
How to teach students to transfer technology through multidisciplinary teams

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Abstract

Mexico imports most of the technology it needs to solve its big national problems. For example, Mexico imports more than 96% of the technology it uses. The main product of Mexican scientists and engineers are papers which are published in many Mexican or international journals and books. For real every-day industrial needs Mexico imports technology. Mexico produced 3.4 million vehicles in the year 2016 and exported 2.5 million vehicles to the United States, however those products are mostly assembled in the country from parts imported by Mexico. Mexico frequently imports software to analyze its national problems; however, not all this software is adequate for the country's conditions and in certain cases does not exist for certain problems. For example, at the end of the year 2012 the Mexican government tried to promulgate a Mexican regulation for fuel consumption and carbon dioxide for new heavy duty vehicles but there was not an appropriate computational tool to calculate the fuel consumption of those vehicles. The Greenhouse Gas Emissions Model (GEM) from the US Environmental Protection Agency was not appropriate because of the characteristic operations of the heavy-duty vehicles in Mexico. The Mexican roads and the configurations of the vehicles in this country are very different to those modeled in the GEM. In this work it is described how at the Mexican Universidad Autónoma Metropolitana a multidisciplinary team of undergraduate students was put together to study the problem of fuel consumption and contaminants of the Mexican vehicle fleet, in particular of the heavy duty fleet. In this paper, it is described how students were taught and learned to do research for this important problem and how they carried out a collaborative work. Some of the research consisted in the creation of a software which is named UAMmero which models the operation of a heavy-duty vehicle traveling in a road or simulating the US Federal Test Procedure 1975. The results of the collaborative work is reported. The collaborative work of the assembled multidisciplinary team could be a model to follow in Mexico to develop some technology with undergraduate students.

Keywords: collaborative work, national problem, problem-based learning.

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Introduction

The Mexican industry and government as well as the transnational companies do not acquire Mexican developed technology, because it is basically inexistent; 96% of the technology used in Mexico is imported (México recurre a tecnología extranjera, 2017). However, there is technology patented in Mexico by transnational companies to be protected in Mexico (IMPI, 2016). Although, it is developed somewhere else in the world and technology innovations created in the country by some of those companies. The main products of Mexican research and development and higher education institutions are papers and books published in Mexico or elsewhere. The technology developed in those Mexican institutions is hardly used as it is confirmed in the fact that there are just a few patents produced in the Mexican institutions which are hardly licensed. For example, currently none of the patents developed by the Universidad Autónoma Metropolitana (UAM) is being licensed.

Directors of the Mexican Science and Technology Council (Conacyt), the Scientific and Technological Advisory Forum and those of the Science and Engineering Academies complain that the main reason why Mexico does not develop technology is that the Mexican Government does not allocate enough federal funding to finance those activities. However, even a small budget should be used productively by the research and higher education institutions to prove that with that funding they are developing technology for the Mexican industry to be more productive and competitive. However, most of the researchers aim to produce papers to obtain more points in their evaluations which determine their economic incomes. Of course, the federal budget for research and development is scarce, less than 0.5% of the gross domestic product (GDP) and funding from states of the Mexican Republic is basically inexistent as it is the Mexican private funding for those activities. Mexico is very far from financing research and development appropriately and to also significantly develop technology for the Mexican industry or to help to solve big national problems. Nonetheless, it is very important to point out that there are very prestigious Mexican scientific groups recognized worldwide mostly working on basic sciences. There are also a lot of very well renowned thinkers in social sciences and humanities. Furthermore, Mexico has given to the world some of the finest poets and artists.

Mexico has not yet found a technology innovation model to foster competitiveness and productivity of the Mexican industry and abandoned the technology development strategies that it had before the 1980s (Domínguez & Zavala, 2009). There are some very good inventions and innovations created by professors and students of higher education institutions in Mexico like drones, electric generators, electric vehicles and small robots. After graduation, most students barely find jobs developing technology and end up as salesmen, translators of manuals, maintenance engineers and the like. All that despite that in a lot of higher education institutions they are formed as inventors or innovators. Successful innovation models (Sánchez, 2017) have to be developed in Mexico to solve national problems.

In this work it is described how a group of undergraduate students is being formed at the UAM Azcapotzalco (UAM-A) to study a large-scale national problem, the one re-

garding the fuel consumption and carbon dioxide emissions from heavy duty vehicles. The projects at the UAM-A which have been created to form the group are described as well as their objectives. Finally, the results of the projects are listed as well as the future work of the team. All these projects constitute part of an innovative model which could be foster at the UAM-A.

Social service project, research project and career final projects at UAM-A

In Mexico, most of the technology to solve industrial and big national problems will continue to be imported for the foreseeable future, unless new ways and more funding to develop technology are found and fomented. Likewise, technology based companies are being difficult to create because there is not much technology developed. Although there are efforts for their creation, as well as programs for the students to become entrepreneurs after graduation. The Instituto Politécnico Nacional (IPN) has business incubator programs and the Universidad Nacional Autónoma de México (UNAM) has also a program to incubate businesses and to have stronger linkages with industry. The UAM also has a few programs to foster entrepreneurship in the students and some programs to reach industry. The students could develop some technology as part of the assignments of the courses of their career curricula but also in the social services programs of the higher education institutions, in their career final projects for graduation or by collaborating in a research project. The career final projects for graduation are projects carried out for the students to graduate under the supervision of a professor or two professors; these projects last one or two trimesters. In Mexico, in order for a student to graduate must dedicate a few months to work without salary serving to society. In some special cases they have some small payments for their services, which are extremely low (like 154 US dollars a month). That work is called social service and is basically carried out in 480 hours for some careers in the span of at least six months. For the career of medicine is longer.

Social Service Projects at the UAM

We describe how a multidisciplinary team of professors and students is being created aimed to contribute to solve a big national problem. The students must have covered 70 percent or more of the career curricula credits to start working on a social service project. The objectives of the social service projects at UAM are very broad. Some of them have to do with helping professors to improve their didactic material for their courses. In some others, students help professors in their research. In this paper we describe a social service project towards solving one of the Mexico big national problems. The name of the social service project is *Limits for the energy efficiency and greenhouse gas emissions for new motorized vehicles in Mexico*. Two of the authors of this paper direct the social service project.

The National Problem To Solve

There are many big national problems to solve in Mexico, among them: corruption, impunity, social inequality, poverty, violence, drugs, insufficient water resources, contamination, discrimination, sexism, racism and classism. One of the big national problems is air contamination in the large urban areas due to the use of fossil fuels by the vehicular fleet. This air contamination does not only affect big cities causing health problems to the inhabitants, like asthma and lung cancer, but also increases the concentration of greenhouse gases which cause global warming. The air contamination by mobile sources is mainly caused by automobiles and heavy duty vehicles. In Mexico, the automobile fleet is of 29.80 million cars and that of the heavy duty vehicles of 11.07 million units (INEGI, 2017). A heavy duty vehicle has a mass of more than 3857 kilograms like tractos, redi-la-type tortons, pipe-typetortons, six-ton trucks, tank-type semi-trailers (carbon steel and stainless steel), vocational vehicles and cage-type trailers. The most contaminant of the heavy duty vehicles are the heavy trucks due to the amount of them and the tractos with trailers because of the amount of fuel they consume. In Mexico, heavy duty vehicles use diesel, which is not very clean. Diesel is sold in Mexico with about 15 parts per million (ppm) of sulfur in Mexico City, Monterrey, Guadalajara, cities of the Northern border and in a few other places. In the rest of the country diesel is sold and used with 350 ppm of sulfur or even more.

It is necessary to decrease the contaminant emissions from the new and old heavy duty vehicles. For the new ones through a federal regulation just like the one in the United States of America (EPA NHTSA, 2011) which the manufacturers have to comply. And for the old ones through programs to replace them. The result of this last measure is not guaranteed because most of the owners of the trailers do not have the financial resources to buy new ones. In Mexico, the heavy duty fleet is around 17 years old; the owners of small and even medium size logistics companies replace the parts of the vehicles as they are failing and they have savings to replace the broken parts with new or used parts bought in junkyards. So that, a lot of the heavy duty vehicles traveling on the streets and roads of Mexico have been heavily reconstructed.

Saving fuel is also very important because fuel cost represents between 30% and 40% the total operation expenses of the companies dedicated to the transportation of goods. In Mexico, the price of the diesel increased from less than 0.31 US dollars per liter in January of 2007 to 0.89 US dollars per liter on May 11, 2017. And Mexico imports more than 50% of the diesel it consumes.

UAM projects to study the national problem

Mexico has a lot of big national problems. The ways and tools to solve a problem, depend on the problem. For a lot of them, soft or hard technology is needed, or low and high tech are needed. Most problems need a set of technologies to be solved and multidisciplinary approaches, so the university has a good stand to take on those problems by assembling

multidisciplinary teams to tackle them. The creation of multidisciplinary groups is not difficult in universities because there are a lot of professors with very different academic backgrounds, experiences and knowledges. Problem-solving teams could be assembled with professors of different divisions; for example in UAM-A from the Division of Basic Science and Engineering (DCBI), the Division of Social Sciences and Humanities (DCSH) and the Division of Design Sciences and Arts (DCYAD). With professors of the three divisions, tools can be created with two purposes: 1) on one hand, to solve big national problems, and on the other, 2) to start creating internal technological capabilities. We are taking Domínguez's proposal (Domínguez, 2017) to start developing technology by creating multidisciplinary groups. In this way, there are chances of solving large-scale national problems which are the ones the Mexican society faces. So far, at the UAM-A there are a very few multidisciplinary projects.

As the multidisciplinary teams can solve formidable problems it could be possible to obtain funding from the government and international organizations. Nationally, Conacyt could fund them as well as Secretariats-Conacyt funds for research. Later on, teaming with the local, regional or federal governments proposals could be submitted to the United Nations, World Bank or the International Monetary Fund.

One of the biggest problems at UAM as well as in many other higher education institutions is that the teaching activities are disconnected from research activities. With the projects described in this paper, already in place, it is natural to connect the teaching-learning process with research because the students have to learn the science and acquire abilities not only to understand but to contribute to solve the problems. And obviously a large part of the projects is research to be conducted by the professors and students. One part which does not have current UAM research projects is the linkage with industry, the government and the neighboring communities. This part should be embedded in searching for funding to apply the results of the projects, and it is something which will be added to the projects for the students to participate.

The lack of multidisciplinary approaches to solve big problems is in part because in the DCBI the only research projects allowed are divisional and non-interdivisional; all the participants of the other two UAM-A divisions are considered as external. One of the first things that the UAM-A should do is to allow interdivisional projects, in order that those projects are formally carried on.

Domínguez's proposed model to create multidisciplinary teams of professors and students is being taken. The professors lead the solving of parts of the formidable problem and the students help to solve the problem and they lead the implementation of the solutions found in the team.

The complete team is divided in smaller groups. The smaller groups are led by one or more professors experts on parts of the problem to be solved. There are two internet sites (www.ecolaboracion.azc.uam.mx, <http://sistemas.azc.uam.mx/uammero.html>) for the students to learn about the projects and they are asked to study specific topics in order to participate more actively. Besides, students are coached continuously, and the professors create the smaller groups and continuously advise the students that they have to collaborate to reach common objectives.

A part which will be added will be the writing of proposals to national and international potential sponsors. This will be a part of the social service project and of the research projects to be carried out by students under the supervision of the professors. People of the three UAM-A divisions can participate in this new part which will be added to the projects.

A social service project, a couple of final projects to graduate and a research project have been created so far, to create tools and collaborative groups to contribute solving the national problem of the fuel consumption and the carbon dioxide emissions from heavy duty vehicles; which involve the modeling of the vehicles and their operation, as well as obtaining data about the national heavy duty fleet. So far, the professors make the marketing of the projects, but in the near future the students will participate as well.

The main common and complementary objectives of our projects are: a) To find important information and to create tools necessary for a proposal of a Mexican regulation on fuel consumption and greenhouse gas emissions of new heavy duty vehicles. b) To recommend appropriate technology and better operation modes for heavy duty vehicles mainly to help small and medium size logistics companies. c) To improve the management of small and medium size logistics companies which mainly use old heavy duty vehicles.

Social service project

The social service project is: *Limits for energy efficiency and greenhouse gas emissions for new motorized vehicles in Mexico*. The social service project involves: a) Collecting the information about automobile and heavy duty fleets. b) Constructing a data base with the information. c) Modeling heavy duty trucks. d) Collecting information of the main contaminants in urban areas, like in Mexico City. e) Estimating the cost of new vehicular technology. f) Running the software for the different heavy duty vehicles modeled in the developed software and recommend how through better operation of the vehicles fuel consumption and carbon dioxide emissions can be reduced.

Research project

The name of the project is: *Tools to evaluate the fuel consumption and the greenhouse gas emissions of heavy duty vehicles*. One of the authors of this paper is the leader of the project.

The research project involves: a) Developing the software modelling the heavy duty vehicles (UAMmero). b) Modeling in UAMmero the operation of heavy duty vehicles during the Federal Test Procedure (FTP-75). c) Modeling in UAMmero the operation of a heavy duty vehicle traveling on streets and roads of the Mexican Republic. d) Find recommendations for the operation of heavy duty vehicles traveling on streets and roads which allows to reduce fuel and contaminant emissions.

Career final projects for graduation

These projects include visualization of the results of UAMmero, recommendations to improve the management of small and medium size logistics companies, and recommendations to use appropriate technology and improve the operation of heavy duty vehicles

travelling on roads and streets. The final projects for graduation involve: a) Developing small pieces of software to visualize the results out of UAMmero. b) Reaching small companies and help them to improve their management and advise them on better vehicular technology. c) Running UAMmero for cases useful to small companies to give recommendations to improve the operation of the vehicles.

For old heavy duty vehicles it is being concluded that the best way to reduce fuel and emissions is to run UAMmero and make recommendations about the type of transmissions, engine, wheels as well as the best speeds for the vehicles while travelling on streets and roads.

The multidisciplinary team of professors and students

Because of the many different topics involved, a multidisciplinary group was formed. The students in the team are from the 10 engineering careers of the DCBI. The professors which lead the efforts are from DCBI. Social service project: mostly students of industrial, mechanics, chemical, environmental and computer engineering. Research project: mostly students of the careers of industrial, electronics and computer engineering. Career final projects for graduation: mostly students of the career of industrial and computer engineering. One aspect which is very important to note is that students are not paid for working on these projects. It is expected that some scholarships could be obtained for them in the near future.

Main issues in the collaborative projects

We explain some of the main issues so far in building the collaborative model. Lack of funding in Mexico for technology development has avoided that participant students obtain scholarships, therefore some of them dedicate as little as possible of their time to the projects. A lot of the students do not have a laptop to work on campus during their free time and to advance in some of their tasks. A lot of students do not own computers or have internet connections at home, so it is difficult for them to stay in contact from home in case of doubts, search for information or continue other tasks from home. Some students lack proficiency in writing, a few of them copy and paste from internet despite of warnings of not doing so. Most of them do not read proficiently in English so the information that they access is restricted to Spanish. They would carry out a much better collaboration in the projects and would find better job opportunities after graduation if they could read and speak English in a medium proficiency level. Some of the students do not like to collaborate mainly because they have an employment and have scheduled conflicts. Some of the professors do not dedicate enough time to tutor students and to supervise their work so that students sometimes do not have an appropriate guidance.

Results of Know-How and technology developed

With all the information collected a software was developed, UAMmero. This is the best and most important result. UAMmero has been written in C language. Many publications are being prepared. Some career final projects are being directed in order to use the software for small and medium size logistics companies to reduce their fuel consumption and carbon dioxide emissions.

Social service

a) Information on the Mexican automobiles and heavy duty trucks fleets has been obtained and is being completed. b) *PowerUAM*, a software using a simple mathematical model to determine the needed power to move a vehicle was developed. This was the first computer model developed at UAM-A to estimate the consumed fuel and greenhouse emissions from vehicles. c) Most results of the social service project are uploaded in the internet site of the UAM-A: *ecolaboración.azc.uam.mx*.

After *PowerUAM*, *UAMmero* was developed and presented to functionaries of the Energy Secretariat, as well as to functionaries of other Secretariats, manufacturers and other stakeholders and shareholders, on February 19, 2015. It was recognized by the audience during that presentation that the results of our projects are unique and original, and that this work distinguishes the role of a public university in support of the Mexican society. *UAMmero* was developed by the three authors of this paper.

The social service project was the seed to develop several computational tools whose developments continue, but now under the research project and the career final projects for graduation. One of the main results of the social service project has been the information on energy efficiency of new vehicles that not only operate in Mexico but also in the United States. It was found that vehicles sold in Mexico and in the US of the same mark and submark have different energy efficiencies, as well as prices. The reason is that they are different; for example, metal parts were not the same (some are manufactured with iron while the others with aluminum). Also, the amount and quality of their accessories are very different.

The Mexican NOM-163 regulation on fuel consumption, greenhouse gas emissions of automobiles and new light duty vehicles was also analyzed. The information obtained in the social service project can be useful to improve the NOM-163 approved in 2013. The information can also be used to elaborate the norm for heavy duty vehicle.

The information that has been obtained on the vehicles is: number of light and heavy duty vehicles assembled in Mexico. Number of exported and imported vehicles. Main manufactures in Mexico. Energy efficiency of the different vehicles sold in Mexico. Special features of the small, medium and large automobiles and heavy duty vehicles. As well as their prices and the differences in energy efficiency among the luxury, sport, and vocational vehicles. Regarding heavy duty vehicles information from the Communications and Transportation Secretariat, the National Institute of Statistics and Geography and of the Energy Secretariat has been analyzed and stored. A data base with all the information is being generated and a lot of that information is already in excel files to be analyzed.

Research Project

The main result has been the creation of UAMmero which is useful to estimate the fuel consumption and greenhouse gas emissions of heavy duty vehicles during the simulation of the operation of the vehicle during the Federal Test Procedure FTP-75 and while travelling on a road or street.

Career final projects

Small parts of software for visualization have been developed.

Future developments

Linkages of UAM with the private, governmental and social sectors are very important in order for the UAM to obtain funding for applying the know-how and technology developed at UAM. DCYAD innovates in lightning, buildings, landscapes, windmills and vehicles. DCBI invents cements, electric and hybrid vehicles and tools to save energy and water. Domínguez, has proposed to use UAM-A technologies in the UAM-A's neighborhood. The professors of DSCH can contribute to this effort by identifying the needs, the mechanisms and the cost involved in applying UAM-A innovations and inventions. The UAM-A should lobby with the local and city governments to fund the innovative integration of capacities which could be a step to assemble even more formidable projects towards solving the big national problems. As it has been mentioned above, the main research and development products of UAM-A are published papers and a few patents in which nobody is interested in paying for their license. With Domínguez's proposal the UAM-A's developed knowledge not only would be used but it would contribute to social improvement. That is, the UAM-A would return benefits to the society which pays for the university's existence. On top of that, the UAM-A would obtain extra funding which could be crucial in the next years of reduced funding by the government. Domínguez's vision is that the UAM could be the university which creates science, technology and innovation for the citizen and to become an example of a public, autonomous and laic university.

Social service project

To develop a Mexican Energy Transportation Data Book. This would be unique, original and useful to the government, private and academic sectors. We are starting to construct it. To use UAMmero to help logistics companies located around the UAM-A. To try to obtain funding from stakeholders and shareholders (county and Mexico City governments, logistics companies and non-governmental organizations) to give scholarships to the participant students in these projects. To obtain green bonuses for the fuel consumption reduction.

Research project

To build UAMmero as an application for cellular phones because some of the owners of trailers do not have computers but they do have cell phones. To obtain intellectual rights

on UAMmero and other pieces of software already developed. To obtain green bonuses for the fuel consumption reduction using UAMmero. To identify services using *UAMmero* for small and medium size logistics companies.

Career final projects

To try to reach as many possible companies around the UAM-A campus in order to benefit them with the developed know-how and technology.

Global goals

To form an undergraduate group responsible for writing proposal for potential sponsors (marketing). Job hunt for students in the companies participating in these projects. Obtain funding for the continuation of the projects and for scholarships for the participating students. To form students with a social conscience. To obtain green bonuses for the greenhouse gas emissions reduction.

Conclusions

There are ways in Mexican universities in which technology can be developed using complementarily the social service projects, research projects and career final projects to graduate. Multidisciplinary teams can be created and that it is possible in universities like UAM in which there are many careers. The technology can be used in companies located in the neighborhood of the higher education institutions. This model is being created in part to develop technology and applying it to improve the businesses around the UAM-A. The model can be later expanded to bigger areas. Models like these should be replicated and ensure its continuity. Also these projects should be part of programs of incubators of companies. Students participating in these projects develop abilities like self-study, distance learning, collaborative work and social conscience. These projects also help to connect teaching learning processes to research.

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