best assistance in the mathematic definitions of a concept. In this sense, the fulfilment of work or problem solving are considered outstanding principles to achieve mathematic comprehension.

3. Cooperative Learning

Cooperative learning [11] is achieved when students cooperate each other in order to reach a target. In such cases, there are disagreements among the subjects, which provides different perspectives and finally, an agreement is accomplished. Nevertheless, pondering and meditating on a process is needed to reach this result. As this table demonstrates, the traditional teaching method might be compared with the strategy of cooperative learning.

Table 1. Comparison between the traditional method and cooperative learning

	Traditional	Cooperative Learning
Lectures	Presentations	Expositions and cooperative activities
Outside class time	Study	Study and cooperative work
Assessment	Exam	Exams. Cooperative tasks. Continuous Assessment.

Source: based on [12].

There are some key concepts to consider regarding the structure of the formal groups - groups that remain together for some classes, where each of the students are worried about both their own learning and their classmates' one. Then, five characteristics of cooperative learning might be underlined:

1. Positive Interdependence: a student might think that he cannot succeed, if the other members of the group do not succeed as well and vice versa.

2. Positive Interaction: students explain among themselves, the way to solve problems or the nature of the concepts.

3. Individual Enforceability / Personal Responsibility: the teacher must ensure the examination of the results of each student.

4. Cooperative abilities for the effective functioning of the group: capacities such as leadership, decision making, ability to gain trust…

5. Self-analysis of the group: discussion within the group in order to evaluate the degree of objectives' achievement [13].

Therefore, there are several studies in physics that display, with the use of this strategy, an increase of motivation in the students [14], as well as its positive effect in learning [15,16,17,18].

4. Logical Reasoning

As matter of fact, in order to bring students closer to science and mathematics comprehension, academics must know how reasoning processes are necessary for: the comprehension of these concepts, the students' reasoning and the way to improve this former reasoning to facilitate comprehension. Consequently, teachers must expect students' level of knowledge regarding their stage of intellectual development (that is, preoperational, specific, formal, or post-formal) and their knowledge in specific subjects[19].

Thus, in order to favor abstract concepts, the way to develop certain abilities must be found, such as abilities of abstract or logical reasoning. This reasoning, is a creative process which possesses some recognizable elements. Firstly, a confusing observation takes place. Secondly, logical reasoning produces one or more hypothesis. Another possibility as well, might be the use of combinatory reasoning to create a list of every possible combination or hypothesis [20].

Moreover, this reasoning implies a creative thinking; in this way, both the development of the hypothesis and the following process (of which hypothesis is the right one) are facilitated in order to reach the final conclusion. As a result, the development of this ability might be encouraged through a method which provides reasoning, for instance mathematic problems [21].

Ogan-Bekiroglu & Eskin [22] reached the following conclusions about the relationship between the scientific reasoning and the conceptual knowledge:

1. The quantity and the quality of the students reasoning improved in time.
2. It is possible to predict their quantitative contribution, inspecting their qualitative contribution. Because, if a student make few quantitative contributions, their qualitative contribution will be lower as well, and vice versa.
3. When students are involved in thinking activities, their knowledge does not improve immediately. In other words, the development of knowledge in the reasoning process entails its appropriate quantity of time.
4. Former knowledge affects reasoning involvement. If students are familiarized with the concepts or they have scientific notions about those concepts before starting the reasoning, it is undeniable that they are much more involved in that reasoning and produce new elements.

Problematic qualitative and quantitative situations not only develop curiosity, but also demand reflection, teach how to analyze the results as well as to express them correctly, and they favor a better perception in the relationship between science and technology [23]. In addition, they facilitate an increase in the involvement, and they promote an improvement in the reasoning of both ideas and opinions, which facilitates access to knowledge.

Formal Reasoning is an important skill not only at the moment of making predictions, but also at the moment of learning science and mathematics. However, it is true that people's former ideas and the use of logical rules of reasoning have a great effect in learning. Moreover, it also exists a partial dependence between the procedures of learning and the conceptual content. Therefore, abstract reasoning is the skill that goes beyond the particular case and, that abstract concepts are especially important to learn and understand. [24].

The Test of Logical Thinking (TOLT) was used in order to get the measures of abstract reasoning and, it was designed by Tobin and Capie (1981). The TOLT, the Spanish and the original version, has been used in several situations. Acevedo & Oliva [25] measured the formal reasoning of 1400 students from 13 to 21 years old. Valanides [26] used it with students from 13 to 17 years old. And this test has been used with engineering students [27], chemistry students [28] and pre-service science secondary teachers [29]. Even, there is an experiment with in-service elementary teachers in order to develop the formal reasoning, they used another test of logical thinking, inspired by the TOLT, the GALT. [30] The experiment, was a comparison between the effect in this skill with a group with lab instruction and another with traditional methodology.

According to the level of formal reasoning, there are some different ways of division: the concrete level corresponds to a score from 0 to 3, the transitional level from 4 to 6 and the formal level from 7 to 10 [31]. Valanides [32] distinguished four levels: concrete (ranges from 0 to 1), transitional (from 2 to 3), formal (from 4 to 7) and rigorous formal (from 8 to 10). And Valanides did another division: concrete (0 and 1), transitional (2 and 3) and formal (from 4 to 10).

5. Methodology

The experiment has been carried out by six groups. Three of them belongs to the control group and the other three to the experimental one. Totally, 159 students from

18 to 21 years old, who are studying to be future elementary and pre-school teachers.

The three control groups of control are constituted composed by the youngest, first year students of first year of the Elementary Education degree (two control groups) and, the first year of Pre-School Education degree (one control group). The experimental groups are comprised of the oldest and experienced university students: two groups of third year of Elementary Education degree and one group of third year of Pre-School Education degree.

Regarding the design of the study, these students were considered to do a pre-test by means of the application of specific material, especially designed for this experiment. Soon after, the same test was carried out as a post-test.

The test was the TOLT (Test of Logical Thinking or logical reasoning test), a test to measure the ability of logical reasoning, which must be fulfilled with a pencil and paper for 40 minutes.

There are some research data which support the TOLT as an efficient method in order to identify students with different abilities of formal reasoning, in classroom based investigations.

This test (TOLT), assesses five abilities of reasoning concerning mathematics. This is a multiple-choice test, which provides several and different justifications for the answer. It includes two elements for each of the following abilities and reasoning outlines:

- Proportional reasoning: The knowledge of students' proportional reasoning ability is the key to delimit their ability of working and, understanding the quantitative nature of mathematics. Those students with problems to reason proportionally find harder to understand equations, functional relations and concepts such as volume and density.
- Probability: It allows the student to understand the need to make several attempts in the investigation, as well as the use of the average of compiled data from other similar experiments.
- Control of variables: The process of investigation and control of variables is the most important ability of thinking that mathematics aims to develop. The aim of this process is to design experimental investigations, students must be able to define, distinguish and manipulate dependent and independent variables. This ability is needed in order to understand the relationship between movement-time.
- Correlative reasoning: Students must acquire correlative reasoning in order to identify and verify relationships between variables and problem solving.
- Combinatorial: Students must be able to delimit relationships among the variables of collected data, in order to interpret data according to other variable [33].

Abstract reasoning was measured regarding the test of logical reasoning (TRL), the Spanish version of TOLT, validated by Acevedo & Oliva [25].

Four sessions of fifty minutes were carried out whereby eight mathematic problems were distributed. In the control groups, there was no intervention of the professor. In the experimental groups, after these fifty minutes, the professor explained the problems, solved them and corrected any doubt raised. At the time those sessions were finished, students took the TOLT once again.

6. Results

In the pre-test, groups achieve these results:

Table 2. Results in the pre-test of each group

Groups	Sample	Pre-test	Standard deviation
Control 1 Elementary	26	1.57	1.67
Control 2 Elementary	39	2.23	1.68
Control 3 Pre-school	31	2.16	1.50
Experimental 1 Pre-school	16	3.55	2.08
Experimental 2 Elementary	26	3.67	2.30
Experimental 3 Elementary	21	3.00	1.79

Considering that, the maximum mark obtained after the test application might be 10. However, it is noticeable that the marks of these students (those supposed to become teachers of pre-school and elementary education), in the future, are below 50% in the test.

Thus, the experimental groups get better marks than the control groups. The standard deviations are quite similar; nevertheless, it is noticeable that the groups with a higher deviation are those with better marks in the pre-test.

Consequently, the gain is calculated with the aim of verifying the percentage rate of increase or reduction of the logical reasoning [34]:

$$g = \frac{s_{post} - s_{pre}}{10 - s_{pre}}$$

That is:

s_{post} → marks in the post-test;
s_{pre} → marks in the pre-test;
10 → maximum mark in the test.

After this procedure, the marks achieved and their gain are the following:

Table 3. Results in the tests and the profit of each group

Groups	Pre-test	Post-test	Gain
Control 1 Elementary	1.57 ± 1.67	2.19 ± 1.60	0.07
Control 2 Elementary	2.23 ± 1.68	2.83 ± 1.68	0.08
Control 3 Pre-school	2.16 ± 1.50	2.45 ± 1.75	0.04
Experimental 1 Pre-school	3.55 ± 2.08	4.81 ± 1.97	0.14
Experimental 2 Elementary	3.67 ± 2.30	4.38 ± 2.51	0.20
Experimental 3 Elementary	3.00 ± 1.79	3.71 ± 2.24	0.10

Apparently, deviations do not suffer excessive variations and, marks of the post-test are better than the pre-test. Therefore, logical reasoning has been developed in these tasks and, gain in experimental groups is better than in control groups.

- If the specific data, of each of the five abilities that analyze the test, are considered; it concludes the following results:

When results are analyze regarding different abilities, it is noticeable that:

- The higher gain is given in the "Proportionality" section (four groups) and in "Probability" (two groups).

Table 4. Results of the gain according to the five abilities analyzed by the test of each group

Groups	Proportionality	Probability	Control of variables	Correlation	Combinatorial
Control 1 Elementary	0.22	- 0.09	0.01	0.15	0.04
Control 2 Elementary	0.05	0.20	0.03	0.04	0.03
Control 3 Pre-school	0.12	0.05	0.01	0.03	0.03
Experimental 1 Pre-school	0.37	- 0.04	0.08	0.32	0.21
Experimental 2 Elementary	0.28	0.32	- 0.18	0.07	0.06
Experimental 3 Elementary	0.22	0.16	0.07	0.09	0.03

Table 5. Results of the gain according to the five abilities that the test analyze in each group, considering the average of their marks

Groups	Proportionality	Probability	Control of variables	Correlation	Combinatorial
Control	0.13	0.05	0.02	0.07	0.03
Experimental	0.29	0.15	- 0.01	0.16	0.10

- The lower gain is given in “Control of variables” (in three groups), “Combinatorial” (one group) and in “Probability” (two groups).
- There are some groups (control 1 Elementary, Experimental 1 Pre-school and Experimental 2 Pre-school) which have negative gain in some abilities.
- There is a positive gain in each of the items (totally 30 items: six groups and five dimensions), except in 3 (10%): “Probability” (two groups) and “Control of variables” (one group).

In the control groups, it is noticeable that the gain is virtually non-existent in “Combinatorial” and in “Control of variables”; in “Correlation” the gain is lower as well, except in one group (Experimental 1 Pre-school).

Regarding experimental groups, the gain is negative in “Control of variables” and in “Probability”, although barely significant in this one. And, gain is lower, besides in one group (Experimental 1 Pre-school) in “Combinatorial”. In “Correlation” this is greater than in control groups.

As it can be fathomed from Table 3, considering the results of the gain, in Table 4, regarding the five abilities analyzed in the test of each group, the experimental groups improve especially in “Proportionality”. They improve also in “Probability” and in “Correlation”. In “Control of variables” they remain almost the same.

In this Table 5, it is proposed the average of the three control groups in each of the five abilities, as well as the average of the three experimental groups.

Concerning the control groups, gain is clearly inferior in every case, except in “Control of variables” which slightly increases (very little). In fact, considering all abilities, in experimental groups the gain is altogether 0.14 and, in control groups is 0.06.

7. Discussion

The results of our future teachers of pre-school and elementary education in the logical reasoning test are low. As a matter of fact, this is noticeable comparing the current results with other samples taken from other investigations:

The results, demonstrate that the proposed mathematic problems have been useful in order to develop logical reasoning. Nevertheless, this development has not been very significant. However, considering that learning or motivation are not assessed, but the development of an ability; this task should be carried out for a longer period and maybe the results would be better.

When contrasting the hypothesis it has been noticed, that there was no significant difference between experimental and control groups. This happens regarding what has been said previously: since it is an ability, it changes slowly.

In addition, the number of sessions, allocated to the development of this ability, has been small. Although, focusing on the levels of reasoning, the marks obtained in the tests are related to three levels of reasoning according to the following classification:

- A mark in the test between 0 and 3 belongs to the concrete level of reasoning;
- Between 4 and 6 to the transitional;
- And between 7 and 10 it is the formal level of reasoning.

Thus, the three control groups were in the concrete level of reasoning and they do not change.

Regarding the other three groups, they remained in the concrete level, and two of them rise to the transitional level. Therefore, even though they are small, it is true there are some differences between those groups that received help from the professor, and those who not.

Table 6. Comparison of the results from other investigations in the logical reasoning test

Roadrangka, Yeany & Padilla (1982) [30]	Hackling, Garnett & Dymond (1990) [29]	Acevedo & Oliva (1995) [25]	Valanides (1997) [26]	Maris & Difabio (2009) [27]	Méndez & Souvirón (2015) [35]
Students of chemistry	Teachers from high school sciences	Students from 13 to 21 years old	Students from 16 to 17 years old	Student from 1st year of engineering	Students of 16 years old
7.73	6.74	3.70	5.59	5.60	5.05

8. Conclusions

To sum up, the results achieved by students, our future teachers of pre-school and elementary education, are low comparing with different groups of students; whether they have or not some scientific background. In other words, our future teachers (of pre-school and elementary education) have a low ability of logical reasoning, which means a problematic situation, since they will have the responsibility to provide knowledge of mathematics and science to younger students in the future.

- Subsequently, we can conclude as well that: students develop their logical reasoning when solving mathematic problems. Thus, this means an aid to understand more and better science and mathematics. In fact, this is important since it is an ability, but also because it might be interesting to discover any possibility to develop it further and easily in the classroom.
- The experimental groups achieve higher scores than the control groups. Consequently, the intervention of the professor has proved a positive effect in the development of the students' reasoning.
- Finally, despite the result is not meaningful since it has held only four sessions, the existence of some differences in logical reasoning is clearly seen. However, increasing the number of sessions in the future is recommended.

References

[1] NCTM. *Focus in high school mathematics: Reasoning and sense making.* National Council of Teachers of Mathematics, Reston, VA. 2009. Recovered from: http://www.nctm.org/ [Accessed: 05/03/2012].

[2] COSCE. Informe Enciende. Rubes, Madrid, 2011.

[3] Solbes, J., Ruiz, J. J. & Furió, C. Debates y argumentación en las clases de física y química. Alambique, 63, 65-75, 2010.

[4] Tabach, M., Barkai, R., Tsamir, P.; Tirosh, D., Dreyfus, T. & Levenson, E. Verbal justification- is it a proof? Secondary school teachers' perceptions. International Journal of Science and Mathematics Education, 8, 1071-1090, 2010.

[5] Etkina, E. & Van Heuvelen, A. Investigative science learning environment. *Forum on education of the American physical society,* spring issue, 12-14, 2004.

[6] Hofstein, A., Kipnis, M., & Kind, P. Learning in and from science laboratories: Enhancing students' meta-cognition and argumentation skills. En C. L. Petroselli (Ed.), Science education issues and developments, Nova Science, London, 2008, 59-94.

[7] Sánchez Huete, J. C. & Fernández Bravo, J. A. La enseñanza de la Matemática. Fundamentos teóricos y bases psicopedagógicas. CCC, Madrid, 2003.

[8] PISA. 5 keys in order to understand mathematic competency in PISA (2013)). Recovered from http://blog.educalab.es/inee/2013/12/02/5-claves-para-entender-la-competencia-matematica-en-pisa/ [Accessed: 24/02/2016].

[9] Mayer, R. Pensamiento, resolución de problemas y cognición. 91. Paidós, Barcelona, 1986.

[10] Mialaret, G. Las matemáticas. Cómo se aprenden, cómo se enseñan. Madrid: Pablo del Río. (Mathematics. How to learn them and how to teach them, Pablo del Río, Madrid, 1977.

[11] Johnson, D., & Johnson, R. *Learning together and alone: Cooperative, competitive and individualistic learning,* Allyn & Bacon, Boston, 1999.

[12] Bará, J., Domingo, J. & Valero, M. *Techniques of cooperative learning*. Training Workshop in Autonomous University of Madrid, 28th and 29th April, 1995.

[13] Méndez, D. Motivational change realized by cooperative learning applied in thermodynamics. *European Journal of Physics Education,* 3 (4), 13-26, 2012.

[14] Hänze, M. & Berger, R. Cooperative learning, motivational effects, and student characteristics: An experimental study comparing cooperative learning and direct instruction in 12th grade physics classes. Learning and instruction, 17, 29-41, 2007.

[15] Desbien, D. *Modelling discourse management compared to other classroom management styles in university physics. Dissertation presented for the requirements of the degree doctor of philosophy*. Arizona State University. Available, 2002. Recovered from http://modeling.la.asu.edu. Accessed July 20, 2012.

[16] Harskamp, E. & Ding, N. Structured collaboration versus individual learning in solving physics problems. International journal of science education, 28 (14), 1669-1688, 2006.

[17] Méndez, D. El aprendizaje cooperativo y la enseñanza tradicional en el aprendizaje de la física. (Cooperative learning and traditional teaching in the Physics learning). *Educación y futuro*, 27, 179-200, 2012.

[18] Méndez, D. The influence of teaching methodologies in the learning of thermodynamics in secondary education. Journal of Baltic Science Education, 12 (1), 59-72, 2013.

[19] Lawson, A. E. The nature and development of scientific reasoning. A synthetic view. *International Journal of Science and Mathematics Education* 2 (3), 307-338, 2009.

[20] Hand, B.M., Prain, V. & Yore, L.D. Sequential writing tasks' influence on science learning. In P. Tynjala, L. Mason & K. Lonka (Eds.), Writing as a learning tool: Integrating theory and practice, Kluwer Academic Publishers, Dordrecht, 2001.

[21] Veerman, A., Andriessen, J. & Kanselaar, G. Collaborative argumentation in academic education. Instructional Science, 30, 155-186, 2002.

[22] Ogan-Bekiroglu, F. & Eskin, H. Examination of the relationship between engagement in scientific argumentation and conceptual knowledge. International Journal of Science and Mathematics Education, 10 Investigative science learning environment. Forum on education of the American physical society, spring issue, 12-14 (6), 1415-1443, 2012.

[23] Carrascosa, J.; Gil-Pérez, D.; Vilches, A. & Valdés, P. Papel de la actividad experimental en la educación científica. *Cuaderno Brasileiro de Ensino de Física*, 23, (2), 157-181. 2006.

[24] Tobin, K. G. & Capie, W. The development and validation of a Group Test of Logical Thinking, *Educational and Psychological Measurement* 41, 413-423, 1981.

[25] Acevedo, J. A. & Oliva, J. M. Validación y aplicaciones de un test razonamiento lógico, *Revista de Psicología General y Aplicada*, 48, 339-352, 1995.

[26] Valanides, N. Formal reasoning abilities and school achievement, *Studies in educational evaluation,* 23 (2), 169-185, 1997.

[27] Maris, S. & Difabio, H. Academic achievement and formal thought in engineering students, *Electronic journal of research in educational psychology,* 7 (2), 653-672, (2009).

[28] Gupta, T. *Guided-inquiry based laboratory instruction: investigation of critical thinking skills, problem solving skills, and implementing student roles in chemistry.* A dissertation for the degree of doctor, 2012. Recovered from http://lib.dr.iastate.edu/cgi/ [Accessed: 13/05/2016].

[29] Hackling, M., Garnett, P., & Dymond, F. *Improving the scientific thinking of pre-service secondary science teachers,* Australasian journal of teacher education, 15 (2), 20-27, 1990.

[30] Roadrangka, V., Yeany, R. H., & Padilla, M. J. *GALT, Group Test of Logical thinking*. Athens, GA, University of Georgia, 1982.

[31] Oliva, J. Structural patterns in students' conceptions in mechanics. *International Journal of Science Education*, *21*(9), 903-920, 1999.

[32] Valanides, N. Formal operational performance and achievement of lower secondary schools' students, *Studies in educational evaluation,* 24 (1), 1-23, 1998.

[33] Rotter, C.A. *Predicting Student's Level of Reasoning Through the TOLT Test.* 1999. Recovered from: http://www.as.wvu.edu/phys/rotter/phys201/1_Habits_of_the_Mind/Test_of_Logic_Thinking.html [Accessed: 30/03/2014].

[34] Hake, R. Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics' test data for introductory physics courses, *American journal of physics,* 66 [1], 64-74, 1998.

[35] Méndez, D. & Souviron, P. Desarrollo del pensamiento lógico por medio de la metodología de enseñanza ISLE. *Aula de Encuentro*, 17[1], 212-238. 2015.