Courses in Programmable Controls for Engineering Technology

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Abstract:

The EET program at the University of Toledo contains two courses in PLCs. One is a fundamentals course taught at the sophomore level. The second course, in the senior year, is structured to add depth of understanding and familiarize the student with problems similar to those faced in industry. Changes that occurred to upgrade both courses but especially the second course are the topic of this paper. The process of preparing to re-configure the labs, the procurement of equipment and the changes in how labs were to be developed are discussed. Reasons for re-configuring the labs to include the new equipment as well as benefits gained by switching to this equipment and a new series of labs provide the rationale for the paper.

Introduction:

Equipment had aged and was breaking down. Software licensure was at risk. Student complaints were numerous. Job placement was not good. These were some of the reasons to consider changes in the PLC courses and especially in the senior course where complaints were most severe. The capital for buying any new equipment seemed an insurmountable challenge. However, steps taken to upgrade the coursework had to be taken!

Observations of teaching the two courses over a number of years have been reviewed at the conclusion of each class. The evaluations received with each class were noted and comments were scrutinized to update labs and the class experience. It was noticed that students were struggling in the advanced course. There seemed to be a division between those who desired a job in the manufacturing environment and those who did not. Motivation for a job in the manufacturing environment was thought to be at the core of the division. The difference could have also been attributed to "senioritis" or some variation of that phenomenon. Whatever the cause, the division was real. Some wanted the course content and others resisted.

Equipment began to wear out and not in just one area. All areas seemed to age together. The obsolescence of electrical controls equipment is about 10 years and much of this equipment was at least 10 and in some cases, 15 years old. Since the computers in the labs were at least five years old, the inherent slowness of these older boxes accentuated

the problem.

A single seat per lab assignment was noticed to be less tolerable than originally assumed by the instructor. When the lab was originally designed, there was only one seat (with a second seat for a lab partner) for a particular lab experience. Labs were designed to be round-robin. With the other negatives described above, this design of labs became unacceptable and students let it be known through their evaluations and comments.

Also, equipment to accomplish some of the labs was not safe. Safety rules have been in place for years and they were somewhat adhered to in that barriers were placed in the most obvious danger points. The European initiatives of recent years do not allow the solutions that were presently in use. US law is moving quickly to embrace these safer systems and these laws are taught in the safety portion of the advanced course. The equipment that had been used in labs over the years was not safe and the safety issue had to be addressed!

Software licensing had become an issue. A-B has a relatively new concept for licensure including a unique MAC address per copy. While the lab had enough licenses, the practice of ghosting the software onto an entire lab of computers would not work with the newer A-B software.

Evaluations for the advanced course were spotty at best and less-than-acceptable at worst. Evaluations were even more dramatically negative with students at exit interviews for the EET program just prior to graduation. These exit interview evaluations were not encountered until accidently discovered in the ABET review meetings prior to the ABET visit fall of 2011. These were even more negative than the class evaluations that were routinely returned to the instructor. Evaluations at exit interviews were not shared with the instructor until the ABET evaluation team was fast approaching. The instructor was surprised that the exit interview comments were one of the core common negative threads at the exit interview.

Problems other than the exit interview reports were vetted after the summer 2010 class for the senior course. In that summer session, several labs were performed for the last time. Many pieces of equipment no longer worked and a decision was being forced on the program to replace the equipment with other used equipment (since the budget for replacement equipment was significantly less than needed to replace existing equipment) or discontinue the class.

Preliminary Design:

Faculty discussions during the fall of 2010 focused on the type of equipment to use in the future and cost to replace existing equipment. The advanced class is not given in the fall semester and the term was used to discuss what could be done to upgrade the labs. No good consideration was ignored. Several radical new ideas had surfaced but none were as acceptable as maintaining the A-B (Allen-Bradley) presence while adding some Siemens equipment. A-B representatives were asked to meet with instructors and support

staff and discussed several what-if scenarios. No budget was discussed since the department was operating with essentially no money for new equipment. But, by having the discussions and developing a relationship with the A-B personnel, when a grant surfaced, preliminary plans were in place that only needed to be refined in order to develop a good equipment list and purchase the needed equipment. A plan was in place if money were provided to move forward with a re-design of the labs and curriculum. Prior to fall 2010, relations had deteriorated with A-B to the point that no sales or technical people had called on the EET department for several years. With no money to spend, A-B had no need to partner with this program. The relationships re-established during the discussions left a positive attitude so that if there was a solution, A-B would partner with the EET program in order to find it.

In addition to the A-B connection, Siemens had been approached and some work done to learn their software and hardware platforms. The instructor attended several schools by Siemens. These included a school in Germany in the fall of 2008 (two weeks) and a second shorter school in Williamsport, Pa during the summer of 2010 (three day) to introduce their newest PLC offering (the 1200 processor). Other one day seminars were also attended by the instructor on Siemens and A-B. While A-B was the largest PLC manufacturer in the US, Siemens dominates the world market. With the inclusion of Siemens into the curriculum, it was thought that students would be more employable for a wider range of job opportunities. Siemens also was an unknown to many in the US since many in the US market had successfully resisted Siemens initiatives. This resistance is changing. However, being able to teach the Siemens' language and provide instruction at a level similar to the A-B equipment was considered difficult to accomplish (and still is).

A sample PLC training class from a third party company – Divelbiss - was purchased, studied and dismissed.

During the spring of 2011, a grant became available for lab equipment and the EET Program was ready to purchase since the major vendors had been contacted during the 2010-2011 academic year and relationships had been built. During the fall of 2010 and spring 2011, both vendors had said: "what would you like if budgets were no problem". In other words, if all the equipment could be donated, what would the U of Toledo EET Program like? This was considered entertaining but the staff was extremely skeptical since it was believed only to be an exercise that would probably not yield any real result. This assumption was wrong. Grant money did appear from a year-end budget source (if spent by a certain date) and the faculty and staff responded. Vendor relationships had been developed to the extent that equipment was quickly able to be purchased (and at a fraction of the real buy price for industry).

The summer 2011 advanced course was taught with the goal of introducing a sample of the new equipment. The course also was re-designed to include no labs with only one seat at the lab but a fewer number of labs that all were able to participate in at the same time. The old lab environment had not worked and the new method was readily accepted by the small but eager group (only seven students were in this class).

Executing the Project:

The basic philosophy of the courses that would guide the process of creating new lab experiences was:

A. How to best to continue the basic ideas of the present courses (lab content, style of delivery)
B. The requirement that multiple stations of individual labs would be necessary - No longer would students accept one station for a lab and then rotate to another station for another lab. Everyone would perform the same lab at the same time.
C. Discontinue RS232 COM ports - Ethernet programming with static IP addresses would be the norm.
D. Licensure of software would be legal and up-to-date
E. With the need for students to get jobs, a switch to Siemens was considered over A-B but the decision was made to teach a hybrid course in which both A-B and Siemens would be taught.

What occurred was the purchase of the two major PLC vendor's best processors. The decision was also made to teach both simultaneously. The step, while bold, has been accepted enthusiastically by the students since the comparison between the two most popular PLC brands in the world can only lead to a better learning environment than if either one was to be taught exclusively. The competition between the two vendors is as intense today as at any time in recent history. Both vendors knew that if they faltered, their equipment would appear to be "less-than" to the next generation of graduates. In other words, the decision to incorporate both in the same lab kept the competition by both venders at an extremely high level.

Much thought had been given to the present lab exercises and the new equipment purchase led to a hard decisions to pare down the number of exercises (since there were double the number of experiences with each lab now being performed with both A-B and Siemens hardware). The process of how many lab exercises to include in each course is still in the development stage and will continue to be refined. Student comments in Appendix 2 address this issue and warn instructors to not reach too far.

With respect to labs such as PID (Proportional-Integral-Derivative) lab of the senior course, the number of labs was reduced but the number of ports to get to the two PID stations was increased so four groups could be active at one time. With a lab schedule in which various groups could work in different time blocks, all groups would be accommodated simultaneously. With respect to the motion labs in which safety had been the primary concern as well as the need to accommodate more groups at once, a great deal of effort was expended. The lab devised is still waiting for an initial trial but it is believed to be a good next step. The etch-a-sketch was found to be a good 2-dimensional problem with stepper motors direct coupled to the shafts in the x and y direction. Stepper drivers were tried and a stepper output instruction was supported by each processor chosen. Similar instruction sets from the two vendors provide a common framework to

output the stepper commands to move. Couple a direction command to the pulse output command and a stepper can effectively be controlled to move in a variety of directions. This was a good move in that two-axis motion could be explored and safety was not a concern. Safety still should be considered in a demo with "real" equipment in the lab but to turn students over to the heavy equipment had an element of risk not necessary (or possibly even legal). Demos will be given on older equipment in which the students were at one time required to perform the lab one student at a time.

Both the A-B and Siemens processors have the same instructions for action such as PID and servo control due to the standard for PLC Open - IEC 61131-3. One may be tempted to ask if it would be equal to adapt one of these PLCs as a standard since the languages are similar. The two manufacturers are significantly different in their execution of the IEC 61131-3 standard and therefore not really compatible. The questions of contrast and compare between the two are of great value, however, and an excellent by-product of the choice to implement the two together.

Review of Lab Experiences:

Original lab experiences were maintained as much as possible. The old labs in their round-robin format are given on the left while their new counterparts for the advanced class are given on the right:

Communication with Processors	expanded in new labs
Human-Machine Interface (graphic development)	greatly expanded in new labs
MSG Block	discussed but no lab
PID Block	expanded
ASCII Block	discussed but no lab
Fault Recovery Instruction	discussed but no lab
Stepper and Servo Control	changed and expanded labs
Device-Net Network	discussed but no lab
ControlLogix (RSLogix 5000)	greatly expanded
Safety	expanded but no lab
Other PLCs	greatly expanded
Networks and Protocols	discussed with lab in future
AUTOCadd ELECTRICAL	discussed – labs moved

While it is interesting to review these over-all categories, the labs that are being developed have been designed primarily to give a group of parallel experiences with a common due date for all class members. The class executes the lab at the same time with problems emerging from one or more groups that are discussion material for the whole class. The mistake of the round-robin design has hopefully been permanently fixed.

The design of the labs was to include an introductory lab to help those without the Siemens background come up to speed quickly. This lab, while placed as the first lab for the advanced class, did not fully meet the expectation of bringing all students up-to-speed on Siemens. The software from Siemens needs much more time and this deficiency will have to be addressed. The present spring 2012 advanced group needed more time to address this problem. Even the A-B experience needs to be reviewed since most students are only familiar with the older equipment and older software platforms.

Software licensure issues were accommodated by allocating a server to the A-B license from which every computer in the domain successfully will boot to the present programming software. As long as the proper number of software licenses is in house, all can work adequately from the one license on the server. This is perfectly legal since a combination of permanent licenses and student licenses were purchased. Siemens offers their basic software free with the purchase of a hardware system. The problem with Siemens is that each time the software upgrades, the hardware must be upgraded in tandem or significant problems ensue. For example, if the Siemens TIA software upgrades to version 11, sp2, the hardware must be upgraded to version 2.2. There are exceptions to this rule but students are more quickly confused when different versions are encountered. Siemens also does not handle the static IP address as well as A-B. Numerous times, students have over-written the static IP address of their processor. It is entirely too easy to supplant the static IP address of the machine with a default address after which it is impossible to directly address the PLC except with a set of instructions for re-establishing communication through a diagnostic process.

Labs are being archived at the instructor's website. They are part of an on-line text that serves as the present text for both courses. Siemens has given authorization to use their text material and this gives the present on-line instructional material a starting point for a new text. The instructor was previously involved in a text that was implemented using the older A-B processors. Updating the A-B material is less difficult due to the similarity between the older processor and the present A-B material. Access of this present text to others is free and available upon request via email. At present no plans are in place to publish the material although this may be done at some future time.

The difficulty in using the Siemens software should not be minimized. While great strides have occurred with their new TIA Portal software, it is still a more difficult software package to use. It takes longer for this instructor to explain concepts and have good results using the Siemens programs than with the A-B material. This may be due to the lack of experience with the German TIA software. The software is very flexible but is a frustration to use at times. Students usually agree that the Siemens software is more difficult to use although their frustration may be due in part to the lack of experience or

trust from the instructors' background. When the instructors gain sufficient experience with the software, the students may become more eager to learn the Siemens software. This software is radical in its design and new to Siemens and has gone through many upgrades just in the short time since first introduced.

It was difficult walking away from old equipment that had served well over the years. The COM port was no longer being used. Teaching RSLinx was no longer a priority. There are times that it seems that the new course may have reached too far and left the old equipment in its dust. Some content had to be eliminated, however, and this was a compromise that was made. While a demonstration was given using RSLinx with the DF1 communication path, the lab experiences requiring this activity are no longer being used, as are most of the COM ports on the computers in the labs.

The appendices contain a material list of what was ordered. The order was so rushed to meet timing requirements of the grant that there was no time to critically question each component. The purchase, however, was overall very successful and the project was a great success. The A-B network switches were a waste of money since they were not used in the present design. The Siemens safety equipment may likewise never be used. The Siemens power supplies were not stout enough to power the PID loops in addition to the processor and digital I/O. A-B's power supplies were capable in this area.

Also included in the appendices is a list of comments from students in the fall 2011 second year class. Although several labs were removed from the old list, the students still felt stressed in this class. The evidence points to further paring down of the list as the class moves forward. The part-time instructor is presently teaching the second year class in the evenings. His experience is only A-B with no Siemens background. He has had several emails and phone calls to the lead instructor of the course but is picking up the material and teaching it well. He also embraces the need to teach both A-B and Siemens and has joined in supporting the overall plan.

Summary:

The courses are in a good state of development at present. While the instructor may have considered waiting for the course material to stabilize, the concepts were new enough and important enough to begin a dialog with colleagues such as are here at this conference. The students are aware that the equipment is being used in this way for the first time in the US (using the Siemens 1200s). It is also believed that this is the first course and lab using a hybrid approach with the Siemens and A-B equipment together anywhere.

The stress encountered in the student comments was shared by the instructors. These two courses could have been totally eliminated if equipment were allowed to deteriorate much further. Most issues have been identified and solutions found. But, tomorrow or the next day, there will be another bug or other difficulty to overcome. Students are excited at the prospect of using their new experiences in finding jobs and they seem to be having great success. The success stories they share make the difficult decisions and effort expended worth the effort.

This experience needs to be told to fellow colleagues to encourage those who may be in a climate of budget cuts and subsequent discouragement. This was a time of planning with no hope of finding a suitable solution but a story of success none-the-less when an unused budget surplus became our lab equipment seed money. The result was a new approach to two courses that was much more pleasing than anyone could have foreseen.

This is also a time to renew a commitment to offer only the best in the best format. A lesson learned anew was that comments and criticisms from any source must be addressed as they occur. To let any time pass without acting appropriately to the evaluation process only cheats those students who today deserve our very best effort.

REFERENCES

Sample of Existing Texts on Programmable Logic Controllers

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John Webb, Ronald A. Reis, (1999). *Programmable Logic Controllers, Principles and Applications*, 2nd Ed, PrenHall

Systems Manuals used for the Lab Experiences:

Kelvin T. Erickson, (2011). Programmable Logic Controllers: An emphasis on Design and Application, 2nd Ed., Dogwood Valley Press

Wm T Evans, Programmable Logic Controllers: Fundamentals and Applications, Stipes Publishing LLC

Appendix 1 – PLC Vendor Equipment Lists

Allen-Bradley Package

9324-RLD700NXENE	RSLogix 5000	4	
9398-EDCTKIT5B	5 install Student Kit	1	
9398-EDCTKIT10B	10 install Student Kit	1	
1769-L23E-QBFC1B	Processor	18	
1769-ECR	I/O End Cap	3	
1769-IF4FXOF2F	Compact Analog I/O	3	
1769-IQ16	Compact Dig In	3	
1769-L32E	Compact Processor	3	
1769-OB16P	Compact Dig Out	3	
1769-PA2	Compact Power Sup	3	
1734-AENT	Ethernet Adapter	5	
1794-PS13	Ether/IP I/O	5	
1734-FPD	Ether/IP I/O	5	
1734-TBS	Ether/IP I/O	20	
1734-IA4	Ether/IP I/O	10	
1734-OA4	Ether/IP I/O	10	
1783-US5T	Ethernet Switch	23	(would not purchase this Ethernet switch)
1783-US08T	Ethernet Switch	1	(would not purchase this Ethernet switch)

Siemens Package

S7-1200 Trainer Package DC/DC/DC - 6 pack	2	
KTP600 Basic Panel Trainer Package - 6 pack	2	
S7-1200 Power Supplies	12	
S7-1200 Analog Module 4 in / 2 out	12	
ET200S Safety I/O Trainer Package	5	(would not purchase this Safety equip again)

Appendix 2 - Student Comments on First Offering of Second Year Course (Fall 2011)

Student 1:

"The labs were very stressful including having deadlines so close together the work piled up to fast. The book should have been done and finalized before the course. Changing the book so many times made it difficult to follow along in class. Also, he seemed to ramble on into stores that really did not matter."

Student 2:

"The course text was incomplete and confusing at times. If it was finished it would be more helpful. Doing both Allen-Bradley and Seimens is a good thing for experience."

Student 3:

"This class moved way to quickly. The text was relevant to the course material, however, the material was very hard to grasp. Professor does describe this class with enthusiasm, but he does talk way to fast. The material used in this class was very new to most students and the concepts needed be done in a slower manner."

Student 4:

"The class moved at too fast of a pace. It was impossible to complete the numerous labs as well as pay attention during the lecture. I always felt like I was 5 steps behind the pace he was moving, and so did everyone around me."

Student 5:

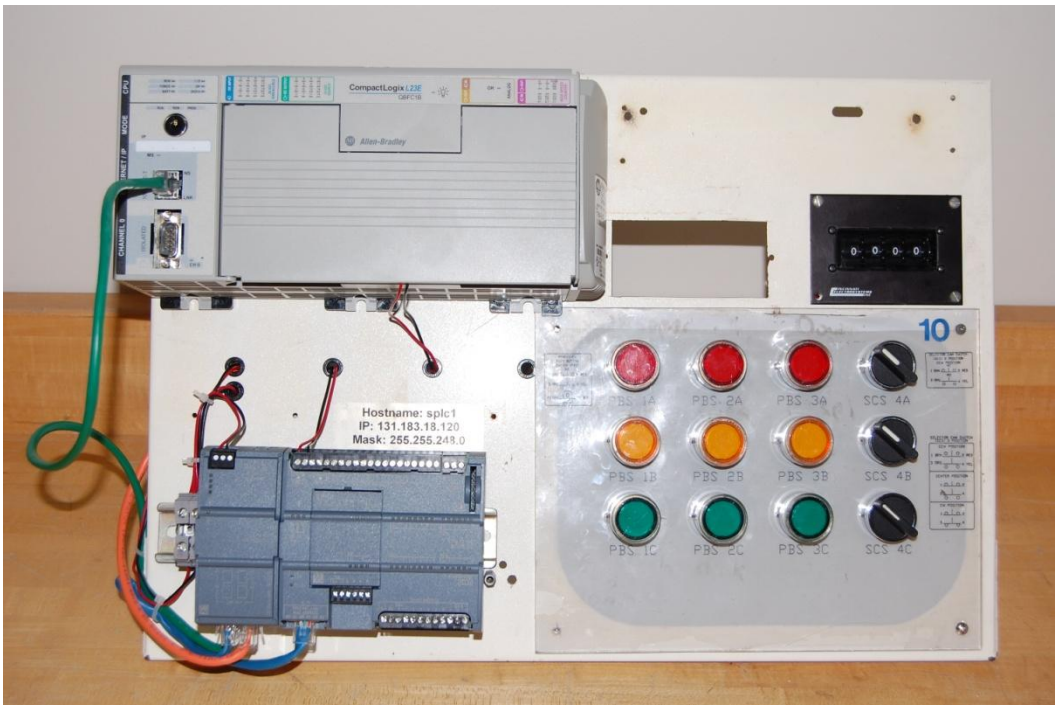
"The deadlines and the amount of labs were very stressful, sometimes almost impossible. Having a textbook would have been awesome."

Student 6:

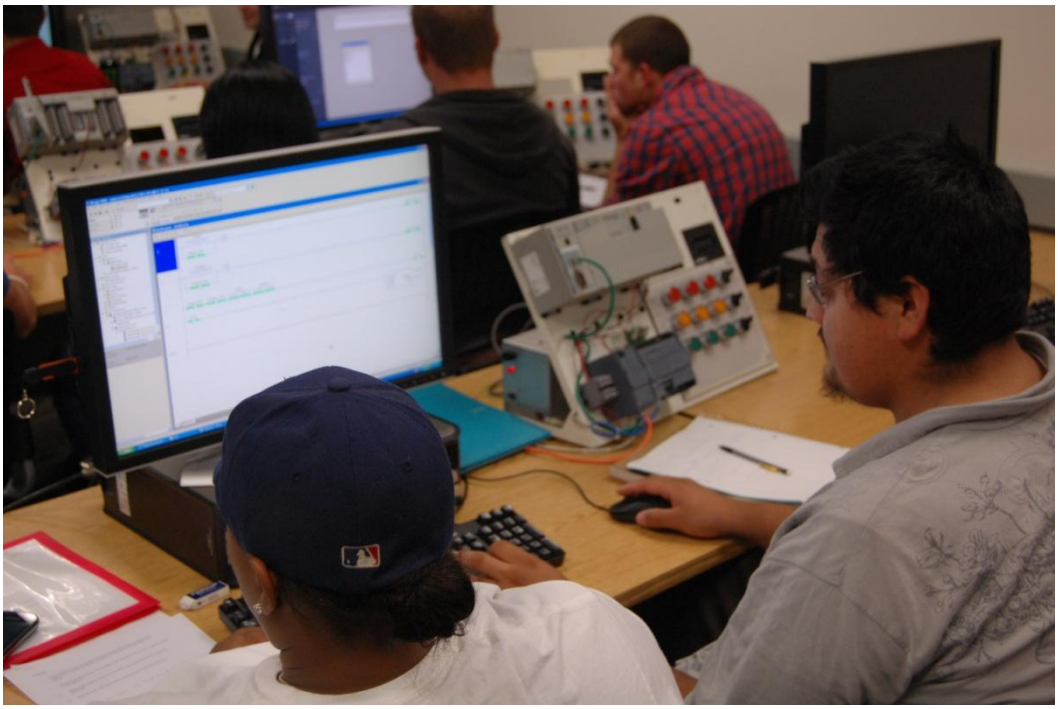
"I feel like the teacher's lectures were worthless. If you did not get a good understanding from the very beginning (like myself and many other students) you fell behind QUICK. The teacher sped along through the material and threw you into the water expecting you to swim. The teacher did not explain the material very well and his expectations for us were too high.

- I liked the course to the new improvements but I wish I could have got more out of the class as in actually understanding something I did."

Appendix 3 – A Pictorial Review of the Equipment



Pictured above are the two PLCs located on the trainer. On top is the A-B L23 processor. On the bottom is the Ethernet switch and Siemens' 1200 processor. Below is a picture of some students in the lab using the new trainer.



Pictured below are close-ups of the two PLCs. They support digital I/O as well as analog I/O. Additional I/O can be added but none was necessary for the lab exercises in these courses. Both processors support multiple languages including Ladder, Function Block and Structured Text (a procedural language).