Int. J. Engng Ed. Vol. 26, No. 2, pp. 430–437, 2010
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Teaching Creativity and Innovation Using Sustainability as Driving Force*

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Undergraduate and graduate students are often exposed to definitions and lectures about creativity and innovation to accomplish some internal or external requirements about the syllabus and curricula, but they have little opportunity to do and experiment the creative processes and create innovative products and services.

The teaching philosophy at Instituto Tecnologico y de Estudios Superioress de Montererry (ITESM) is focused in active a learning methodology which gives students an opportunity to learn by doing hands-on-projects with different goals. This opportunity has been used to do projects that face real problems but defining the problems using sustainability issues as part of the problem definition and to address solutions that are better than using just economical or technical goals.

There are many of challenges and even more possible forms of failure while trying to implement active learning in an creative and innovative way in the framework of sustainability, because it depends in the student, the problem setting, the availability of needed resources and that the teacher states the problem properly, has the flexibility to handle unexpected situations as well as results that are either negative or not the original ones, but that should not affect the grades of the student if he accomplished the learning goals.

Keywords: creativity; innovation; active learning; sustainable solutions

1. INTRODUCTION

FOR A LARGE amount of people, sustainability is a fuzzy word that is in vogue now a day and has something to do with environmental care, but has little meaning to real life. ITESM designed core courses focused on Sustainable Development and Integrated Design Experiences at graduate [1, 14] and undergraduate levels and there is a program for teachers to incorporate sustainability in courses of all disciplines is more common every year.

An example of a multidisciplinary course with several teachers working as a team to address complex themes like urban planning using active learning techniques was presented by Bremer & Porsen [2] at the 6th International Workshop of Active Learning in Engineering Education. [3] Presents the results of an experiment with two groups of freshmen mechanical engineering students taking the course 'Introduction to Engineering'. One group label control group had the traditional lecture-based format, while the experimental group received instruction in systematic creativity tools (Theory of Inventive Problem Solving, known as TRIZ) and the students were asked to identify and work in the solution of challenging engineering projects based on active learning methods. The expectation was that the students in the experimental group would enhance their creative and critical thinking skills during their educational endeavor, but the initial data shows that the exposure time was not enough to reflect it in a measurable form and that it is necessary to expose the students to creative tools and challenging problems in order to get the expected results [3]).

The teaching philosophy at ITESM incorporates active learning methodologies which give students an opportunity to learn by doing hands-on-projects with different goals. This opportunity has been used to do projects that face real problems but defining the problems using sustainability issues as part of the problem definition and to address solutions that are better than using just economical or technical goals.

A group of professors and students is working in issues about creativity, innovation and inventive in engineering, doing research and development through regular courses and master thesis combining techniques to improve results and applying the techniques to solve real life problems[4, 5 and 6].

2. OBJECTIVE

Incorporate sustainability and ecological themes in undergraduate and graduate courses as part of a complete formation of engineers.

* Accepted 10 November 2009.

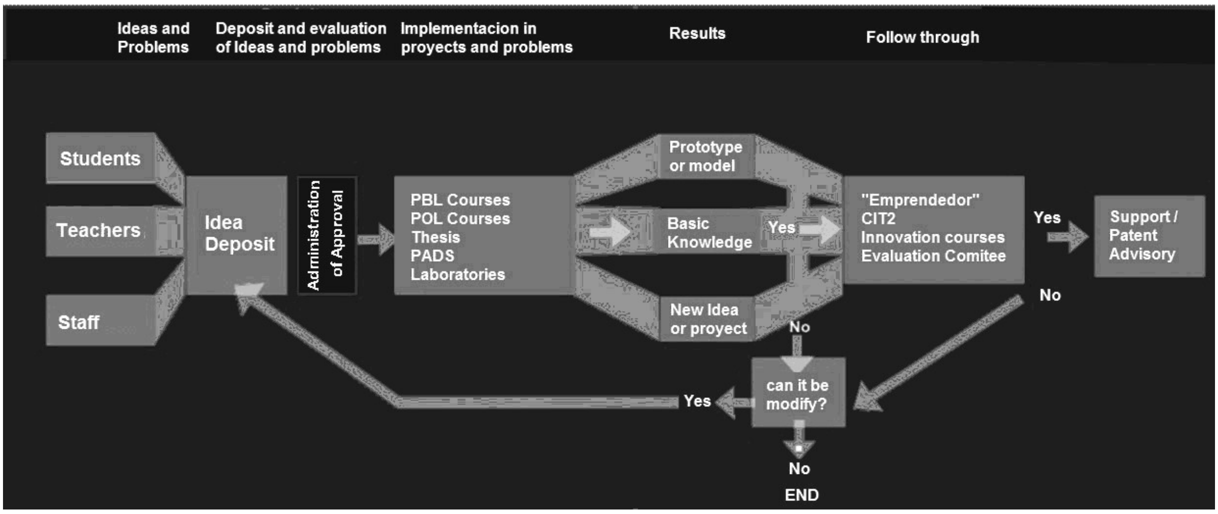

Fig. 1. Flow diagram proposed for management of ideas and technological innovation.

Expose students to the innovation and inventive culture through the definition of challenging problems, which will demand higher commitment and creativity in order to find solutions which are able to meet both the technical and sustainability requirements.

3. METHODOLOGY

To introduce the students into the innovation culture, it is very useful to defy their intellect and creativity by exposing them to challenging problems and the use of Active Learning methods to have hands-on experience about the benefits and possible pitfalls associated with the process of exploring new ways to look for creative solutions, instead of just reading about the creative and innovation processes from the literature or solving predefined projects where the outcome is predictable and they only need to look for a pre-stated way to solve it.

Globalization and actual challenges require the incorporation of environmental and social aspects in addition to the technological and economical ones. This gives the opportunity to improve the problem settings and to look for more challenging solutions that can be useful, not only in the present but also in the future.

A pilot program at ITESM on 'Management of Ideas and Technological Innovation' tries to document the process from the problem identification, to the solution proposal up to the implementation, integrating the educational process using the courses, workshops, laboratory, thesis and other courses with practical orientation. The goal is to 'test ideas while the students learn'.

Figure 1 presents a flow diagram of the proposed process. It begins with a pool of ideas or statements that defines a problem and a possible solution as well as a general search to look for state of the art in patent databases and web searches. The kind of solution can be proposed on different level:

- General solution without any proof of feasibility
- A solution that has at least a conceptual feasibility
- Development of a working prototype
- Improvement of prototype for manufacture and commercialization

In all cases, it is necessary to define at least one specific problem or inquiry that will be solved by the students and the kind of knowledge that should be necessary to use in order to get a solution. Those ideas/problems will be reviewed by professors of the corresponding departments in order to validate that the problem will have the required level for the course.

At the end of the course, the solution proposed by the students (prototype, model, analytic solution, etc.) should be evaluated by the teacher in order to direct the project back to the pool of ideas and problems if the solution has still potential for future courses or, if the solution was good, it can be patented or used in advanced courses in design and innovation to refine models or to manufacture and commercialize depending if the goals where reached.

One important fact to challenge the students to be committed and explore new ways to solve the stated problems is that they must find the problems attractive and appealing thus becoming worthy of all the hard work that will be required if they are aiming for a solution that is good enough to be implemented. Sustainability issues cannot only determine new challenges to be solved, but also can help redefine some standard problems in a more integral and challenging way, in order to get the students more interested in the search of a creative solution.

Some examples of projects done with graduate and undergraduate students using (more or less) this approach will be discussed ahead.

Fig. 2. Erosion effects on a landfill slope (left), regulated scrap tire piles (center), fire in an unregulated tire pile (right, picture taken by Jorge Castillo).

Fig. 3. Insertion of an anchored rope through the tires (left) to build the lines that will cover the slope (right).

4. PROJECTS

4.1 Erosion control with scrap tires

The first problem addressed was to reduce soil erosion in slopes of a sanitary landfill using scrap tires. The erosion of slopes in sanitary landfills is a general problem due to the unconsolidated material that can be easily eroded from the generally steep slopes from the landfill cells. On the other side, the use of cars derives in the production of huge amount of scrap tires that accumulate in regulated and unregulated tire piles when no regulation or another economically feasible option can be addressed.

Fig. 4. Improved tire 'collar' using straps and boring drainage holes.

Israel Lewites addressed those problems during his Master Thesis [7], designing and implementing a system that covers the slope with anchored and perforated scrap tires, achieving an impressive 83% reduction of soil erosion against the unprotected control slope during an intense rain season in summer 2002 [8]. The system worked well, but demanded quite an intensive labor therefore and unsuitable for regions with high labor costs.

w>This labor intensity and associated costs were the initial problem statement for a group of students taking a course in Product Design and Analysis. The students made a morphological analysis and Quality Foda Deployment (QFD) using TRIZ techniques, improving the labor time by 75% and diminishing material costs by 18% [9]. Both systems where submitted in 2005 to the Mexican patent office to claim for a patent [10, 11] and were published in 2007, but are still pending.

4.2 Low cost mini (400W) wind generator

Another task addressed with this approach was to develop and construct a low cost electrical wind generator of about 400W to charge an electric car battery. This battery will supply electricity for lighting in poor rural regions that are not connected to the electric grid. The restrictions where: low cost (< 150-200USD), easy to construct

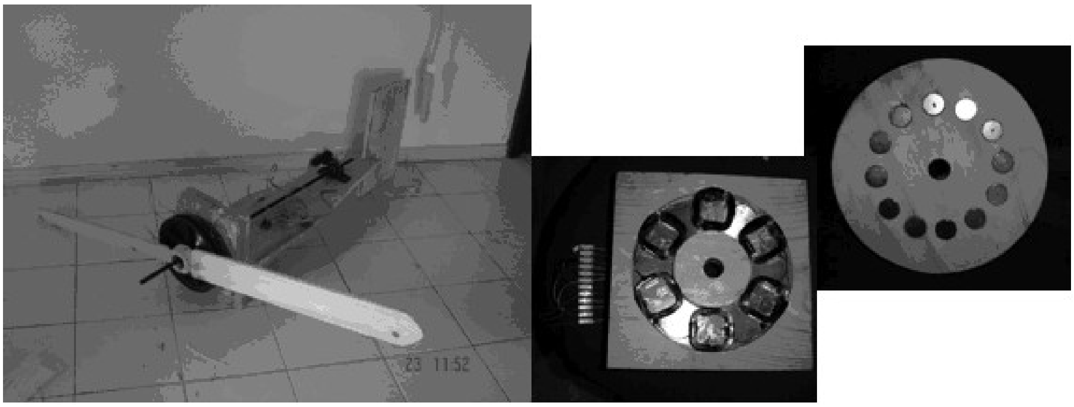

Fig. 5. Frontal, back and prototype assemble views.

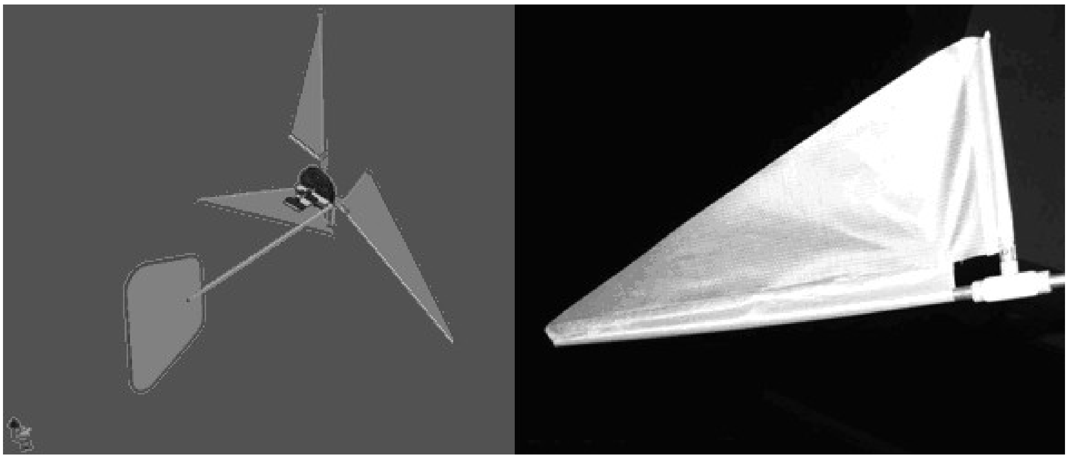

Fig. 6. CAD Model vs. Protype.

and to maintain, using 'standard' materials that can be purchased in any hardware store (except the magnets).

Several groups of students from different engineering disciplines have tried in the last 2 years to construct (different versions of) a device that can achieve the power goals, but the best trial was about 140W. The main problems they faced where with the implementation of a rotor with magnets very close to the stator with wire coils. Either it was not well balanced or, not parallel or, the wires has an irregular outer shape that clamped with the magnets or led to larger distance between rotor an stator, and so on.

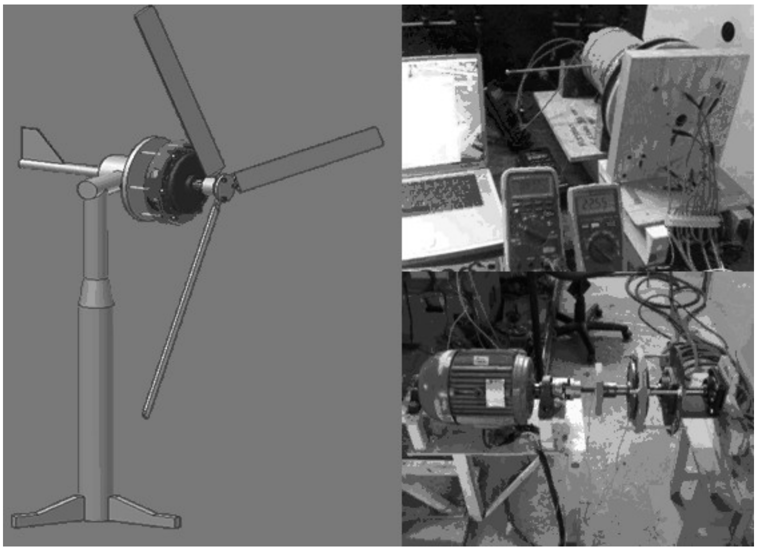

Fig. 7. Virtual assemble and lab testing.

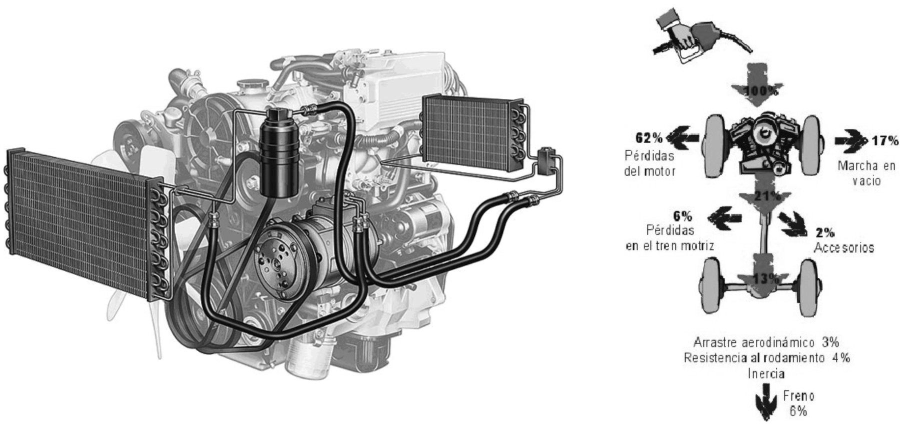

Fig. 8. AC and connection diagram as presented in www.fueleconomy.gov

But in all cases, the students realized that the theory and computer models they learned in their courses were useful but not enough to get a real 3D working device, even for this kind of 'simple' devices (as this tend to happen in almost all devices no matter how basic they are). They realized that the properties of materials (strength, weight, homogeneity, conductivity, etc.) are not trivial, as well as the connections and moving parts. Finally these models done by students will be continuously improved in a close loop cycle in each class.

4.3 Inertial sensor for energy distribution control in cars with air conditioning (AC)

The last project to present this time is a device that can be installed in a car with air conditioning and will help to reduce the power loss of the motor derived from the compressor power drain, which also increases the mileage efficiency with respect of the extra gasoline consumption associated to the AC use.

Cars with AC have a higher driving comfort, but the response to acceleration decreases, the contaminant emissions increase and the gasoline consumption increases about 10%. Most of the power withdrawal due to the AC comes during the acceleration period, because full power is required to change the velocity of the car, but the compressor drains some of this, causing a decrease in the response of the car.

The problem for undergraduate students of mechatronics coursing their final semester in the course named'projects of mechatronics engineering', was to search for existing devices and design/ construct a device with an inertial sensor that can 'feel' the change of inertial state due to acceleration and/or in an ascendant slope and that should disconnect the AC compressor during some time and after this period, initiate en new cycle.

The first step was to characterize the function of the AC, measuring the air velocity and air temperature of the exhaust air and the temperature of the interior of the car in a warm (38ºC) summer day.

Figure 9 shows that the AC system has a thermal inertia for about 0.3 minutes, because during this time, the cold air blown from the AC fan experienced no measurable temperature increase.

The undergraduate mechatronical engineering student Coamin Cruz searched more than 60 patents and was the first to achieve a working

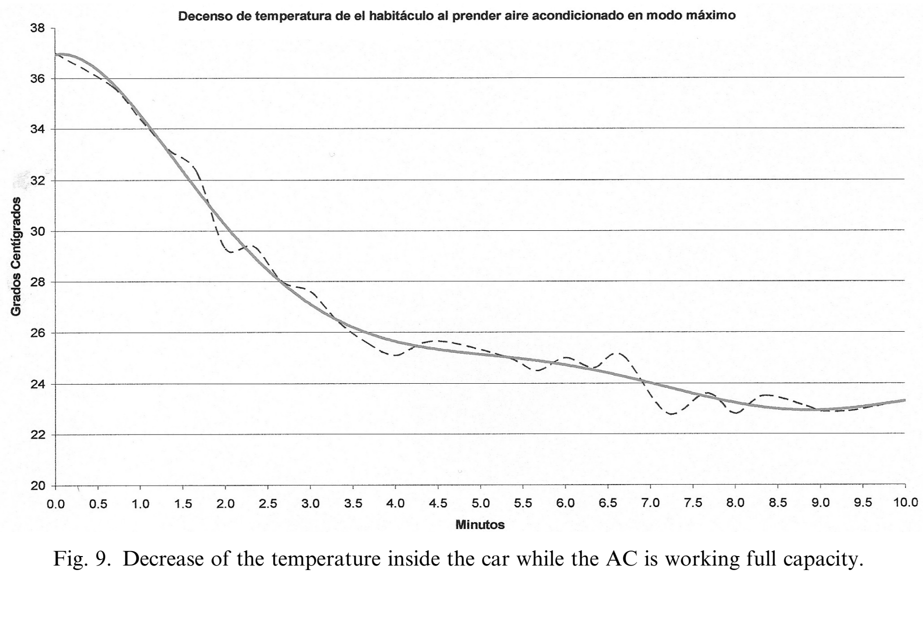

Fig. 9. Decrease of the temperature inside the car while the AC is working full capacity.

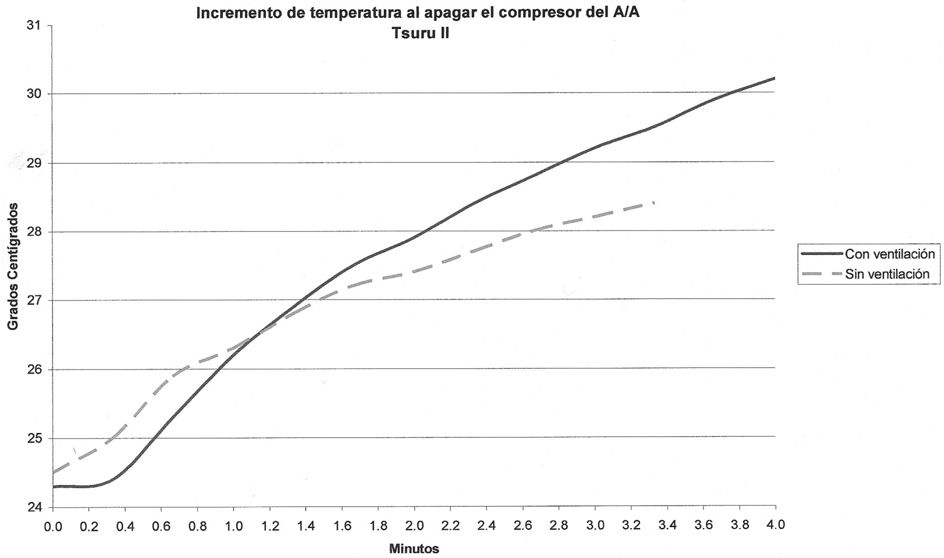

Fig. 10. Increase of the temperature inside the car after the compressor is disconnected.

prototype (after 'just' 2 previous trials), using as 'inertial switch' an opaque sphere inside an inclined plastic tube and photoelectric diodes. With a 'temporizer', the device was able to disconnect the compressor for 15 seconds and reset the system for the next change of inertial state. The time lapse was set to 15 seconds in order to maximize the comfort, but could be longer in order to maximize fuel efficiency.

After the first prototype, several other student have been involved in the miniaturization of the device, trying a pendulum as sensor and the last group, changed the self-made sensors by an accelerometer using Micro Electronic Mechanical Systems (MEMS) technology.

Preliminary results indicate that the 10% extra consumption of gasoline with AC can be reduced to 3–5%. This device was submitted to the Mexican patent office in 2006 [12] to ask for a national patent and in 2007 for an international PCT patent [13].

5. CONCLUSIONS

Most students involved in high challenging projects with unknown solution and the possibility to solve a real problem react normally with high commitment, especially when they see that the solution will address more than one problem from different perspectives of sustainability.

In some cases, where the commitment of the students and/or the outcome of their projects were not the expected, it is difficult to give them the grade they deserve. Especially difficult is when the outcome was not the expected, but it was not due the lack of commitment of the student but more a lack of time, or because they choosed the wrong materials/components, or an incorrect approach, etc. (all this is inherent to innovation . . .). In those cases, they can get a better grade if they can explain the causes of the pitfall and what can be done to fix them.

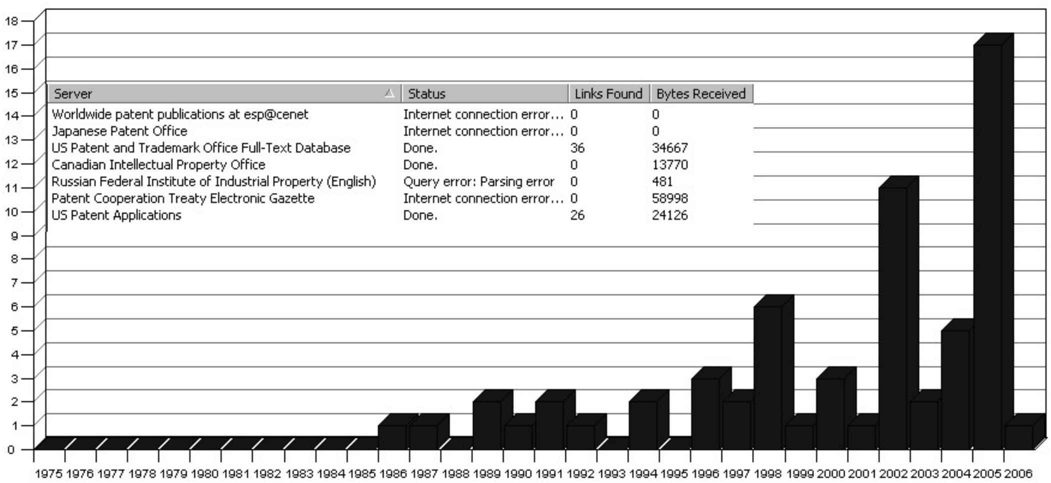

Fig. 11. Frequency of patents associated with the term acceleration sensor, air conditioning, energy distribution.

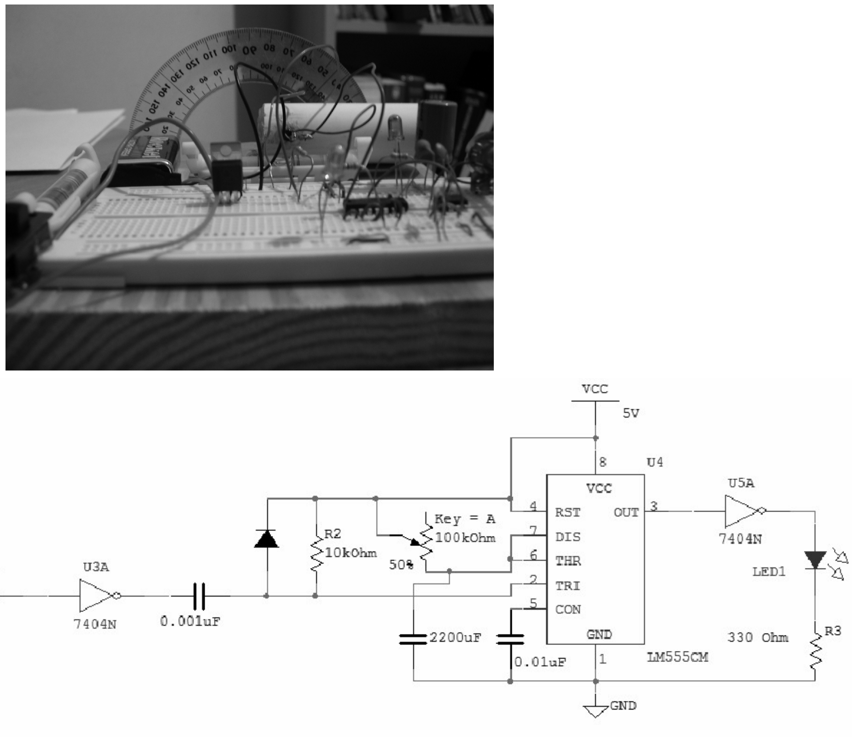

Fig. 12. First working prototype developed by undergraduate student Coamin Cruz.

Until now, the experiences have been only with problems stated by the authors and from colleagues that participate in the research chair of Creativity, Innovation and Inventive in Engineering leaded by Prof. Noel Leon, but the challenge in the near future is to open the 'call for problems and projects' to other people and therefore incorporate other colleagues advice for projects and that can be flexible enough to: (a) address problems with unknown solution and (b) to grade the students accordingly without regard of the problem outcome.

At the present, one relevant area of work could be the fully successful inclusion of sustainability issues in the definition of problems and the search of solutions in order to foster the commitment and creativity of the students.

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