Innovative Laboratory Model Based on Partnerships and Active Learning

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***Abstract*—The advent of the internet of things and industry 4.0 bring new paradigms that tend to affect the way of organizing several human activities, among them the production processes that are ruled by production and human work on a large scale in the production lines. Therefore, it is inevitable to think of how to prepare students for this new, oncoming reality, since these students will have to deal with a society where usual jobs will no longer be available. This paper presents the initiative of two laboratories developed to prepare students in engineering and computer science to deal with the Internet of Things (IOT) and industry 4.0 (I4.0) subjects. These laboratories were developed in partnership with companies: the first one of Digital Manufacturing (DM) and the second one of IOT, and the integrated work of these laboratories approaches with the students the concepts of I4.0 or advanced manufacturing. The collaborative environment between academia and companies, as well as the joint work of two laboratories, allowed graduate students to develop discussions and works that integrate issues of society and companies with academic studies.**

I. Introduction

The transformations that are taking place in modern society generate an additional challenge for education. The advent of the internet of things and industry 4.0 bring new paradigms that tend to affect the way of organizing several human activities, among them the production processes that are ruled by production and human work on a large scale in the production lines. These new paradigms indicate that the labor force employed in the productive processes will be drastically diminished in the coming decades, and that large amounts of autonomous services will emerge with the advent of the internet of things [1], [2]. Therefore, it is inevitable to think of how to prepare students for this new, oncoming reality, since these students will have to deal with a society where usual jobs will no longer be available, requiring them to be able to understand and relate different concepts and situations that can be characterized as complex.

The future employees would have several skills to deal with this new reality of industry and society, such as cognitive skills which comprises creativity and to work with complex problem-solving, system thinking and social skills. In social skills it is under consideration persuasion, emotional intelligence, teaching skills and active learning [3]. Active learning for World Economic Forum (WEF) [3] is ".. understanding the implications of new information for both current and future problem-solving and decision-making".

The same skills is expected by professionals that will work with Internet of things, including creative design abilities, collaboration, ethical issues and how the technology will contribute to business and also daily life of the community [2].

The professional of the future should be a lifelong learner, and such concept in forums about education means a creative person with critical thinking, good communication skills and able to solve complex problems [4]. The techniques used and discussed in education, such as blended learning, active learning, and peer tutoring, among others, seek to create an environment, according to [5] as: "learning activities that engage students in a continuous collaborative process of building and reshaping understanding as a natural consequence of their experiences [...] ". Schools are using active in all levels of education, and it also has relevant outcomes in Science, Technology, Engineering and Mathematics (STEM) courses and their subjects. Several report significant improvements in the outcomes obtained by students in these areas [6]. Simulations through software and laboratoty activities can be used for students to experience the concepts, as proposed in the active learning concept, and so they can reflect on the experience's results from their homes (online) without attending classes in the university's laboratories, or even in traditional lectures. The IoT subjects and available prototyping hardware and software has potential to engage students in STEM subjects, since IoT promotes an interdisciplinary context, give a context and purpose to students (since they may think about everyday situations), promotes collaboration and generate feedbacks [7]; important values from active learning and for the professional of the future. The active learning approach is under use by several institutions that identified the importance of active learning to develop a deeper understanding of topics and improve the information retention [7], [8].

This paper presents the initiative of two laboratories developed to prepare students in engineering and computer science to deal with the Internet of things and industry 4.0 subjects. The set of equipment and technologies available to students develop the learning activities are described, as well as their use in undergraduate and graduate student projects. These lab-

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oratories have been developed in partnership with companies: one of digital manufacturing and another of internet of things, and the integrated work of these laboratories approaches with the students the concepts of industry 4.0 or advanced manufacture. The medium- and long-term objectives of these initiatives are to establish the sequence of steps to be taken and to develop activities related to knowledge consolidation, necessary for the deployment of the Internet of things and industry 4.0. The laboratories are used both for undergraduate students to take classes and for company professionals who also work on research topics and solutions supported by the laboratories.

The collaborative environment between academia and companies [9], [10], as well as the joint work of two laboratories, allowed graduate students to develop discussions and works that integrate issues of society and companies with academic studies [11]. The results of this initiative are projects that could be deployed as new business, scientific initiations and master's dissertations that are being used in research, with publication of results in various congresses and specialized professionals forums and both undergraduate and graduate students dealing with innovative issues.

II. The IoT Laboratory

The innovation laboratory in IoT comes from a partnership between FEI and an international telecommunication company and is focused on the development of projects by undergraduate, graduate and "scientific initiation" students. The projects should be about IoT, applications, data analytic among others.

The laboratory is composed by two associate professor and master degree candidates and undergraduate students. The active learning techniques were used only with undergraduate students. The advisor professors of the laboratory gather a team of undergraduate students, which learned about topics as hardware prototyping, and programming using the problem based learning (PBL) technique. Each student received a challenge to study and purpose a solution, an advisor (a teacher from lab) to help student in order to find materials and help students with concepts and a tutor from the company that support student to develop a solution and to solve questions about technologies. The students that solved the challenges were invited to work in scientific initiations, and they start to study topics based on learning by teaching approach, i.e. the students that work in related projects teach to each other topics related to their research. This kind of work must have a set of experiments and the results are published in reports and sent to some conferences. In order to verify whether the learning approach was effective, all student work was submitted to peer evaluation. From nine students that work in scientific initiations, six had preliminary or final results. From that, six published posters in national scientific initiation symposium, one student was accepted to develop his work in partnership with an university abroad.

Other twenty-six students developed ten technical projects, mostly working in teams and using problem based learning approach. Each team of students had one advisor that helped them with research and development of prototypes, and the scientific initiation students also gave support to solve questions or using learning by teaching approach when requested by advisor, who was responsible to select a topic of study, organize the class when students would teach other and supervise the activity. The results where ten final examinations approvals by supervisory committees composed by professors from several universities and professionals from companies. Usually, about 20% of all technical projects are not approved by supervisory committees at first time and must be corrected and re-evaluated. In the case of the laboratory, eight of ten were evaluated as above the expectations; and one work was published in an important scientific conference and one also had a paper published in a periodic (all submitted papers were accepted).

One of the challenges to use learning by teaching and problem based learning is the differences of students' background, since the students that work on those projects do not study in the same undergraduate course. About 70% of the students are from Computer Science, and others are from Electronic Engineering, Automation Engineering, Mechanics Engineering and Textile Engineering. Instead of there is no numerical evaluation or statistics about the students behaviour or opinion, the obtained results of publications and supervisor committees suggest the learning by teaching and active learning approaches were effective. Working with students from several courses it was possible to work with several issues of one subject. Table I presents the relationship between issues and subjects that undergraduate students worked. Most topics were studied in a multidisciplinary way to reach the results.

III. The Digital Manufacturing Laboratory

Negotiations for implementing a DM laboratory at FEI have started in 2013. To reach this goal, some initial partnerships were considered with companies that have a solid experience in that subject. We had at that time two demands: to acquire the software licences of the DM package software tool, and to design an efficient approach for the laboratory, considering its utilization in several different levels.

This way, initially two companies established a partnership to support the laboratory. One of them is a DM software provider and the another is an automation company. The first one provided the access of 100 DM software licences which include Discrete Event System simulation, Robotics simulation, Virtual Comissioning, Ergonomy simulation, among other tools. The laboratory was launched in February, 2016, and the DM software licences donation were about US$ 2,000,000. There are 28 stations (Fig. 1) and a robotic cell (Fig. 2) in the laboratory. The second company, an automation company, participated to all the discussions, the design of the laboratory, providing its solid experience in the implementation. Moreover, it provided a digital project (Fig. 3) of a robotic cell as well as the donation of the robot and physical construction of the robotic cell.

One important contribution of these kind of laboratories is to support the small and median companies as proposed

TABLE I
SCIG PARAMETERS

Market Verticals	Agriculture and Water	Industry 4.0	Smart City & e-Healthy	Services
Research Topics				
Mobile Technologies / Infrastructure	Water quality measures	Communication Protocols	People monitor	Consumers' monitoring
Analytics	Evaluation of Soil	Manufacturing Cells	Geomorphological Models	Cars as sensors
Artificial Intelligence		Energy Management	Energy and water	Exploring human behaviour
Sensors	Integration and Monitoring	RF and Intelligent sensors	Monitoring landslides prone areas	Communication / Wearable
Security		Threats in manufacturing	People's Privacy	

in [12]. We have developed and finished a consulting for a small company of lifting platforms. The work involved undergraduate students and provided a process innovation in that company. It is an example as how enterprises can be aided from a solid partnership with educational institutions.

It is important to sign an agreement term to provide a solid partnership, as mentioned in [13]. We have at FEI an institute of research and innovation (IPEI) which has among others the role of attracting enterprises to FEI and also boundary the agreement terms.

Fig. 1. FEI Digital Manufacturing Laboratory (DML)

IV. INTEGRATION OF DML AND IOT LABORATORIES

After the establishment of the DML and IoT laboratories, in partnerships with enterprises, the next step is the collaboration between the laboratories. The aim is to have at FEI all the I4.0 concepts which is impossible without this integration.

A previous manufacturing laboratory at FEI (Fig. 4) was launched in the earlies of 2000 years and used didactic equipment. Over more than a decade several uses and teaching experiments were carried out there with outstanding achievements as described in [14] and [15].

Considering the integration itself, the I4.0 concepts consist in a very complex problem and encompass a lot of technologies and resources. Therefore the integration is considering

Fig. 2. Detail of the DML Robotic Cell

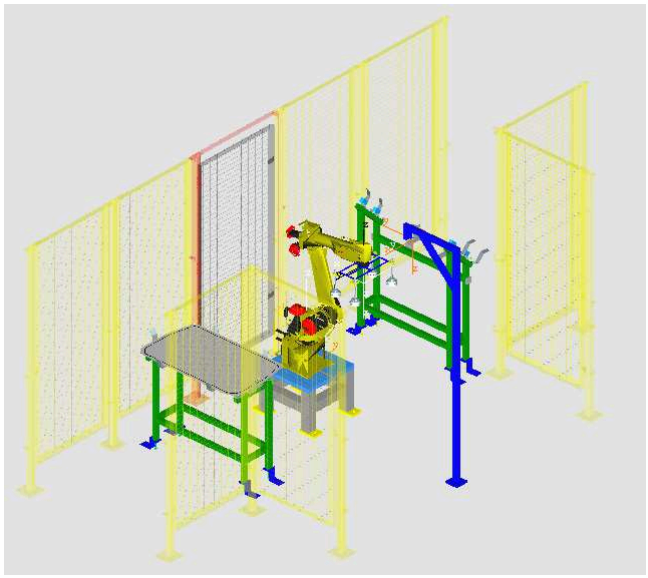

Fig. 3. Digital project of the Robotic Cell

some parts of the problem to be solved separately and afterwards the connection of them will be carried out. One of the problems related to I4.0 is the communication among the

machines and systems. To perform that several IoT sensors will be included in the old machines as well as new equipment and systems will be acquired. New industrial robots are coming to the laboratory in substitution of the old ones allowing the connection and communication with the existing LMD robotic cell. We still have several students working on this subjects. There are also students working on security, OPC-UA protocol, modelling and simulation of manufacturing systems and machine learning. We are also receiving a collaborative robot to explore and develop solutions in the advanced robotic subject.

A. The collaborative integration project

In 2016, an advanced manufacturing collaborative project was launched in Brazil by the Brazilian Association of the Machines and Equipment Industry (ABIMAQ). Now in its second edition, the advanced manufacturing demonstrator gather several industries (sometimes concurrent industries) and universities (like our institution) in a collaborative development environment.

It was an opportunity for involving both the IoT and DML technologies and personnel in a real complex project. In this way, the improvement of the laboratories should be accelerated. The project was useful also to involve graduate students providing an active learning environment for them.

The project approximate the educational institutions involved on it. The next steps are towards the interconnection of different laboratories in different institutions creating an exciting and productive base for researching and learning.

The IoT and I4.0 concepts and technologies are well known as complex. Therefore, it will impossible for one educational institution alone dominate all the subjects involved in. These educational institutions' collaboration should foster the fortification of the individual expertises of each of them.

Finally, the scientific initiation program at FEI provides an excellent opportunity to students developing academic research at initiation level. We have now two undergraduate students, supported by the scientific initiation program, studying and developing projects related to the laboratories subjects. The first subject conducted by the students is the multi-agent systems that covers the machine to machine (M2M) communication problem in I4.0. The second is the study of the OPC-UA protocol which has been established as the official I4.0 communication protocol.

V. Conclusion

The collaborative environment between academia and companies, as well as the joint work of two laboratories, allowed graduate students to develop discussions and works that integrate issues of society and companies with academic studies. The results of this initiative are projects that could be deployed as new business, scientific initiations and master's dissertations that are being used in research, with publication of results in various congresses and specialized professionals forums and both undergraduate and graduate students dealing with innovative issues.

Fig. 4. Integrated Manufacturing Laboratory

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