Conference Proceedings

EuroSun 2016
Palma de Mallorca (Spain), 11 – 14 October 2016

Methodology in the teaching solar energy, IDEA

Torres Montealban Jonas

Universidad Autónoma Chapingo, Km 38.5 Carretera México-Texcoco, MEXICO

Abstract

The aim of this paper was design, apply and evaluate a teaching-learning experience in physics, by means of implementation of a methodology: integration didactic with exploration applied (IDEA), with students of precollege level. We considered for this study, solar energy applications and we worked in four stages, each one of which represents the elements of methodology: the integration of learning theories, the teaching of discipline, the exploration with worksheets and the application in prototypes. Participated in this study 47 students and we review the topic of transfer of thermal energy. Therefore, through exploring with PreTest and PostTest, during and after the intervention methodology; we get an integrating conceptual in the topics studied. Finally, was possible to achieve a significant conceptual gain in both the acquisition of cognitive and procedural elements. Accordingly, the methodology can be an alternative in the teaching-learning process of physics.

Keywords: *Physics education, worksheets, didactic integration and solar energy.*

1. Introduction

We can apply different strategies for understanding physical situations, this depend of historical moment or and theory teaching learning that is fashionable. However, there is no recipe that can be applied in solving contextual problems, or a general theory of education that give respond to different aspects of thinking of students in the classroom and their relationship in everyday life. In this sense, behavioral learning theories; Humanistic, Cognitive and Information Processing, to mention some; which develop activities that fail to be consistent with the results obtained by educational researchers in the classroom. However, they try to give an order to guide students in solving science problems (Hardin, 2013).

Based on the above, it is to reflect on: the what, the how and, what for, the problems are solved in physical situations into the classroom and these can be transferred to situations of human activity. Move from something memoristic to the critical thinking; from to simple association, to the understanding of problems in the classroom; from lab, to the problems in everyday life. We have implemented in the topic of transfer of thermal energy, for the course of pre-university physics: the IDEA methodology (by its acronym), based on the following four processes concatenated.

Integration of learning theories

In a classic sense, and with proven qualities in the teaching-learning process, we know that students can be involved them with many differences styles of strategies, as shown in Figure 1; collaborative work, the problem solving, (Mendez, 2014), active learning (Sokoloff and Thornton, 1997). Lab activities (Gros, 1990). Thus, develop of attitudes and critical point of view, about the phenomenology. With this, it was possible the achieve objectives, as: developing of skills cognitive, metacognitive and instrumentals, (Segura, 1984).

doi:10.18086/eurosun.2016.10.02 Available at http://proceedings.ises.org

Didactic of Physics

In the case of thermal energy, in which we pretend to analyze and describe the ideas that students have about the transfer of thermal energy: conduction, convection and radiation; in order to generalize the transformation and conservation of energy. The information with we begin the study, we obtained from data collection instruments, questionnaires, which is designed through reliability and validity a analysis process (Sampieri, et al., 2006). These instruments are referred to previous teaching experiences on the same theme and with discussions in academic meetings with physics teachers. With these criteria, we approach reliably to an appropriate instrument where we could observe the representation the concepts and variables that they were taken into account for the measurements, (Sampieri, et al., 2006).

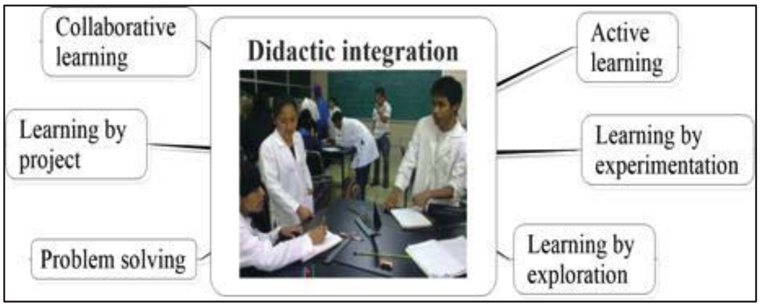

Fig. 1. Didactic integration, theoretical-experimental.

Furthermore, we also consider the concepts that students have in everyday language about the "heat" (Lara and James, 2013). And there are two points of view on how to introduce the concepts of thermal energy transfer. The first one, has to do with the systematization of the concept of energy conservation. The second one, has to see with a gradual process of knowledge nucleus, which are incorporated into the new attributes, to complete the meaning of the mechanisms of thermal energy transfers; conduction, convection and radiation, (Solbes and Tarin, 2004). The two aspects were part of the design of data collection instruments and the IDEA learning activities, It was with the aim of introducing the concept of "heat" as a measure of thermal energy transferred in a particular type of process; for our study is the use of solar thermal energy, (Sandino and Lilia, 2012).

Exploration with worksheets

Through explorations with sheets, a path didactic methodology IDEA of teaching learning is obtained in the classroom-laboratory, by way of elucidate the problems to be explored, and the analyzing the possible resolution and their documentation. With these data collection instruments, learning is monitored, the difficulties to be addressed are identified and also we make emphasized on developing thinking skills and characteristic procedure of sciences like physics, (Michelini and Stefanel, 2012).

On the other hand, for us like teachers, they became design tools and reflection, on the learning processes of students. And with that obtain instruments work and data collection, with the possibility of transforming teaching practice in a research on action. It is so, as were designed, they implemented and analyzed four PretTest and their posttest. The worksheet were designed between peers academics and open discussions. As result we have eight elements to highlight in each of these worksheets, as show on Figure 2.

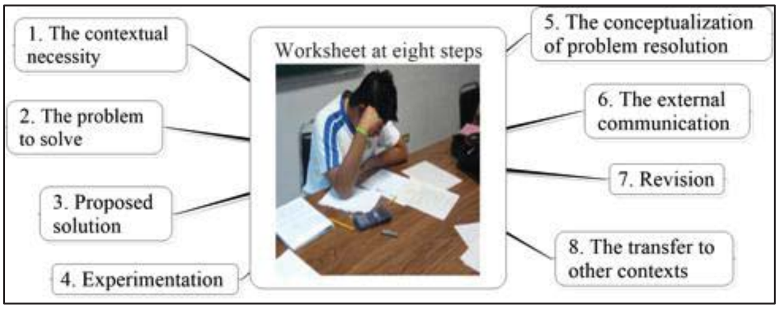

Fig. 2. Eight elements of worksheet.

The surveys features are listed below and are part of the integrated assessment through of methodology implementation. Survey I, questionnaire that provides conceptual information before methodological intervention. Survey II, questionnaire that provides information on previous experimental work on admission from course and before the methodological intervention. Survey III. Questionnaire that provides introductory information on concepts like temperature, thermal equilibrium and system, (Solbes and Tarín, 1998). Survey IV. Questionnaire that provides information on the theme of this study, which has to do with concepts the transfer of thermal energy, (conduction, convection and radiation). With this information, we have been able to document and to contrast the conceptual gain, through to the four Pre/Post Tests, before and after the methodological intervention, (Benitez, et al., 2010).

Application with an integrator project

This implies leave sideways the mechanical and memoristic learning, to focus on a job more challenging and complex; using a multicultural approach that encourages collaborative work; from the manufacture of a prototype solar energy (Rincón, 1999). By engaging of students in developing educational experiences in the classroom-laboratory, forming teams with different students and promoting research methods in order to solve real problems, (Eggen and Kauchack , 2005).

It is not the purpose to solve exercises of the final chapter, which only require a predetermined sequence and automated actions, with the possibility of obtaining a unique solution. Rather, the problem must be contextualized, open to the possibility of thinking different routes and other solution ways, (Pozo, 2002). This allows deploy collaborative dynamics between students and mediation by the teacher, with spaces for reflection and review. Thus preparing students in the constant participation: collectively, with the solar heater water, individually, with the solar stove and a team work, with the photovoltaic panel (Ramirez and Santana, 2014).

2. Objetive

To design, to implement and to evaluate the effect of integration didactic with exploration applied (IDEA), proposed methodology to develop learning on the subject of transfer of thermal energy, with college-level students, correlating conceptual and procedural aspects of physics, obtained through an integrative project on solar and with in worksheets exploration.

3. Methodology

We work with 47 students from precollege level. Students involved in the study are those who completed the four questionnaires after the intervention methodology. They have between 17 to 20 years old and 50% are women. Students are studying a year before to entrance to careers offered UACh. The specialties are around the agricultural studies, most are scholarship students and live within University or around in; are students from different Mexican states and therefore, they are of differences high schools, mostly public and many of them had not worked in the physics lab, (Barrera, 2009).

The IDEA methodology as a model of integration, It not only seeks the integration of organized bodies of knowledge, but also, the integration of educational proposals that are incorporated from the possibilities and experience of teachers. Also it depends on the knowledge and skills developed by students at diagnosis, Figure 3.

The IDEA methodology are based on four stages; integration, teaching discipline, exploration and application. Indeed, we taken as base, the essential elements to attack of a problem situation, (Gansoso, 1999), which are: An initial state, determined by the situation in which the student is at the moment to address the problem; that is, knowledge of the problem, the attitudes on problem, motivations to find a solution, and the skills theoretical and experimental. A final state, characterized by the objective or goal that is required to achieve and that meets a need contextualized. And a problem space, consisting of all possible educational strategies to reach the final state, as active learning, problem-based learning and projects, the leaves of exploratory work, collaborative work, representational changes; and all that teachers consider, (Hillside, 2009).

The integration of different teaching methods of physics extensively tested, as well as, the contributions that the proposal adjusted IDEA to our study, are part of this alternative methodology, which aims to help students in the study of physics and you find it useful to meet problematic situations outside the classroom-laboratory.

Based on the above, we should start our study with real needs, to identify and analyze everyday problems and possible solutions (McDermott, 1996). Therefore, IDEA activities were designed to support students into cognitive construction, learning and understanding of the phenomena involved, as shown in Figure 4. All these related to the topic of study as: temperature, thermal equilibrium, heat, thermal energy transfer (conduction convection and radiation) and energy conservation.

As consequence of this were interpreted other phenomena as: the thermo syphon principle, the greenhouse, the concentration optics and the photoelectric effect. The teaching of physics helps us understand the functioning of systems that involve concepts around energy and its transformation such as solar thermal energy at a level of compression on subsystems, for instance, a solar water heater (Milena, 2013). Any photothermal prototype contains several subsystems that require physical concepts and his understanding; in order to give accurate explanations, such as solar concentration, insulating materials and heat conductors, the convective effects and interaction of electromagnetic waves, (Perrotta et al., 2013). It is clear that we need to compare studies related to alternative energies, as consequence of interest in clean energy, to help mitigate pollution and help with the family finances, considering that in Mexico every day gas prices and gasoline increase.

Learning activities IDEA

Methodology, integration didactic with exploration applied (IDEA) recovered what in recent years has been called the cognitive revolution, which are considered aspects such as: the impact of context on the thought processes of students, integration of bodies organized knowledge, the social nature of learning, the need to understand specific knowledge of the discipline (physics), problem solving developed by novice and experts; all this with the conviction that students construct their own understanding of the issues studied, (Eggen and Kauchack, 2004).

In our approach, we give opportunity to students to weave mental networks, by incorporating all types of experiential activities and information analyzed; in order to support their learning. And with this have deep understanding; and in context outside of the classroom-lab (teaching for understanding) with the integrator project, (Blythe, 1999). By working with nucleus of organized knowledge. The 47 students have already revised the mechanic topics; it corresponds to the unit previous to our study. We recover these prerequisites and prepare students so that after the methodological intervention. With this, they are getting ready to study electromagnetism, the last unit of the course.

This meant act accordingly, taking up what the student knows, and preparing them to the topic that they studied at the end of physics course, and immediately following the methodological intervention. Using a continuos knowledge spiral construction and with feedback, this is the basics for the begin of the application of the methodology. The evidences suggest that start with the students know about the issue and their misconceptions of it, (Quesada, 2005). Thus, it is about building and "genuine learning"; which involve performing a wide and variety of activities of all kinds of experiences, not only to achieve the concept understanding, if not, at the same time, increase the understanding topic, (Perkins and Blyte, 2006). Based on information obtained in the 10 activities "IDEA", Figure 5. We implemented and applied the concepts studied in the integrator project.

In the analysis of the first survey (pretest-posttest), Showed an average rating of 3.8 out of 10, based on the exploration at entrance. Thus, we decided to choose, design and implement experiences and exteriorizations on the integrator project, as a result for the cultural differences by provenance (characteristic in Mexico). This have an effect on the goal of achieving a deeper understanding of the contents studied (declarative, procedural and attitudinal). Further, It is also of great importance to our proposal, the continuous assessment all process, (Diaz-Barriga, 2002).

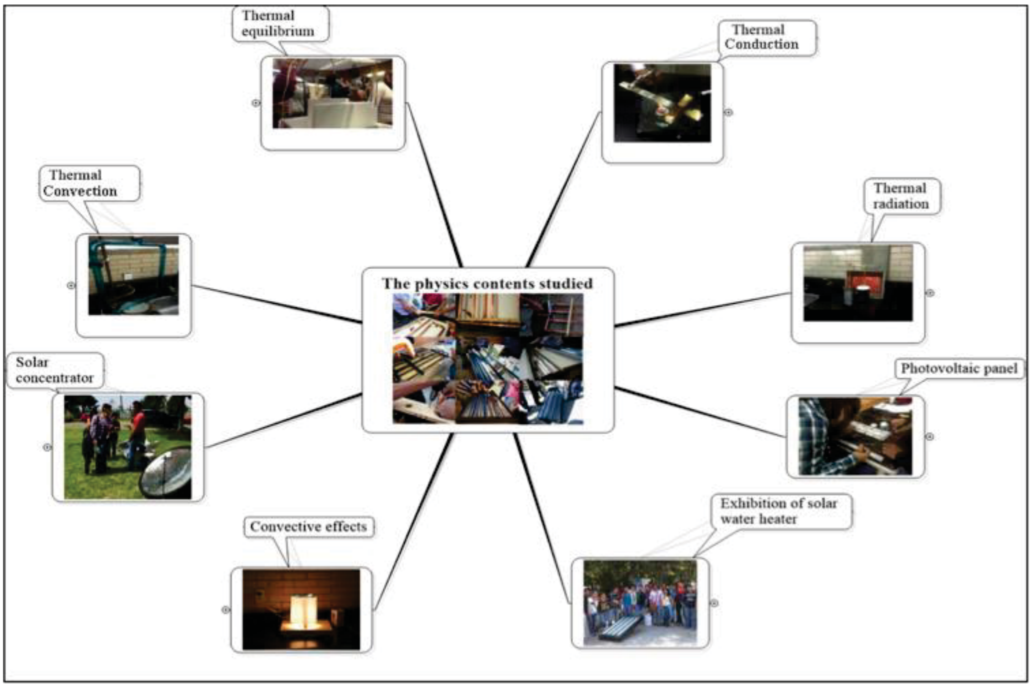

Fig. 3. Contents studied around thermal solar energy.

The entrance exploration, we reviewed general aspects of experimental work and the introductory concepts of thermodynamics at the precollege level. The experimental exploration, is central to our methodology propose, we emphasized lab job and the methodological of the sciences. In this questionnaire, students showed many shortcomings, mainly due to the few experience in a physics lab. This questionnaire has a result of 3.6 out of 10. So, emphasis on interpretation of the information obtained in learning activities. Referred to conceptual exploration (I). It gives us the opportunity on the previous ideas that the students have and the misconceptions that should be attacked with activities proposals "IDEA" .

Hence, the rate of 6.1 out of 10 that was obtained in this survey, gave us the guidelines to establish that phenomenology on temperature and thermic equilibrium, are very close to the daily life of students, and they can do inferences about the laws governing such thermodynamic phenomena to cognitive level they have in the this study, (Hierrezuelo and Molina, 1990). The conceptual exploration (II), is an accentuated exploration. It studies aspects on transfer of thermal energy; it gave us the challenge to increase the conceptual gain in this part. According, to the result obtained in the PreTest, it was 3.2 on 10. Therefore, by introducing the integrator project as a motivation means, we seek to strengthen the active participation, the collaborative job among students, and weave conceptual networks between what is known and what we are studying.

Worksheets explorative for students

For our research, the worksheets elaborated for students have been developed according to the teaching physics by inquiry. With this has been learned, how the worksheets can provide, "what ideas and what categories" were related each other, and "when and in what" context are used. Also, what alternatives and what meaning, were given during experience realized. The evidence suggests that the learning improve, when students work actively involved with worksheets guided activities in. It is clear that refers to the declarative, procedural and attitudinal content.

The IDEA learning activities are worksheets explorative for students, It enabling them to face the challenges in a flexible manner, to follow different learning issues, for instance: more directed to conceptual, formal, procedural aspects, and / or attitudinal. It is noteworthy that the worksheets explorative are own materials, these were reviewed among academic peers, and have characteristics as: phenomenological, experimental, formal and application. However, the worksheets can be combined depending on the objectives of the activity, (Michelini, et al., 2008).

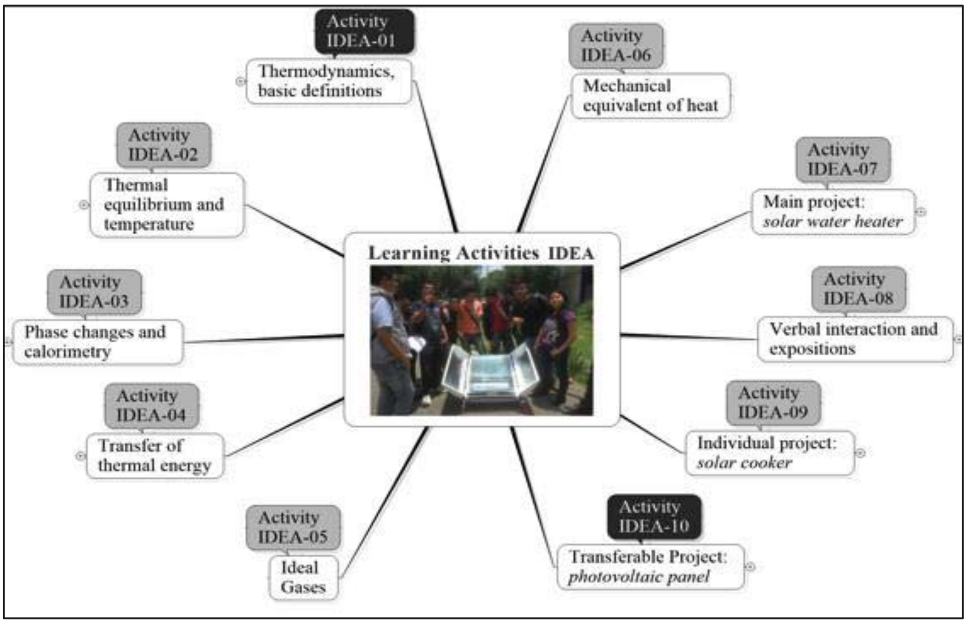

Fig. 4. Learning Activities IDEA.

Methodology implementation

After the results obtained on diagnosing, the Learning Activity IDEA-01. It has been called "Thermodynamics basic definitions" this implemented activity. It is phenomenological-experimental type. In this activity we should explain thermodynamic physical situations, ensuring that students decipher the meaning of the experience, so that the effect of the experience manages to be reflexive and with appropriation of something significant for them. Described below are the 8 steps integrated into each IDEA activity. These are listed as:

Step 1. *Contextual necessity*. With a sequence of concepts, these is presented to explore the characteristics and meaning, providing the formalism of the thermodynamic definitions.

Step 2. *Problem to solve*. In the beginning, the questions are presented based in to the concepts previously studied.

Step 3. *Proposed solution*. The students are prepared in the experimental part and they should have conceptual elements in order to start the possible solutions.

Step 4. *Experimentation*. Students carry out the experiments and make a description of each of the cases illustrated; putting attention on observation and in some specific aspects, describing the main features of processes.

Step 5. *Conceptualization of problem resolution*. The ability to solve problems successfully depends on a number of factors related to the information processing, thus writing a solution of the problem, means to communicate and interpret the reasoning process leading to the solution.

Step 6. *External communication*. The strategy being employed is a verbal interpretation as: lab notebook, group expositions, science fairs, and another academics events.

Step 7. Revision. All the previous steps are considered again and we find a route that allowed us to study situations in the phenomenological and experimental plane in order to detect possible conceptual errors, false or unnecessary assumptions, wrong calculations, and confrontation with predicted answers.

Step 8. Transfer to other contexts. Finally, How to integrate the situations of Physics that have been learned to another context? That means, give continuity to the methodology; beginning with new questions and to transfer new goals to another project, in which concepts new can be learned, according to next unit. By way to get a virtuoso spiral of knowledge.

Integrator project

The aim of an integrator project is the application of concepts physics, through to manufacture three solar prototypes: a solar water heater, a solar oven and a solar panel. All of them are part of the integration project. The first one, a main project that involved 47 students in manufacturing solar water heater. The second one, an individual project, solar stove with readily available materials. The third one, a transferable project, a photovoltaic panel, (Chavez, 2008), which opens the possibility of transferring the methodology to another context, Figure 5. Thus, we can give continuity to the methodological, without give opportunity to traditional learning, (Harper, 2009).

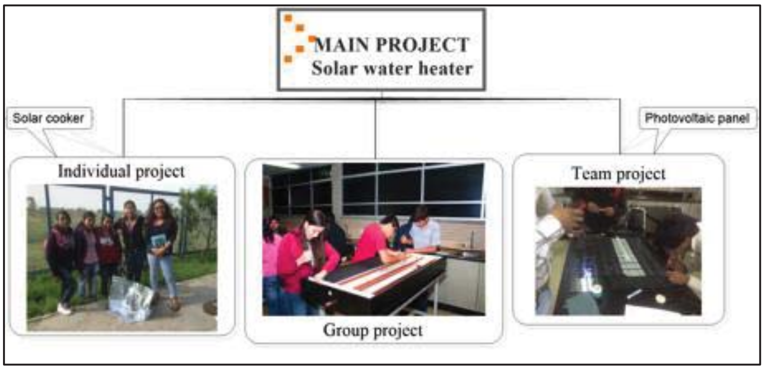

Fig. 5. Projects that are part of the proposal.

Therefore, we believe that it is necessary to provide a minimum of concepts to students not just to build their projects but also to have elements of communication in their expositions and consider physics as an important discipline for their professional development, (Parisoto, et al., 2014)

Integral evaluation

Our methodological approach does not consider the assessment as a synonym for test, exam or control; whose purpose is to qualify the student performance by a “foreground". For our proposal, evaluation is an important part of the teaching-learning process; serves as a starting point for further reflection to help us continuously improve the work of teachers, (Perez and Moreno, 1998).

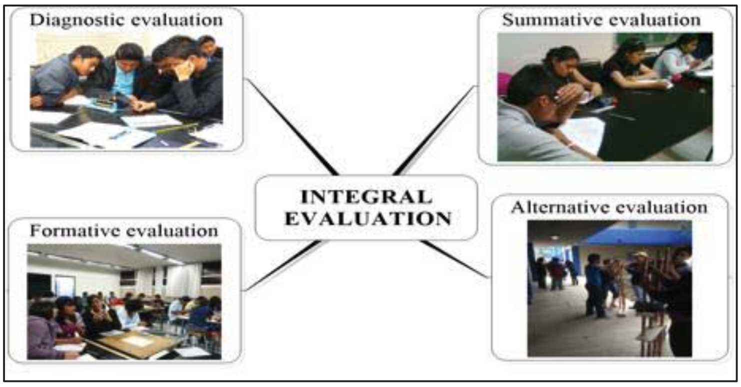

Fig. 6. Methodological assessment during intervention.

Diagnostic evaluation, the PreTest applied is compared with the PostTest, in order to know what the students have studied and act accordingly. Formative evaluation, the worksheets exploratory are analyzed with the performance rubrics, these give us guideline to attack difficulties or conceptual knots, (Michelini and Stefanel, 2012). Summative evaluation, the lab notebook, the teamwork, the PostTest result, and all kind of participation are part of this assessment. Alternative evaluation, not just the exhibitions but also the creativity in designing prototypes and application of learning in context, show us another possibility to motivate students in the physics study.

Gain Hake

It allows measuring and comparing the conceptual gain during the methodological intervention. It should be noted that students arrive at precollege level from different schools from various states of the republic, and therefore they have heterogeneous knowledge levels about physics.

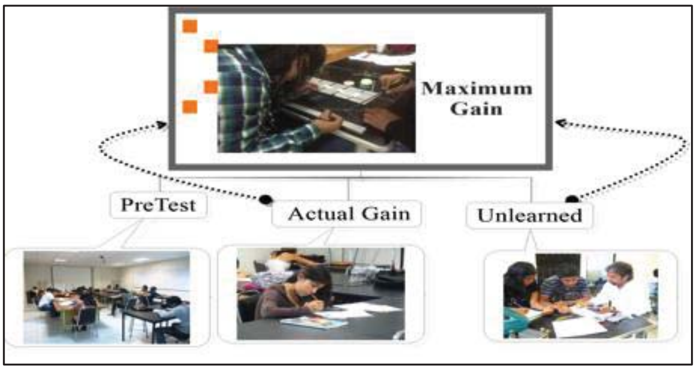

Fig. 7. Maximum gain estimation (g_max).

$$\text{PreTest effective\%} = \text{PreTest} - 20\% \quad \text{(eq. 1)}$$

$$g_{corr} = \frac{(\text{PostTest\%}) - (\text{PreTest effective\%})}{100\% - (\text{PreTest effective\%})} \quad \text{(eq. 2)}$$

where:

$$g_{corr} = \text{average normalized gain}$$

$\text{PreTest effective\%} = \text{correct results in the survey}$

$\text{abefore methodological intervention.}$

$\text{PosTest \%} = \text{Correct results in the survey}$

after methodological intervention.
Maximum gain is calculated by the follow expression:

$$g_{max} = 100 - \text{PreTest effective}\% \qquad \text{(eq. 3)}$$

Average normalized gaing_{ave}; for group, It is calculated through determining the gain for each student and average evaluating:

$$g_{ave} = \frac{1}{n}\sum_{i=1}^{n} g_i \qquad \text{(eq. 4)}$$

$$\mathbf{g}_{ave} = \frac{1}{n}\sum_{i=1}^{n} \mathbf{g_i}\left[\frac{Post_i - Pre_i}{100 - Pre_i}\right] \qquad \text{(eq. 5)}$$

Where $n = 47$, are students who answered no just PretTest but also Posttest, and the sum was made with the n students of the study; obteniendo a real increase called: average normalized gain for the group, (Benitez and Mora, 2010).

Based on the above, we obtained value of ($\mathbf{g}_{corr}$); which quantifies the effectiveness of methodological intervention, shown in Table I. The Hake Gain (g), has values which cover the range [0,1]. Consequently, average differences between Pre/Post Test data give us the different ranges of the Hake Gain, and It interprets the effectiveness of methodological intervention, then: a high gain is ($g \geq 0.7$); an intermediate gain is ($0.3 \leq g < 0.7$); and a low gain is ($g < 0.3$). The results were not compared with a group traditional, considering that the results obtained by Hake for a traditional group (exhibition-conference) have an average gain of 0.2; so it was not necessary to make a comparison of student achievement between the two methods, (Seyed-Fadaei, 2014). However, we took 20% of average, according Hake traditional groups, which we was subtracted and represented the PreTest effective = PreTest-20%. Based on the above, the data allow us to project similar results for the other topics that the precollege level physics course contains, which is a general physics course. Other contents from the physics course are, mechanics and electromagnetism.

4. Results

Students involved in the study have between ages 17-20 years old, 50% are women. 47 students participated in the manufacturing of three prototypes: a solar heater (Group), a solar oven (single) and a photovoltaic panel (computer). The surveys were designed, were applied and analyzed before and after methodological intervention. During the development of the proposed 10 learning activities were implemented, and the concepts revised were: temperature, thermal effects, transfer thermal energy; we emphasized the concept of conservation and transformation of energy.

The activities called IDEA learning activities, covering three aspects: 1) the contents studied to give an overview of the subject studied; 2) The integration project, around the solar energy; and, 3) manufacturing of prototypes: a) solar water heater (collaboration skills); b) solar stoves (reflection skills); c) the photovoltaic panel (transfer skills), in order to move the proposal to other topics. Hence, there is a methodology continuing in entire course. We can see that there is no fragmentation the IDEA methodology, dismissing the possibility to apply a traditional methodology. Table 1, shows the four results of the surveys throughout the study process and the average normalized Hake gain ($\mathbf{g}_{corr}$)

By applying PreTest/Intervention/PostTest, the methodological proposals (Hake, 1998). The learning externalizations or realizations have shown from the results in the instruments applied to students before and after the proposed methodology, improves not just procedural and conceptual, but also attitudinal and application. The IDEA methodology and their tools, the worksheet, showed significantly high and positive achievement in promoting integrative theoretical learning and experimentation.

Tab. 1. Summary of survey and gain Hake.			
Type exploration	PreTest (%)	PostTest (%)	g_{corr}
Exploration income	18.00	71.65	0.6400
Experimental exploration	16.59	59.36	0.5100
Conceptual exploration (I)	41.50	83.60	0.8100
Conceptual exploration (II)	12.98	69.57	0.6600
Average	22.27	71.05	0.6550

The focus was on the different stages of development of the proposal, the consolidation of a group of teachers , which supports the development of prototypes for teaching physics. Result from the interest among teachers to give the course of precollege level with concept of energy and its conservation; and this is a reason for to use the methodology IDEA proposal. Similarly by comparing the final grade of physics course, progress is observed with respect to information of the scores at ingress/egress of intervention methodological, from 42.27% to 71.05%.

5. Conclusions

With the development of a planned and comprehensive proposal; It was possible to design, implement and analyze the methodological effect in teaching physics concepts with prototypes of solar and an evaluation along to the methodological intervention. The results were compared by analysis of the information collected, which were results the surveys and worksheets applied; in order to evaluate the proposal.

This research favor the development of a collaborative learning environment and with based on the factor of Hake, we get a conceptual Hake gain entry 0.6400. It is considered intermediate to high according to Hake rate. The evidence suggests significant progress, despite the student diversity.

For experimentation, we get a conceptual gain of 0.5100, a value low to intermediate according to Hake rate. The conceptual stage of introduction was the most effective with high gain of 0.8100, favoring the methodology in the first level of conceptual approach. The conceptual stage on accentuation; the gain is intermediate-high between 0.6600, which requires a higher abstraction level and a deep reflection on the last stage.

We can see there is an average gain of 0.6550 conceptual, which means a significant advance in understanding the concepts, involved. Also, the integration project at three levels (group, individual and team), enriches the study on organized bodies of knowledge, considering the daily needs, motivation and resolving a problematic situation.

The fundamental elements of the proposal methodological are the integration with different educational proposals interactive and the issues of transfer of thermal energy to be studied in context; achieving the effect of moving from the phenomenological (lived experience) to a thoughtful and appropriate description of the students at this university level.

It is about developing a critical thinking when transferring the information in context and a continuous assessment: diagnostic, formative, summative and alternative (exhibitions, solving everyday problems and creativity). Research supports the development of a collaborative learning environment the study of physics and with reflexive analysis and also retrieval of information is encouraged to make decisions that improve IDEA methodology and strengthen its structuration in next implementations.

Finally, the different ways to communicate information such as worksheets, all kind of information in the lab notebook, mathematical models in solving exercises, school exhibitions in scientific events, discussion between peers, the reconceptualization of problems, creativity and the use of solar energy. They are the basis of the didactic integration with applied exploration (IDEA), an alternative methodological to support students in the study of physics.

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