

# Implementation of a Teleoperated Didactic Manufacturing Cell through Internet2 as a Means of Engineering Education\*

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Not all students are able to use didactic manufacturing cells in order to experience real-life project development, owing to their cost and availability. Given the advances in communication media, such as the Internet2 network, which is designed for education purposes, it is easier for universities that have such manufacturing cells to share their resources. Under this premise, this paper presents the development and results of a case study involving a didactic teleoperated cell and the interaction between the ITESM in Mexico and the ESPE (Escuela Politécnica del Ejército) in Ecuador, through the Internet2 network. The universities have similar graduate programs for automated systems but only the ITESM (Instituto Tecnológico y de Estudios Superiores de Monterrey) has a full didactic manufacturing cell: a CNC, a transportation band and an automated storage system. For the aforementioned cell, the software that integrates all the control systems was developed by students of both universities and operated as a server for client software given to the students of the ESPE. Practices and surveys for the students were developed and applied in order to compare the knowledge acquired between the students using the cell directly and the students using the cell via the teleoperated cell. This kind of system helps universities to provide more advanced courses and the subject treated in this paper seeks to support the feasibility of telepresence systems as a mean of education.

**Keywords:** education; teleoperation; Internet2; Labview; manufacturing cell

## 1. Introduction

Manufacturing education has usually been limited to classrooms and laboratories; there have been improvements in didactic activities that allow the students learn topics using equipment or installations that are not usually available for them, such as simulations or learning scenarios. Approaching these scenarios is teleoperation, in which the students can obtain the knowledge gained in developing manufacturing projects using a manufacturing cell located in another place with the help of communication networks like the Internet2 network. With this technology, students at any campus or in any location can acquire skills on how to use and manage a manufacturing cell with automated systems. [1]

Internet2 is a powerful network designed for academic purposes known as the Next Generation Internet Initiative (NGII) [2]. Among the innovations to improve the Internet are fast fiber-optic networks, more efficient switches and routers using the new Internet Protocol version 6 (IPv6) to provide more Internet addresses and multicast technology that allows a user to disseminate data to multiple recipients simultaneously, thereby saving bandwidth for other data.

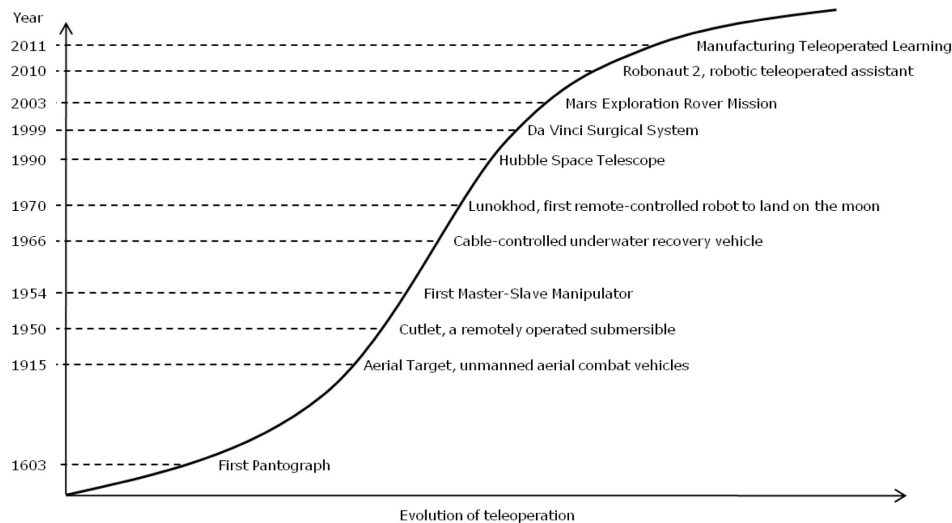
This paper describes the advantages of applying a learning system that uses teleoperation, which refers to remote control, as a support tool to link theory and practice. In addition, a methodology is described with the necessary steps so that other universities or companies can implement it and follow this type of educational method.

A case study is included in which the Escuela Politécnica del Ejército (ESPE) connects with a didactic manufacturing cell located in the Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM); this uses the well-known academic network Internet2 and compares learning using a manufacturing cell in person and by learning using teleoperation. As an objective, the student should be able to learn about the use and development of Manufacturing Execution Systems (MES).

## 2. Historical review

As the science fiction writer Robert Anson Heinlein presaged, there are many concepts that have become actual products; some of the most outstanding products related to the use of teleoperation are presented in the S curve (Fig. 1).

About 60 years ago, the term 'teleoperation' came



**Fig. 1.** Evolution of teleoperation use and implementation; it can be seen that remote control has reached several areas of knowledge.

into use for activities operated at distance. The patent of the first remote-control manipulator of Raymond Goertz [3] shows that remotely operated mechanisms have been used to access inhospitable environments.

In the 1980s, different applications for teleoperation appear as studies [4, 5] and real-life applications [6, 7]. Knowing the benefits of teleoperation, it was possible to reach the unexplored areas of the sea with remotely operated submersible, as well as other planets with Mars Exploration Rover Missions.

Academics started looking for new areas of opportunity for teleoperation; an example of this is remote education in subjects such as physics [11] and engineering [12]. Later they began to produce more elaborate schemes using academic networks, such as that of Colombia [13], where teleoperation was used so that students learned manufacturing techniques such as milling and turning.

Owing to the creation of new applications that demand more bandwidth, security, better quality for the arrival of information, and the need of real time communication, among other requirements, it was necessary to develop a new network, this new technology was called Internet2. This project, initiated in October 1998, started with 34 EU universities sharing applications that did not have adequate performance on the commercial Internet. Examples of these applications are: virtual laboratories, remote laboratories, remote education, digital libraries, real time and complex calculations, remote medicine and artistic creations, among others [14]. Internet2 is managed by UCADI (University Corporation Advanced Internet Development) and directed by university members who work along with collaborators [15].

Table 1 gives a classification of papers with significant contribution to these fields, in order to give a complete overview of the literature that inspired this work and gave the basis for this research. From this simple analysis where other publications with similar topics are shown, it can be deduced that even though there are similar elements and developments there is no full implementation and analytical information regarding the knowledge obtained by the students. There is sufficient statistical analysis obtained from the test results, where the impact that this type of effort to approaching resources to enable better learning in different geographic areas was corroborated.

In addition, there are great economic advantages as mentioned in diverse publications [26], the requirements needed to implement a teleoperated laboratory are less than for a complete manufacturing cell. This shows the importance of developing this type of low cost application that brings a new method of education.

### 3. Infrastructure and equipment

The laboratory installed at ITESM consists of two identical cells equipped with a one loop conveyor belt, one robot (Motoman UP6), one ASRS (automatic storage retrieval system) installed in a warehouse of  $2 \times 12$  storage slots, a CNC machine (EMCO PC MILL 155), and an assembly table for each cell. The conveyors have three docking stations: robot, inspection and storage station. There are two motorized cameras, one on top of the manufacturing cell and one inside the CNC machine. A photograph of this manufacturing cell with all the equipment is shown in Fig. 2.

**Table 1.** Citation of papers with the same topics

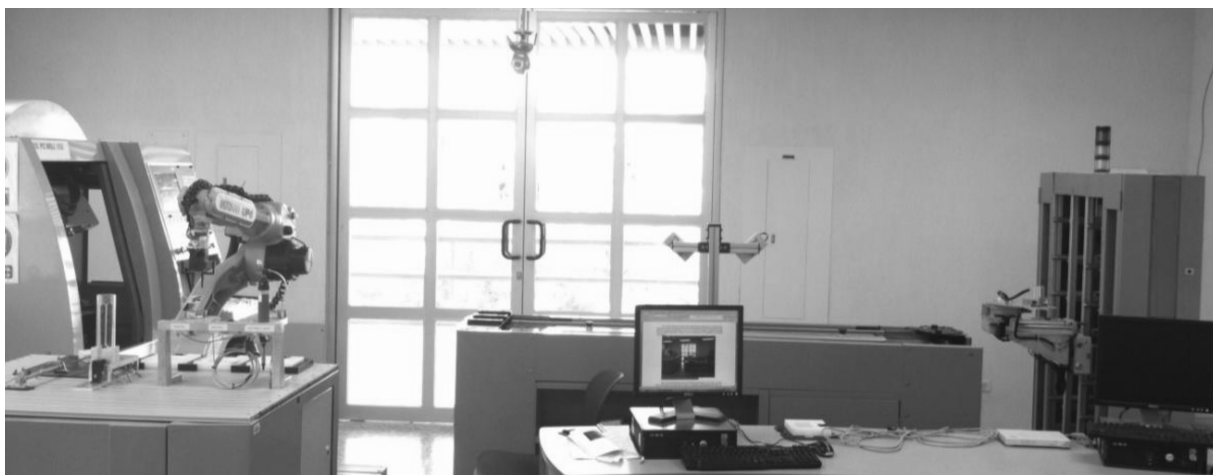
	Place/Year	Subject			
		Edu	Tel	I2	MC
Web based learning for engineering education [12]	Kingdom of Saudi Arabia/2004	*	*		
Comprehensive collaborative web-based experimentation: integration of teleoperation and simulation for supporting active learning in higher education [16]	Spain, Switzerland/2004	*	*		
On-line laboratories for undergraduate distance engineering students [17]	United States/2004	*	*		
Internet based manufacturing technology: intelligent remote teleoperation [18]	United States/2000		*		
Laboratory tools for robotics and automation education [19]	Italy/2003	*	*		
Control and robotics remote laboratory for engineering education [20]	Slovenia/2005	*	*		
Teleoperation in the undergraduate physics laboratory—teaching an old dog new tricks [11]	United States/1999	*	*		
Teleoperation of a mobile robot through the Internet [21]	Brazil/2000	*	*		
Requirements for real-time laboratory experimentation over the Internet [22]	United States/1999	*			
Teleoperación de robots: técnicas, aplicaciones, entorno sensorial y teleoperación inteligente [23]	Spain/2004		*		
Interconexión y supervisión por medio de Internet de una celda de manufactura flexible [24]	Colombia/2007		*	*	*
Teleoperation of a manufacturing system for vocational education [25]	China /2000	*	*		*

Edu = Education, Tel = Teleoperation, I2 = Internet2, MC = Manufacturing

This cell is used by students on the mechatronics engineering bachelor Automation of Manufacturing Systems course, so the theory seen in class is complemented by the didactic manufacturing cell. On the other hand, in the ESPE, Quito, Ecuador a course with the same objectives, named Flexible Manufacturing Systems, is taught. Nevertheless, this educational institution is not properly equipped to meld the theory with practice. This is why it was decided to execute the teleoperation between these

two universities. It is important to mention that both universities use a system of qualification based on 0–100 points, where the pass mark is 70 points.

A student group taking the mechatronic projects course at the ITESM began the development of the control of the manufacturing cell. The group was made up of: Carina Viteri (ESPE), Oscar Salas (ITESM) and Baltazar Carranza (ITESM); the course was under the tuition of Dr. Miguel Ramírez y MsC. Mauricio Hincapié



**Fig. 2.** ITESM Manufacturing Cell, Mexico. From left to right: CNC machine (EMCO PC MILL 155), robot arm (Motoman UP6), loop conveyor belt, automated storage system.

## 4. Methodology

The methodology for the development of this research can be divided into six phases (Table 2).

### 4.1 Phase 1: Establish a bond with the counterpart and decide on the subject that is going to be the focus

Both universities, host and guest, need to have the proper connection and elements in place to assure that the experiment is carried out well. The host university has to provide an instructor and a fully operational teleoperated manufacturing cell through Internet2 broadband connection, while the guest university has to provide its students with a computer connected through Internet2.

The chosen subject must have a positive impact on the students and must significantly improve their learning experience, so the project has the best impact on their education and will subsequently improve their performance in industry. Another important factor in the decision is that the user must have some previous knowledge, so that when a problem arises during the implementation of the project, the student will be able solve it, while understanding where the problem originates. The last and more important point is that the chosen experiment must be able to be realized with the teleoperated cell.

### 4.2 Phase 2: Establish the necessary tools

As mentioned before, the ITESM has a manufacturing cell so, in the first phase, professor Miguel Ramirez of the ITESM contacted students and professors from the ESPE, as this university is not equipped with a manufacturing cell. In this specific case it was decided to use the Manufacturing Execution Systems (MES) implementation, because it can

be explained with the manufacturing cell and its control in real time.

As is shown in Fig. 3, students will use only a Human–Machine Interface (HMI) to control the manufacturing cell and cameras to watch how the environment changes with their input. But behind the HMI is the interaction between the two local networks connected through Internet2, handling the data, audio and video to control the elements of the manufacturing cell. The ITESM's standard Didactic Cell of Advanced Manufacturing comprises five elements: robot arm (Motoman UP6), CNC milling machine (EMCO), transportation band and the automated storage system. This cell is used by the ITESM to teach the students how to design automation projects and show them the importance of integration by real-life experience. Each one of the elements has a PLC, which is connected in the same network to a 3M router, and each one of them is configured using RSLogix and controlled by the OPC protocol; this will be explained later.

The required software to execute the client is the Labview Run-time and the Remote Live Viewer that comes in the D-ViewCam package. There are two ways to mount the client computer or computers: using two computers with minimum requirements or one computer that can be attached to monitors, since both applications, teleoperation client and visualization client, require the whole screen in order to display all the indicators and a good detailed image.

It was decided to use the academic network known as Internet 2, to avoid other delays during the teleoperation. Abilene is the high speed network that supports Internet2, whose connections go from the 2.4 to the 9.6 Gbps. These connections are linked by regional points called GigaPoPs (Points Of Presence), where the universities access this net-

**Table 2.** Methodology of the experiment

<p><i>Phase 1:</i> Establish the bond with the counterpart and decide the subject that is going to be focused on</p>	<ul style="list-style-type: none"> <li>• What is lacking that needs to be resolved fastest?</li> <li>• Who has this shortage in equipment needed to support their education?</li> <li>• On what course would the students benefit most by the application of teleoperation?</li> </ul>
<p><i>Phase 2:</i> Establish the necessary tools</p>	<ul style="list-style-type: none"> <li>• In terms of equipment and software, what tools are necessary to fulfill the requirements of the project?</li> </ul>
<p><i>Phase 3:</i> Application or interface development</p>	<ul style="list-style-type: none"> <li>• Which protocols does the software use?</li> <li>• Are there any special requirements such as licenses?</li> <li>• Which are the activities that the students will be able to realize in teleoperated form?</li> </ul>
<p><i>Phase 4:</i> Design of the tests and practices that will be developed</p>	<ul style="list-style-type: none"> <li>• Which are the specific subjects that the students will understand when developing this practice?</li> <li>• What steps must be followed to understand the subject that is to be developed?</li> <li>• What tests must be realized to know if the students understood the concepts?</li> </ul>
<p><i>Phase 5:</i> Study of the obtained feedback and determine the results</p>	<ul style="list-style-type: none"> <li>• What statistical calculations must be realized to understand the level of success of the experiment in the students?</li> </ul>

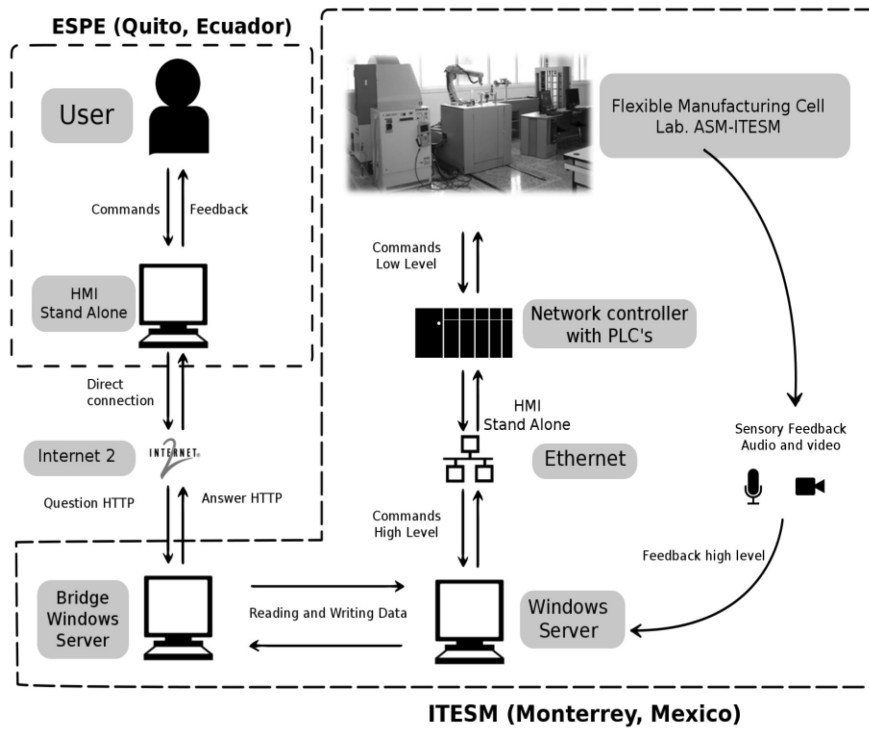


Fig. 3. Scheme of connectivity. This diagram shows the connections and information that travels through the system (adapted from [23]).

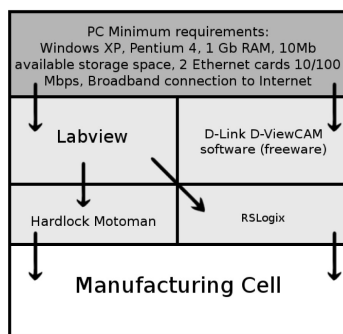


Fig. 4. Architecture of tools required for server. The server runs the control server software and the camera server.

work. Abilene constitutes the bridge to connect other networks with these capabilities such as the CUDI network in Mexico and the CLARA network in Latin America.

4.3 Phase 3: Development of the application or interface

The program used to develop the server is the software Labview, as previously stated. Labview can control the variables in PLCs using the OPC (OLE for Process Control) technology. To connect the server software to the Internet the TCP protocol was used.

There are programmed blocks for each element, each of them controls the PLC of each element in the

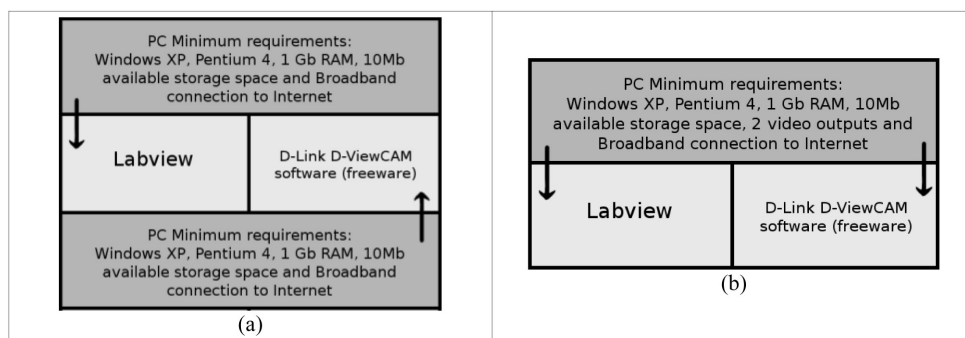
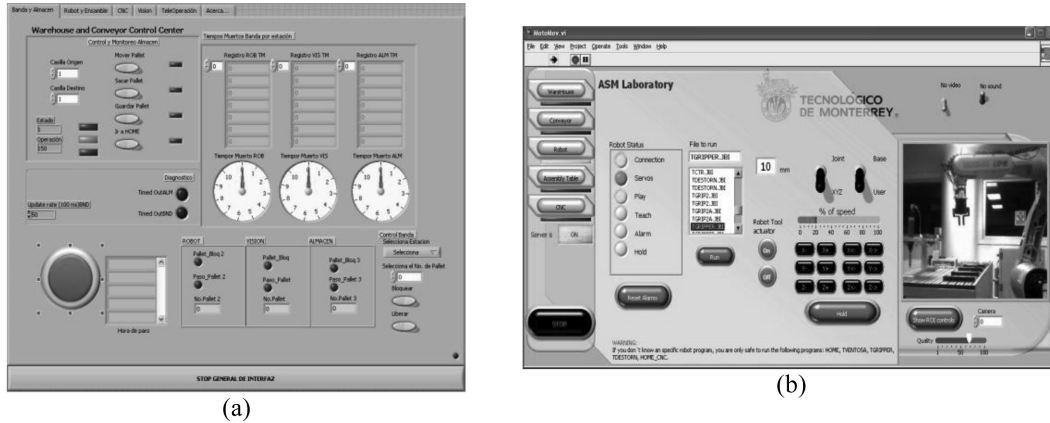


Fig. 5. Architecture of tools required for client. (a) Two computers setting running the control software and the camera software respectively. (b) This setting uses two monitors and one CPU to handle the control software and the camera software.



**Fig. 6.** (a) Server GUI, this software has digital displays and allows the instructor to control the access from the client. (b) Client GUI, in this version of the client the cameras streamed directly to the control client software.

didactic cell. The storage block, for example, is able to send the pallet number to the PLC and the command to execute, such as move and place (in band), the band vi reads and displays the pallets that are in the band while using the program. The robot control is the most complex program in the server; this part of the software requires several custom scripts and C programs to allow the HardLock given by the supplier.

All the programmed blocks are integrated in a program, one that will work as HMI and Server. As already stated, all the variables are clustered and send by a TCP setup inside the program. Since there are several variables and multiples programmed blocks, the program could get stuck in the main loop; therefore the programmed blocks are in independent loops that are only activated in the polling process.

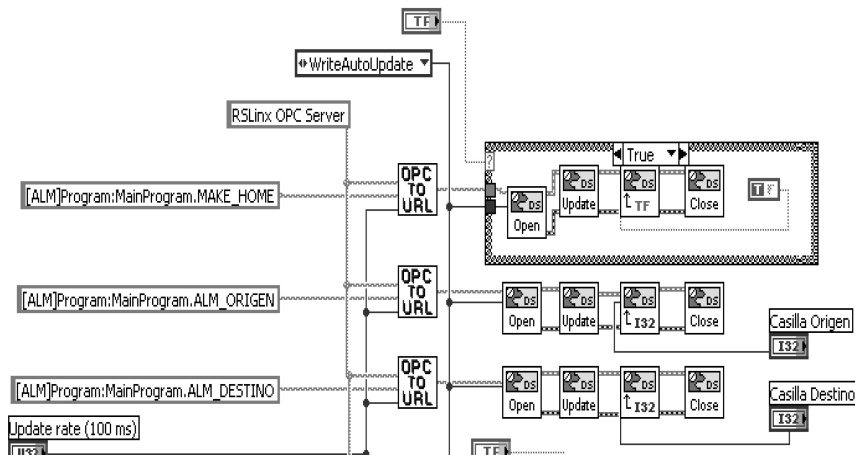
In the prototypes stages, the audio and video were integrated in the Labview program. While testing the prototype with the students, the software presented problems with the response speed; this was caused by the saturation of data in the HMI server,

especially with the video and sound data. The solution to this problem was to use the proprietary software that came with the cameras, as already stated. The camera was operated with its own interface (Fig. 8) to diminish the delays in the server. This also improved the experience of the students, since they could look at a larger display and see the actions of the manufacturing cell in more detail.

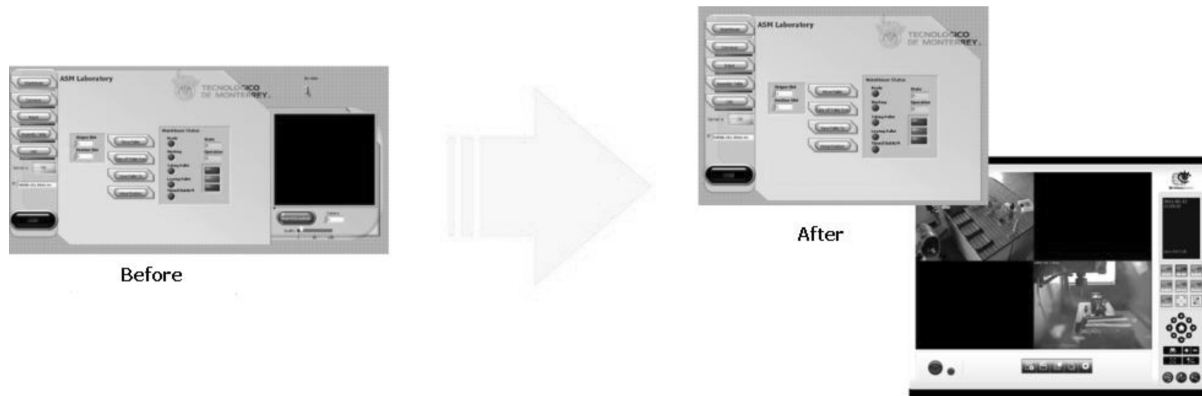
The other problems that the software presented was that some commands were applied several times if the client kept the command button pressed, normally known as bounce, and this generated a lag between server and client. These problems were caused because neither the client nor the server had a buffer to store the commands and deliver them in order.

*4.4 Phase 4: Design of the tests and practices that will be developed*

As it is necessary to analyze the progress of the students in a course that involves the MES as a base, the objectives for such course are: identify, operate, program the components of the flexible manufac-



**Fig. 7.** OPC connection block for this implementation. This shows the handshake process.



**Fig. 8.** Changes in client's interfaces. The video stream caused a huge load on the control software, since it could not handle the streams easily; this was removed in the second version and handled by the proprietary software.

turing systems and design processes that involve the use of manufacturing cells. These objectives are complemented by the teleoperation, where the students will use the interface designed to control the manufacturing cell to perform a test and run it in the CNC vertical milling center with their own code, which should be written previous to the experiments in order to receive feedback.

To develop the experiments' manual, a comparison of each MES course from the ITESM and the ESPE was made. With the information obtained, two practices were designed:

- Practice 1: Identification of the components of the Flexible Manufacturing System and basic programming, milling in a CNC machine.
- Practice 2: Identification of the components of an industrial robot, operation and programming of a transport line and an automatic warehouse.

Finally, sixteen students from the ESPE assisted in carrying out the experiment. The dynamics of the experiment are described in the following steps:

1. The student should read the theory for the experiment that is provided beforehand.
2. The students take a quiz about the theory.
3. The instructors give a brief explanation of the procedures.
4. The students develop the experiment.
5. The students take another exam regarding the experiment.

#### 4.5 Phase 5: Study of the obtained feedback and determine the results

As can be appreciated from other papers [1], a feedback survey must be carried out, since the impact of the teleoperation over the theory learned has to be measured; it is recommended that methods that include all the aspects or variables are used to obtain precise results. With this survey the quanti-

tative part of the analysis can be filled in while the qualitative part could be obtained from interviews with the students

From the interviews the instructors could find the students' opinions and could take them into account to improve the practices. Each question matches a designated variable to analyze the project from the point of view of student satisfaction.

- Question 1: Project's viability
- Question 2: Qualification of project's viability
- Question 3: Theoretical knowledge application
- Question 4: Teachers (4.1 ITESM and 4.2 ESPE)
- Question 5: Acquired knowledge
- Question 6: Facilities and material
- Question 7: Institutional project support

For this part of the study, an analysis was generated by the crossed variable method in the satisfaction survey. Because the questions are linked to each other, we can obtain a congruent answer about Y/N questions and the qualification of the same. For these analyses the program SPSS was used. Some examples of the results obtained are given in Figs 9 and 10.

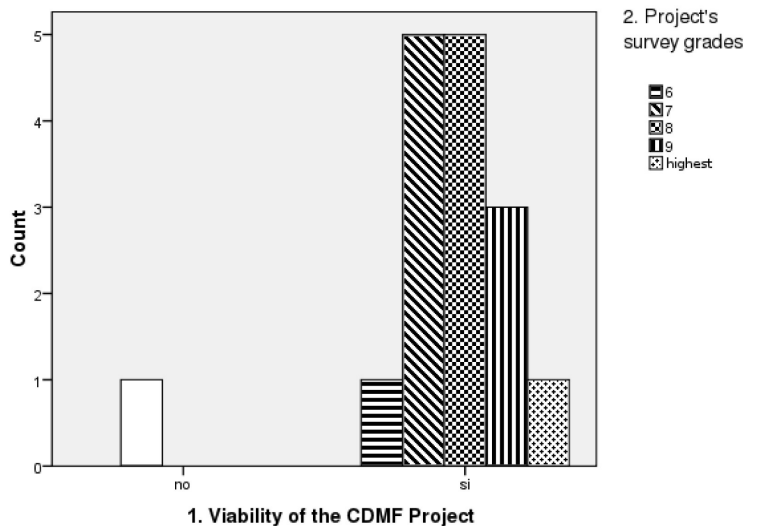
In Fig. 9, the results of the questions are observed and analyzed to ascertain if the project is viable and its level of viability is observed. Although a negative answer was obtained, most of the students replied affirmatively but at different levels. Therefore, it is possible to say that even though the survey did not show a unanimous agreement on the potential of the project, it still had a high acceptance.

Figure 10 shows whether the students actually applied the theoretical knowledge gained from their regular classes. According to the results obtained, all the surveyed students managed to put their theoretical knowledge into practice. The grades obtained by the students start at 6, with grades going on to 9 and 10, which indicates a good

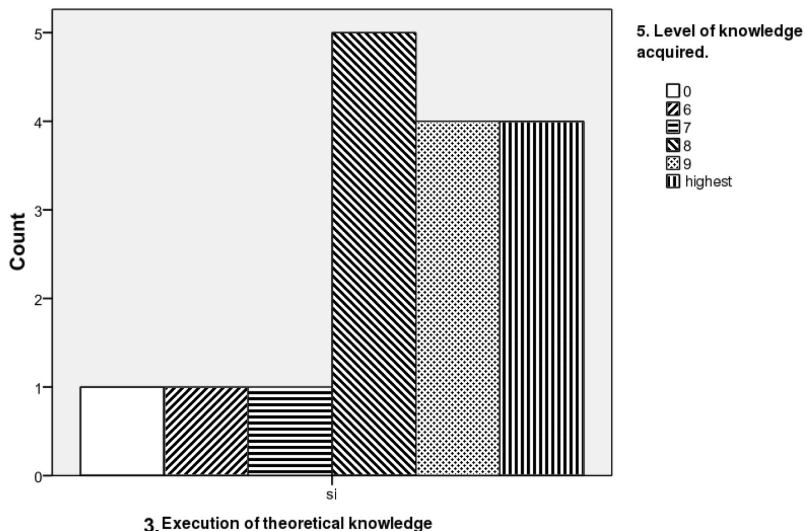
absorption of information, showing the effectiveness of the experiment as an education tool.

Analyzing the grades, a results table is obtained (Table 3) from which it can be seen that the students

get satisfactory evaluations. As mentioned above, the grades have a range 0–100 and an average grade of 89 is good enough to prove the positive effects of the project. Lower scores are presented in the oral



**Fig. 9.** Project’s viability, it shows the acceptance by the students and how they perceive the benefits of the software.



**Fig. 10.** Results of the survey showing the relationship between the theory and the teleoperated practice.

**Table 3.** Qualifications results

Qualifications	Value	Average	Mode	Standard deviation	Kurtosis
Pre-report	/10	9.5	10	1.032	3.209
Oral quiz	/10	7.875	10	2.125	-0.728
Final exam practice 1	/20	14.375	14	2.655	1.259
Final exam practice 2	/20	18.375	18	1.087	0.555
Report practice 1	/20	19.5	19	0.564	-2.308
Report practice 2	/20	19.75	20	0.683	4.839
Total	/100	89.375	92	4.964	0.235



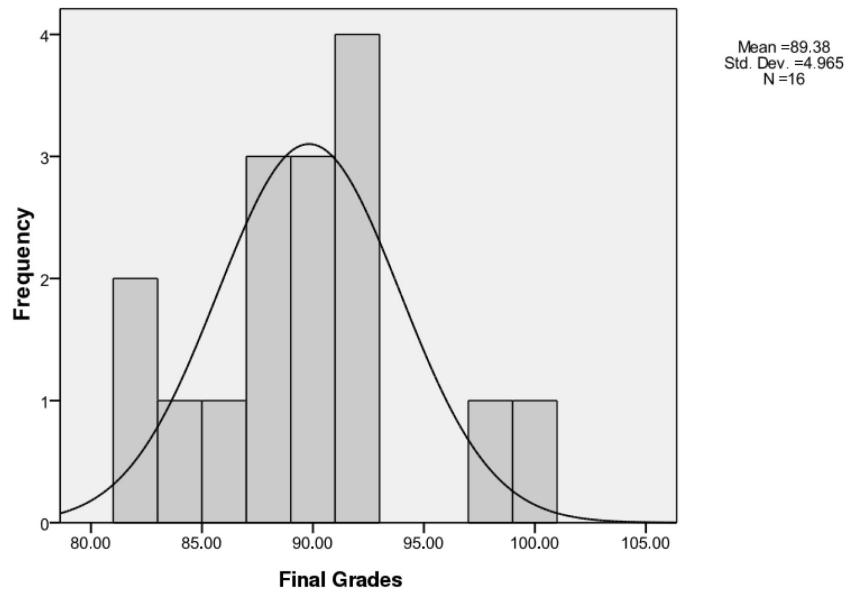


Fig. 11. Distribution of grades. These are grades that the students obtained in the knowledge tests.

quiz and the final exam for the first experiment but these grades are still acceptable to the project. The data obtained from the oral quiz are relevant even if the kurtosis (the measure that represents the level of concentration that the values have in the distribution's central region) shows a negative number, which means a low concentration of the values. It is very prudent to make this type of examination of a student's knowledge prior to the experiments so that the students are aware of the extent of the experiment.

The kurtosis of the total score shows that the values are greatly concentrated in the central value in spite of some grade components. Figure 11 shows a histogram for a better appreciation of the grades by frequency. As can be seen, all the students approved with a minimum score of 82 and a maximum of 100. It is possible to see that the values in the table are near the highest note.

## 5. Conclusions

This kind of project attempts to develop the abilities of the students who may not have access to the necessary equipment, bearing in mind that the remote learning environment is not intended to replace the conventional classroom; instead, it is designed to enhance out-of-classroom learning. The more this technology spreads, the more empiric knowledge will spread.

This paper demonstrates the flexibility of an automated system and how one has only to apply adequate concepts and applications to implement a

full teleoperation. On the other hand, any university, especially those without automation laboratories, could easily benefit from a teleoperated cell connecting it with practically any computer that has a proper connection to the Internet. It may not be as stimulating as the real experience but the students can familiarize themselves with the systems involved. In industry, the engineers would be able to learn how to monitor and control automated systems in order to improve them or modify them as needed.

Finally, this particular project shows the feasibility of the application of a teleoperated manufacturing cell as an educational tool; this was demonstrated with the results of the grades and surveys obtained from the students participating in this project. These students showed excitement and interest in this new method of learning as they were able to try concepts that until then were just only theoretical concepts without any real experience to back them. It can be said that all the students were able to implement at least one of the concepts learned in class, such as manufacturing timing and G-code optimization. Using Internet2 for communication helped the instructors from Monterrey give feedback to the students in Ecuador and vice versa in real time, all of this without losing control of the teleoperated cell and with minimum lag in the shared data.

*Acknowledgments*—The research presented in this document is a contribution for the Development Product for Emerging Markets Chair, Registration No. CAT121. The authors wish to acknowledge the support of the Tecnológico de Monterrey, Campus Monterrey.

## References

1. F. Tsang, The quality of telepresence teaching and learning, *C RoC*, April 2007, pp. 1–6.
2. F. Yeung, Internet 2: Scaling up the backbone for R&D, *IEEE Internet Computing*, March-April 1997, pp. 36–37.
3. R. Goertz, Remote-control manipulator. United State Patent Office. Atomic Energy. 2632574. 1953, March 24.
4. B. Hannaford and R. Anderson, Experimental and simulation studies of hard contact in force reflecting teleoperation, *IEEE International Conference on Robotics and Automation*, Philadelphia, PA, April 1988, 06 August 2002, pp. 584–589.
5. F. Miyazaki, S. Matsubayashi, T. Yoshimi and S. Arimoto, A new control methodology toward advanced teleoperation of master–slave robot systems, *IEEE International Conference on Robotics and Automation*, San Francisco, CA, April 1986, 06 January 2003, pp. 997–1002.
6. G. Clement, R. Fournier, P. Gravez and J. Morillon, Computer aided teleoperation: from arm to vehicle control, *IEEE International Conference on Robotics and Automation*, Philadelphia, PA, April 1988, 06 August 2002, pp. 590–592.
7. C. Fong, R. Dotson and A. Bejczy, Distributed microcomputer control system for advanced teleoperation, *IEEE International Conference on Robotics and Automation*, San Francisco, CA, April 1986, 06 January 2003, pp. 987–995.
8. K. Golberg, M. Mascha, S. Gentner, N. Rothenberg, C. Sutter and J. Wiegley, Desktop teleoperation via the World Wide Web, *IEEE International Conference on Robotics and Automation*, May 1995, 6 August 2002, pp. 654–659.
9. E. Paulos and J. Canny, Delivering real reality to the World Wide Web via telerobotics, *IEEE International Conference on Robotics and Automation*, April 1996, 6 August 2002, pp. 1694–1699.
10. The Telelabs Project, <http://telerobot.mech.uwa.edu.au/>, accessed 27 March 2011.
11. C.L. Enloe, W.A. Pakula, G.A. Finney and R.K. Haaland, Teleoperation in the undergraduate physics laboratory, *IEEE Transactions on Education*, **42**(3), 1999, pp. 174–179.
12. F. Abdessemed, Web based learning for engineering education, Al Jouf University. Al Jouf, Kingdom of Saudi Arabia, 2009.
13. J. Duque, J. Corredor, M. Perez, M. Mesa, D. Amaya, F. Camargo, E. Córdoba, P. Figueroa, J. D. Cardona, M. Ramírez and F. de la Rosa, Accesibilidad a las celdas de manufactura flexible automatizadas a través de la red nacional renata y la red internacional red clara para supervisar y controlar su estado y funcionamiento, *Ciencia, educación, innovación y cultura apoyadas por Redes de Tecnología Avanzada*, **1**(1), 2011.
14. L. Velázquez, G. Lucet and H. Reyes, Internet2, U.N.A.M., 2004, <http://www.enterate.unam.mx/Articulos/2004/noviembre/internet2.htm>, accessed 9 October 2008.
15. J. Carrera, Análisis de la calidad del servicio de video sobre Internet2, Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Monterrey, Monterrey, N.L., August 2003.
16. F. Esquembre, C. Salzmann, D. Gillet, Y. Rekik and S. Dormido, Comprehensive collaborative web-based experimentation: integration of teleoperation and simulation for supporting active learning in higher education, *Computing in Science & Engineering*, 2007.
17. J. L. Watson, G. Bibel, K. Ebeling, J. Erjavec, H. Salehfar and M. Zahui, On-line laboratories for undergraduate distance engineering students, *Frontiers in Education*, **1**(3), 2004, pp. 1–6.
18. K. Brady and T. J. Tarn, Internet based manufacturing technology: intelligent remote teleoperation, *IEEE/RSJ International Conference on Intelligent Robots and Systems*, Takamatsu, Japan, 31 October 2000, 06 August 2002, vol. 2, pp. 843–848.
19. C. Cosma, M. Confente, D. Botturi and P. Fiorini, Laboratory tools for robotics and automation education, *IEEE International Conference on Robotics and Automation*, Taipei, Taiwan, 14 Sept. 2003, 10 November 2003, vol. 3, pp. 3303–3308.
20. R. Šafaric, M. Truntic, D. Hercog and G. Pacnik, Control and robotics remote laboratory for engineering education, *International Journal of Online Engineering (iJOE)*, **1**(1), 2005.
21. R. L. Alves, R. F. Vassallo, E. O. Freire and T. F. Bastos-Filho, Teleoperation of a mobile robot through the Internet, *IEEE Midwest Symposium on Circuits and Systems*, Lansing, MI, 2000, 06 August 2002, vol.2, pp. 930–933.
22. J. Overstreet and A. Tzes, Requirements for real-time laboratory experimentation over the Internet, *American Control Conference*, Brooklyn, NY, 1999, 4 Jun 1999, vol. 2, pp. 1472–1476.
23. N. Ortega, E. Basañez, L. Villaluenga, Teleoperación de robots: técnicas, aplicaciones, entorno sensorial y teleoperación inteligente, Universitat Politècnica de Catalunya, Catalunya, Spain, April 2004.
24. J. A. Corredor and E. Córdoba Nieto, Interconexión y supervisión por medio de internet de una celda de manufactura flexible, *8th Congreso Iberoamericano de Ingeniería Mecánica*, Cusco, Peru, October 2007.
25. F. H. F. Tsang and J. K. F. Lee, Tele-operation of a manufacturing system for vocational education, *IVETA International Conference*, Hong Kong, China, 9 August 2000.
26. M. E. Macías and I. Méndez, eLab—Remote electronics lab in real time. *Electrical and Computing Engineering, ASEE/IEEE Frontiers in Education Conference*, Milwaukee, WI, October 2007, 04 January 2008, pp. 12–17.

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