A Joint Learning Activity in PROCESS CONTROL AND DISTANCE COLLABORATION Between Future Engineers and Technicians

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Recently available industrial automation technologies offer many interesting possibilities, including the operation of production systems from a distance, access to real-time process and plant data, live video feeds from the plant, etc. Such technologies are often involved in distance troubleshooting by service and equipment providers, to reduce the need (and thus the costs) for personnel traveling. Some companies also integrate similar tools into their higher management structure as an almost real-time feed of plant performance and production.[1] For future graduates to successfully integrate this reality, their education has to be adequate and kept up-to-date with these technologies.

This project was realized with the participation of Premier Tech, a world leader in the field of bagging equipment for different types of products. Their experience with distance collaboration between teams for the installation and troubleshooting of various types of equipment was an important added value to this project. A joint collaboration between a university (engineering students) and a college (technical-level students) was elaborated to also add a dimension of integrating people from different disciplines and backgrounds to work toward a common goal: The ability to communicate and interact effectively with other professionals is an important skill for graduates,[2-4] and it is not often acquired during the education stage. This project is a response to those needs, at least in the field of industrial automation and process control.

Most of the work involving remote (or in some cases, virtual) systems is in the context of distance education. Methodologies for preparing and building such laboratory

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activities can be found in References 5 and 6. Interesting examples from various engineering disciplines can be found in References 7-9. Collaboration between students or with a professor in this context is sometimes possible (*e.g.*, References 8, 10, and 11), although it is rarely a requisite of the activity. A form of built-in student interaction activity close to our own was found in Reference 12, where students from two distant universities joined forces in a long-term product-development project. Another interesting paper is Reference 13, where very similar planning to our own was done for a distance controls experiment and interaction between college and engineering students (with technology from more than 10 years ago), but the experiment was never fully conducted with the students, thus no results nor feedback from students were provided. The uniqueness of our work lies in the following: a more complete focus is placed on the software involved in an industrial setup (both the controller programming and the user interface software), with a more concrete collaboration between the distant teams (one engineering student team and one engineering-technology student team) on the software programming and the control design and tuning tasks throughout the activity. Both teams work toward a common goal in process control and system automation using the most recent cutting-edge industrial automation technologies and real-time remote plant access, sharing their different knowledge on the subject throughout the four-week duration of the activity.

The paper is organized as follows: first, the general network and software environment for supporting the activities is presented. The physical setup used is then presented, along with the activities it supported. Feedback and appreciation from the students and faculty are then finally presented, before the concluding remarks.

NETWORKING ENVIRONMENT

As part of the activities, two types of interaction were planned: "people-to-people" and "people-to-equipment." Such events are to be allowed both locally and remotely, at each site. People-to-people interactions, depending on the stage of the activities, need to be allowed either in real-time (synchronous) mode or off-line (asynchronous) mode. People-to-equipment interactions necessarily occur in real-time, through industrial hardware and software. For all such events to occur efficiently, a suitable networking environment had to be deployed and properly configured.

At the university, students have access to a computer, a large videoconference screen, a web cam, a microphone, speakers, and an Internet connection. Whereas the college students, on their part, work in close proximity to the physical industrial setup, and have access to a laptop computer with all the same commodities, and their Internet connection is wireless. Real-time people-to-people interactions were realized through use of Skype software. For the asynchronous people-to-people communications, an e-mail alias was created for each student team (both at the university and the college), which also included the teaching staff e-mails to help them keep track of the communications.

Remote access to the automation equipment was realized through a VPN (Virtual Private Network) bridge over the Internet, linking the LANs (Local Area Networks) of the two institutions. Access is granted through use of a valid username and password. This secure connection allows communications to remain hidden from third-party interventions. The programming of the industrial controllers (Allen-Bradley CompactLogix L32E model) is realized with the RSLogix5000 proprietary software, from either location. Monitoring of the systems was also possible from both locations, using either FactoryTalk (from Allen-Bradley) or InTouch (from WonderWare) HMI (Human-Machine Interface) software. IP cameras were also installed in dedicated locations to allow real-time visualization of each individual workstation of the physical system, and another providing a global view of the installations. These video streams are accessible via any common web browser, protected again by a secure login procedure.

Fast response times and high data throughput are required in automation applications. For this reason, STRATIX 8000 switches have been installed at the core of both Ethernet-IP networks. These switches are specifically designed for handling the data traffic between different sections of an automated plant and network access points. Sustained availability of the Ethernet-IP network is crucial for the adequate operation of the automated system. Special care was taken at the moment of installation to minimize the risk of interference with electromagnetic noise or perturbations throughout the local networks. A simplified general view of the networking environment between and at both sites is shown in Figure 1.

ACTIVITY DESCRIPTION

This section will go into further detail about the physical setup and the activities it allows. In the end, the objective is to deliver a fully functional automated system for use by a hypothetical client, in the context of a distant collaboration between two teams from a same service provider (*e.g.*, an installation team and a system development team).

The Physical Setup

The physical equipment available at the college is an educational setup manufactured by the Lab-Volt® company (Instrumentation and Process Control Training System, # 3531). Two such complete training systems are available, each comprising two independent workstations, thus accommodating a maximum of four student teams. Each system features a large common stocking tank, usually filled with water, which serves both workstations. Each of the latter comprises a variable-speed motor-driven pump, a control valve (pneumatic, with choice of "air-to-close" or "air-to-

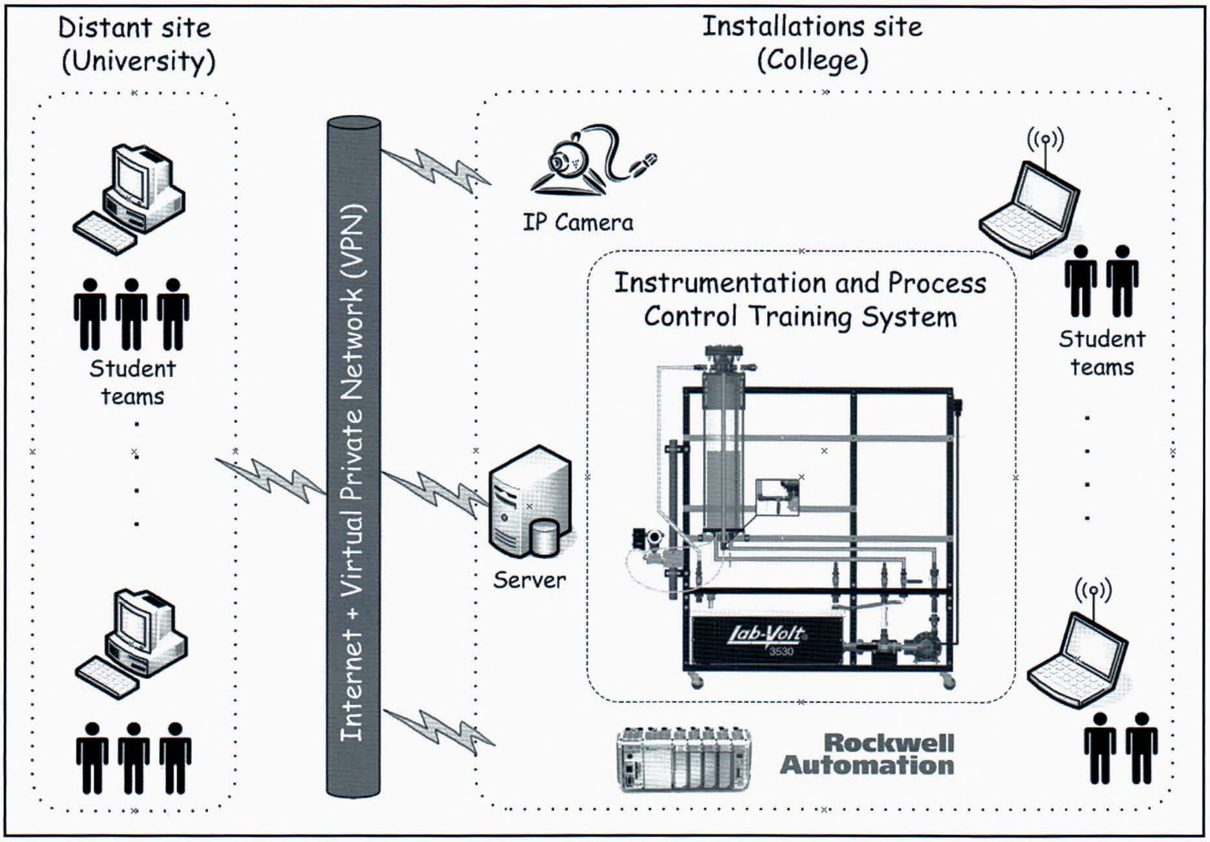

Figure 1. *Overview of the networking environment.*

open" configuration), two tanks of different dimensions (both cylindrical, of either small or larger diameter), level sensors (ultrasonic or capacitance measurement technologies) and flow meters (either ultrasonic or magnetic technologies). Such a setup allows coverage of many aspects of process control engineering, including familiarization with a good variety of sensor and actuator technologies, their calibration and location, and the study of various loop configurations. All controllers are of the Allen-Bradley family, CompactLogix L32E processors with various I/O cards.

Learning Situations

The focus of both courses (at the university and the college) is limited to single input-single output (SISO) situations. A different setup is considered for each student team to limit the risk of plagiarism, and to allow a wider exploration of the system possibilities. In general, all four workstations are used, and the loop configurations include: the control of the level in either (large or smaller) tank or the control of a flow stream, while varying the sensor technology and the actuator configuration. Student teams from each institution are paired to work together on their given situation over a period of four weeks. Technician students play the role of the installation team (being on-site), and the engineering students play the role of the product development team (*e.g.*, system designers). The task of the teams is to deliver a fully functional automated system for a hypothetical client.

The necessary steps include the development of the control programs (for the controller and the user interface), so a general end-user will be able to use it. Compatibility between the two programs has to be ensured throughout the development phase (which involves asynchronous collaboration between the distant student teams), and its effective behavior on the real system has to be validated in practical experiments (synchronous collaboration events). At this stage, the system dynamics have to be understood and quantified, and the tuning of the controller (PID type) has to be realized. Students are invited to implement their different tuning methods and compare their results, as the university and the technology students have different approaches. Finally, the control performances have to be assessed and validated over the entire range of operation of the system. After satisfactory results are obtained, the system is considered to be end-delivered.

At the beginning of the project, university students are taken to the college to visit the installations and meet their co-workers for the activity. They are introduced to the basic procedures for operating the system (start-stop sequences, safety issues, and protections, etc.) and have the actual opportunity to view it running. Specifications are handed out to the teams, and they can start discussing automation issues (number of variables, names to be used, conventions, necessary tags, etc.) to ensure the compatibility of their programs.

They then separate to realize the work (university students have the responsibility of the controller program, while college students are responsible for the user interface) over the first two weeks. They may communicate asynchronously during this period by using their assigned e-mail group alias, as needed, to further discuss different issues.

In week #3, a first (synchronous) interaction session takes place between the two distant teams. A first implementation of the two programs, a potential debugging phase plus the gathering of system response data at different operating points (for system identification), should be realized by the end of this session. During the following week, and before the next interaction session, engineering teams have to analyze the data and determine proper controller (PID) tuning. The last interaction session (week #4) consists of implementing this solution (with potential modifications) and validating the control performances over the system's entire range of operation. A final troubleshooting phase of the programs may also take place in this session, after which the system has to be end-delivered, fully functional.

The activity took place during the third month of a four-month semester course, after the adequate preparation of the students with the automation tools used (L32E Allen-Bradley controllers, RSLogix5000 programming software, and "In-Touch" user interface software from WonderWare). Without such proper introduction, it is the belief of the authors that the activity could not have been conducted over such a "short" period, and that students might have been discouraged with an otherwise longer project.

ACTIVITY EVALUATION

The activity has been conducted twice at the time of this writing, and was evaluated on both occasions at the two institutions independently, by the students' point of view and the teaching teams' point of view. At the university, the evaluation with the students took two forms: a questionnaire and a general group discussion. At the college, only the group discussion took place. Each teaching team at each institution discussed its impressions before a meeting between the two teaching teams where they formed a common conclusion on the matter. These evaluations were realized each year the activity was held, and were used to improve specific aspects of the activity for the following year.

Feedback From Students

The questionnaire handed out to university students is summarized in Table 1. Table 2 (page 14) shows the survey results. The same questionnaire was used on each occasion, covering the communication and the automation tools, the quality of the relationship and communications with the other student team, and general appreciation of the activity. A four-level Likert scale was used for most questions while some more-specific questions offered only three choices. On both occasions (2009 and 2010), student attendance was 15 for the course, although only 14 out of 15 were able to attend the evaluation session the first year (all were present the second year).

Communication tools were considered either highly appropriate (~70%) or somewhat appropriate (~30%) for the activity, and very user-friendly (~40%) or somewhat user-friendly (~60%) in both occasions. Most student had never used Skype before, and active student participation in communications increased from 64% to 80% between the two years. Quality of communications was best perceived the second year, as 53% vs. 29% considered there was no problem at all (or only very minor ones) at the technical level. None of the students were experts in network technologies. All students (but one, the second year) considered controller programming as highly or somewhat important to learn in an engineering curriculum. Programming a user interface was, however, considered less essential, as 20% in each year even felt it was not important.

Quality of the interactions with college student teams has increased over the years as 73% felt it was excellent the second year (vs. 57% the first year). This could be explained by the fact that a physical encounter between all students at the beginning of the project only took place the second year, and helped improve camaraderie. After the activity, the students felt they had achieved a high (~10%) or sufficient (~80%) level of competence on controller programming (similar each year). Students felt less competent, however, on user interface programming the second year (53% vs. 85%), as this task was left to the technical-level students on that occasion (to even the workload between student teams). Student satisfaction about the overall experience was very high or high (~90%) on both occasions. All of them affirmed it definitely has its place in an engineering formation.

A group discussion was held with the university students, where the strong and weak points of the activity were underlined, and what in their opinion should be kept or changed for the next time. The strong points on which everybody agreed were: the possibility to interact with a distant student team, the interaction experience with future technicians, the high quality of the automation equipment and technologies involved, and the quick dynamics (rapid time constant) of the system that allowed a quick feedback during test phases. Students also greatly appreciated the ability to visit the installations and meet the other student team in person at the beginning of the project. The absence of a written report was also something students felt should be kept. On the other hand, students felt they should have received more specific directives on what was to be done, and provided with a systematic methodology to proceed for the programming. They also wished more formal instructions were provided on the role of each team for each step of the process, and some did not like to have to rely solely on the other team for something to be done.

Feedback From the Teaching Staff

It is the opinion of both teaching teams that the activity was a success. Most teams have performed very well, and learned much from interacting with their counterparts. They all had to

TABLE 1
Survey Questions for University Students

Survey Questions	*Choice of Answers*
Theme 1 – Communication Tools	
Q1. Regarding the communication tools used, how would you rate their user-friendliness? Q2. Regarding the communication tools used, how would you rate their appropriateness for the activity?	a) Very good.
	b) Somewhat good.
	c) Somewhat bad.
	d) Very bad.
Q3. About your role in the communications, what was your degree of involvement in the team?	a) Main user / Leader.
	b) One of the users.
	c) Mainly an observer.
Theme 2 – Quality and success of the communication	
Q4. Did you experience any communication problems?	a) No problems at all.
	b) A few minor problems.
	c) Quite a few problems, some of them major ones.
	d) A lot of major problems.
Q5. How do you rate your level of knowledge on network technologies?	a) Expert.
	b) Knowledgeable.
	c) Very limited knowledge.
	d) No knowledge at all.
Theme 3 – Automation tools	
Q6. How do you perceive the pertinence of learning about industrial controller software in engineering? Q7. How do you perceive the pertinence of learning about user interface software in engineering?	a) Very pertinent.
	b) Somewhat pertinent.
	c) Somewhat not pertinent.
	d) Not quite pertinent.
Q8. How would you now rate your competence on the use of the industrial controller software? Q9. How would you now rate your competence on the use of the user interface software?	a) Very competent.
	b) Somewhat competent.
	c) No or somewhat low competence.
Theme 4 – Team interaction and cooperation	
Q10. About the interaction with college students, how would you rate their degree of cooperation? Q11. How would you rate their level of competence?	a) Very good.
	b) Somewhat good.
	c) Somewhat bad.
	d) Very bad.
Q12. About your role in these interactions, what was your level of participation?	a) Main person interacting.
	b) One of the persons interacting.
	c) Mainly an observer.
Theme 5 – General appreciation	
Q13. Overall, how do you perceive the pertinence of distance interaction with another team? Q14. Overall, how do you perceive the pertinence of interacting with future technicians? Q15. Overall, how do you perceive the pertinence of this activity in your curriculum? Q16. Overall, how do you perceive the global added-value of this activity?	a) Very good.
	b) Somewhat good.
	c) Somewhat limited.
	d) Quite bad.
Theme 6 – General comments	
Please state your personal comments on the activities, suggestions for the future, etc.	

learn from each other about terms that describe similar phenomenon, for example. Some were even impressed (favorably) by the level of knowledge of their counterparts. Communication between teams was very good in general (one exception over the last two years), and so was the level of collaboration. The exchange of information was efficient between teams, and the students were respectful towards each other. The last comments from the students about receiving more detailed instructions for the activity shows that they have to further develop their confidence and better tools for project management, as relying on others is unavoidable in the job market. This is an aspect that both teaching teams will insist on in the following years to best prepare the students for this reality.

CONCLUSION

This paper presented an innovative activity conducted between college students (future technicians) and university students (future engineers), in the field of process control and industrial automation. Learning activities were presented, followed with feedback from the students and the teaching teams. Results showed that students worked and understood each other very well despite their different skills, terminologies, and background. Training objectives were attained, while students also greatly appreciated the experience.

TABLE 2
Survey Results for University Students in 2009 and 2010

Question	*Year*	*a)*	*b)*	*c)*	*d)*
Q1.	2009	36 %	64 %	0 %	0 %
	2010	40 %	60 %	0 %	0 %
Q2.	2009	71 %	29 %	0 %	0 %
	2010	67 %	33 %	0 %	0 %
Q3.	2009	7 %	57 %	36 %	N/A
	2010	7 %	73 %	20 %	N/A
Q4.	2009	29 %	57 %	7 %	0 %
	2010	53 %	40 %	7 %	0 %
Q5.	2009	0 %	43 %	43 %	14 %
	2010	0 %	33 %	60 %	7 %
Q6.	2009	71 %	29 %	0 %	0 %
	2010	60 %	33 %	7 %	0 %
Q7.	2009	29 %	50 %	14 %	7 %
	2010	27 %	53 %	20 %	0 %
Q8.	2009	14 %	79 %	7 %	N/A
	2010	7 %	80 %	13 %	N/A
Q9.	2009	14 %	71 %	14 %	N/A
	2010	0 %	53 %	47 %	N/A
Q10.	2009	57 %	36 %	7 %	0 %
	2010	73 %	0 %	7 %	20 %
Q11.	2009	79 %	21 %	0 %	0 %
	2010	67 %	13 %	20 %	0 %
Q12.	2009	14 %	71 %	14 %	N/A
	2010	0 %	93 %	7 %	N/A
Q13.	2009	93 %	7 %	0 %	0 %
	2010	60 %	33 %	0 %	7 %
Q14.	2009	86 %	14 %	0 %	0 %
	2010	47 %	40 %	13 %	0 %
Q15.	2009	100 %	0 %	0 %	0 %
	2010	53 %	47 %	0 %	0 %
Q16.	2009	64 %	36 %	0 %	0 %
	2010	27 %	67 %	7 %	0 %

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