Using Collaborative Technologies in Remote Lab Delivery Systems for Topics in Automation

by

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We hereby certify that this dissertation, submitted by Joe E. Ashby, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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Lab exercises are a pedagogically essential component of engineering and technology education. Distance education remote labs are being developed which enable students to access lab facilities via the Internet. Collaboration, students working in teams, enhances learning activity through the development of communication skills, sharing observations and problem solving. Web meeting communication tools are currently used in remote labs.

The problem identified for investigation was that no standards of practice or paradigms exist to guide remote lab designers in the selection of collaboration tools that best support learning achievement. The goal of this work was to add to the body of knowledge involving the selection and use of remote lab collaboration tools. Experimental research was conducted where the participants were randomly assigned to three communication treatments and learning achievement was measured via assessments at the completion of each of six remote lab based lessons. Quantitative instruments used for assessing learning achievement were implemented, along with a survey to correlate user preference with collaboration treatments.

A total of 53 undergraduate technology students worked in two-person teams, where each team was assigned one of the treatments, namely (a) text messaging chat, (b) voice chat, or (c) webcam video with voice chat. Each had little experience with the subject matter involving automation, but possessed the necessary technical background.

Analysis of the assessment score data included mean and standard deviation, confirmation of the homogeneity of variance, a one-way ANOVA test and post hoc comparisons. The quantitative and qualitative data indicated that text messaging chat negatively impacted learning achievement and that text messaging chat was not preferred. The data also suggested that the subjects were equally divided on preference to voice chat verses webcam video with voice chat. To the end of designing collaborative communication tools for remote labs involving automation equipment, the results of this work points to making voice chat the default method of communication; but the webcam video with voice chat option should be included.

Standards are only beginning to be developed for the design of remote lab systems. Research, design and innovation involving collaboration and presence should be included.

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Looking back, I can see I was far from alone in this venture. I am indebted to the many mentors and colleagues of both my past and current vocations, who took the time to explain and encourage.

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Chapter 1

Introduction

Context of the Problem

In science and engineering education, it is generally recognized that effective learning requires a mixture of both theoretical knowledge and practical exercises (Aktan, Bohus, Crowl & Shor, 1996; Rosa, 2003). A major goal in engineering education is for students to acquire problem solving and creativity building strategies, resulting in the construction and improvement of technical systems. Such strategies can be learned by working on assignments in a problem-based lab environment. Practical lab work is an essential part of every engineering and technology program (Fakas & Gillet, 2002; Ko, Chen & Chen, 2004).

Ma and Nickerson (2006) assert that on-line education has become an educational tool used to reach students at times and places that are not strictly dictated by the schedule and logistical constraints of educational institutions. The need for laboratory experiences in on-line science, engineering, and technology programs is being fulfilled using a number of approaches, with varying degrees of success. The remote lab approach allows learners to access traditional laboratory facilities through on-line digital portals which use Internet interfacing technology. Remote labs best satisfy the needs of the

Internet based on-line learner (Casini, Prattichizzo & Vicino, 2003; Fjeldly & Shur, 2003; Rosa, 2003; Saygin & Kahraman, 2003).

An important area of concern in the design of remote lab delivery systems is the fostering and support of virtual or social presence (Deniz, Bulancak & Ozcan, 2003; St. Aubin, 2006). When selecting remote lab support technologies the designer must consider the issues of basic access to the lab equipment, along with the need to support learner presence. As described by Fjeldly and Shur (2003) and Ko et al. (2004), the primary tools available to support Internet based remote labs include web cameras, voice chat audio equipment, web conferencing software tools and the specialized hardware and software interfaces required to allow remote operation of lab equipment.

Collaboration, namely students working in teams on lab exercises, is a key ingredient in creating an effective learning environment (Fakas & Gillet, 2002; Tomei, 2005). Small group collaboration enhances learning outcomes through the process of discussing technical issues and through social interaction. McNeil and Singh (2002) state that effective collaborative communication is an essential component of successful learning processes.

The exact hardware involved in a remote lab will vary, based on many factors. In general, the learner will control the lab equipment and receive feedback via some combination of (a) video cameras, (b) data displays, (c) audio via microphones, (d) software based human-interface control panels, (e) direct operation of lab computers through virtual connections, or (f) data file uploads (Aktan et al., 1996; Bellmunt, Miracle, Arellano, Sumper & Andreu, 2006; Ko et al., 2004). Due to the variety and complexity of laboratory equipment, along with the breadth of educational topics and needs, a standard approach for remote lab system architectures does not exist (Casini et al., 2003; Deniz et al., 2003; Sepehri, Onyshko, Lehn, Song & Zheng, 2002). Specific to the area of learner teamwork in remote labs, Callaghan, Harkin, McGinnity and Maguire (2007) state that the majority of remote labs developed to date suffer from a lack of support for collaborative group work. New collaborative remote experimentation environments and architectures are needed.

Problem Statement

The problem identified for investigation is that no standards of practice or paradigms exist to guide remote lab designers in the selection of collaboration tools that best support learning achievement.

Deniz et al. (2003) indicates that the technology used in remote lab systems parallels that of remote process control systems used in industry. The researcher brought to this work over 20 years of experience in the field of industrial automation system application engineering, including work on discrete, continuous, and batch process control systems. The researcher has been involved in remote lab system design and delivery projects at Indiana State University (ISU) since 2003. Currently, the focus of this work involves the support of learner collaboration and the enhancement of virtual presence to support robotic, machine control, and chemical process control remote lab systems.

Goals

The goal was to add to the body of knowledge involving the selection and use of remote lab collaboration tools, to the end of providing distance education students with lab experiences that are equal in quality to face-to-face lab exercises. Sharda et al. (2004) assert that the support of lab teams is a fundamental design requirement for remote lab systems and that the application of collaborative technologies to support remote lab teamwork is a vast research area that is largely unexplored. Students working in teams require effective and useful collaboration tools which support social interaction, a sense of community and a feeling of presence, along with the basic exchange of information (Redfern & Naughton, 2002). While this constructivist approach of collective social interaction typically occurs in an unplanned and natural fashion in a traditional lab, the appropriate communication support tools must be purposefully designed and installed in the case of the remote lab. The objective of performing this research work was to aid remote lab designers in matching the best communication tools to the educational needs of their target audience of students.

Research Questions

The following research questions were posed:

1. Which commonly available web communication tools best support team collaboration in a remote lab environment involving automation type lab work?
2. How do the remote lab communication approaches selected (text messaging chat, voice chat, and webcam audio with voice chat) best interoperate with automation

lab exercises which involve designing control language programming, downloading and debugging programs and performing analysis of results?

3. Which combination of currently available remote lab collaboration tools, namely text messaging chat, voice chat, and webcam video with voice chat, most positively impact learning outcomes in a remote lab environment involving automation type lab work?

Relevance and Significance

The level of activity on the development and implementation of remote labs, particularly in the engineering and technology fields, continues to grow (Reilly, 2008). A remote lab has the potential to provide greatly enhanced deep-learning experiences to a larger number of students at a lower cost per student. Many approaches to remote lab architectures are being utilized, but no standard solutions exist (Dormido et al., 2008). Collaboration plays an important role in knowledge building and sharing during the lab experiences. The need continues, according to Gillet, Ngoc and Rekik (2007), for the development and definition of reliable collaborative techniques in the remote lab environment, where students work in teams.

Scope

An important limitation was the intent of the individuals to give full attention to the learning content, the assessments and the remote lab process. As detailed by Gordon

(2005), technology is neither the singular cause nor the solution for communication problems found in a web-enhanced environment. In general, additional tactile and visual capabilities support a broader range of learning and thinking styles and thus should produce better learning achievement than auditory-only or text message-only communication. However, factors such as the attitude of the individuals during any given remote lab session and team dynamics can impact results. As a result, practices were in place to help mitigate these issues, including (a) random team member pairings for each lesson, (b) treatment order considerations, and (c) adequate sizing of the sample.

Several delimitations existed. First, the scope was limited to remote lab pedagogical issues involved with the topic of industrial automation. The participants were ISU College of Technology (COT) undergraduates. The participants completed six learning modules, each with an assessment. Maintenance issues involving the lab and web equipment and systems were minimized, allowing the subjects to focus on the lessen materials and lab activities. Finally, the collaboration tools evaluated were limited to commonly used web meeting communication tools, which were specifically text messaging chat, voice chat and webcam with voice chat.

Definitions and Acronyms

AutomationTek - AutomationTek is an educational delivery system which supports learning content, along with remote lab exercises, on topics involved with industrial automation. Industrial automation is the use of computers to control machinery and processes to improve manufacturing repeatability and quality, reduce waste, and increase productivity. The configuration of the system included four robot learning stations and four machine control system learning systems. The stated goal of AutomationTek was (a) to deliver on-line lab based learning on a continuing basis, (b) to support student research activities, and (c) to introduce Indiana high school students and Indiana State University undergraduates to the field of automation technology (Heath & Ashby, 2007).

Chat or text messaging chat - Chat or online chat can refer to any kind of communication over the Internet, but is primarily meant to refer to direct one-on-one chat or text-based messaging (formerly also known as synchronous conferencing), using tools such as instant messengers or web conferencing software. The expression online chat comes from the word chat which means informal conversation (Downing, Covington & Covington, 2009).

PLC - The Programmable Logic Controller (PLC) is a computer based device that allows for the reprogrammable control of machines and automation systems. The PLC sequentially monitors input signals and controls output signals to coordinate the actions of the machine to which it is connected. It also supports human-machine interface (HMI) connections as well as communication of machine control and production data in the manufacturing environment. The PLCs in the study were programmed using a graphical language called ladder logic (Stenerson, 2003).

HMI - The human-machine interface (HMI) is the access point where people and technology meet. Specific to automation, the HMI control panel is a combination of hardware and software technologies that allows the human users to command operation of a machine or system and observe data changes resulting from those commands in numeric or graphical formats (Stenerson, 2003).

©*RealVNC* - ©RealVNC is a suite of remote control software packages which allows remote users to view and operate one computer desktop (server), using a viewer program on another computer desktop anywhere on the Internet. This allows for virtual control of the server from any viewer who successfully logs-in. ©RealVNC is one of several brands of Personal Computer (PC) to PC virtual control software applications. ©RealVNC was selected for the AutomationTek project during the initial design phase (Heath & Ashby, 2007).

TeachMover - The TeachMover is a five axis educational robot designed by Microbot, Incorporated. The TeachMover is designed for the delivery of basic robotics instruction. Microbot brand robots were selected for the AutomationTek project during the initial design phase (Heath & Ashby, 2007).

Voice chat - Voice chat is a modern form of communication used on the Internet. The means of communicating with voice chat is through messenger or web meeting software applications. Voice chat has led to a significant increase in distant communications where two or more people can to use computers as a telephone conferencing system (Downing et al., 2009).

Webcam - A webcam is a video capture device connected to a computer via a data connection port. Their most popular use is for video telephony, permitting a computer to act as a videophone or video conferencing station. Other popular uses, which include the recording of video files or still-images, are accessible via numerous software programs, applications and devices (Downing et al., 2009).

Organization

The review of literature in the next chapter will outline the important roles lab work and collaboration play in engineering and technology education. Also, architectures and characteristics of the remote lab environment will be delineated, along with a discussion of the types of media typically used for lab partner collaboration. In Chapter 3 the approach for execution will be outlined in detail, along with a plan for analysis and reporting of the data. Chapter 4 details the findings of the work and Chapter 5 addresses conclusions and implications of the work and offers recommendations.

Chapter 2

Review of the Literature

The purpose of this literature review is to furnish the reader with an overview of the educational concepts that support the role of lab exercises in engineering and technology education, the rationale for the development and architecture of the remote lab, a summary of the importance of collaboration in lab work, and an overview of the commonly available techniques for communication by remote labs learners.

The Role of Lab Work in Technical Education

Lab work is a vital part of engineering education (Esche, 2002; Li, Lai, Wang & Wu, 2003). Lab experiments contribute to the students' motivation for learning and strengthen their understanding of the abstract concepts and theories taught in the lecture setting. In addition, coping with the imperfections of lab work is a unique part of education that can not be emulated in written courseware. Typical laboratory activities include measurement, data collection, analysis, design, and hands-on experience with equipment. Remote labs are software environments that support experiments through interaction with real equipment, where remote users are allowed to communicate with the real measurement devices and lab equipment (Deniz et al., 2003). Remote labs possess the interactive nature of simulations, yet possess the reality of working in a traditional lab with real equipment. Remote labs often, by default, also develop user skills in the field of remote control. As described by Carnevale (2002) and Rosa (2003), the remote lab concept was elevated to a new level of legitimacy when The Accreditation Board for Engineering and Technology Inc. (ABET) drafted a list of objectives for engineering lab learning experiences in 2002. These goals, developed by observing activities in traditional labs, were developed for use in the design and evaluation of on-line labs.

The Remote Lab Environment

According to Song, Olmi and Bannerot (2007) and Gurocak (2001), the typical learning activities in a remote lab should parallel those of the traditional lab. The exercise should start with some form of preparatory instruction, retrieved from on-line educational resources. Upon entering a remote lab web site, the learner typically will encounter a secure entry access point for system log-in. Next, all necessary supporting documentation and materials should be accessible. These might include lab procedures, subject matter documentation, or multi-media lectures. A resource area should be available for downloading any required software tools, including software control panels for control and data collection operations. The student will most likely have to schedule lab time by way of a resource management system. Some remote lab work involves the development of pre-experiment logic software, descriptive equations, or calculations which will ultimately be downloaded to the lab equipment for testing and debugging. In some cases simulation software may be used as a preliminary step. Simulation allows for pre-lab debugging of the student's experimental design, ensuring safe and time efficient use of the remote lab equipment. Finally, the student will gain access to the lab equipment. Data collection during the lab session could take the form of screen shots on the learner's computer, manual recording of data from web cameras, data file uploads, or by alternate methods unique to the lab equipment. As students may require real-time help, a lab assistant or instructor should be present in the lab or available to the learner on a timely basis. At the end of the lab period the student will perform required assessments, upload data files, save modified logic files, and collect all other related information prior to logging off (Buhler, Kuchlin, Gruhler & Nusser, 2000; Gillet, Latchman, Salzmann & Crisalle, 2001). Trevelyan (2004) categorizes all of these activities into four main kinds of remote lab activities: (a) Queued batch, where the user sets parameters for the experiment and the results are returned, with no real-time observation; (b) Real-time interactive, where the user sets parameters and can observe the action of the lab equipment; (c) Real-time measurement without control, where the user can observe the process and collect data, but not significantly set parameters; and (d) Programming experiments, where operation or logical code is developed and downloaded, then system operation is observed.

Remote Lab Equipment Architectures

While a standard approach for remote lab system architectures does not exist, there does exist commonality in architectures at the conceptual level, namely at the server side and the user side (Casini et al., 2003). The server side is typically comprised of the lab equipment, the lab server, and the web server. The interface between the lab equipment and the lab server may be directly supported by the lab equipment. In cases where the equipment does not support complex data interfaces, custom software interfaces are developed or, as detailed by Ko et al. (2004) and Watai (2003), commercially available interface input/output systems might be used. In small systems, one computer may be used as both the lab server and the web server. Functionally parallel with the lab equipment are lab presence systems which provide feedback including video, audio, and lab data. These systems usually feed data to either the lab server or the web server. Web meeting systems may also be used for lab presence support. Lin and Lin (2005) cite instances where multiple web servers may be used to increase reliability and breadth of lab equipment support. On the user side, client software or a browser applet, which runs on the student's computer, may be required. The student's data connection speed is a critical issue. Based on the data rate capabilities on the server-side and the amount of data being generated, the user must have data access capabilities which match that being generated. While most remote lab systems are designed around typical Internet connections, Hua and Ganz (2003) describe systems which are designed for Internet2 use. The higher data rates supported by Internet2 allow for remote labs that elevate presence to the virtual reality level.

Collaboration

The design of delivery systems for engineering and technology education, like other disciplines, requires some unique pedagogical considerations. Tomei (2005) defines a taxonomy for the technology domain that has six levels, namely (a) technological literacy, (b) collaboration, (c) problem solving, (d) integration, and (e) technology impact. Collaboration, the ability to employ technology for effective interaction with others, ranks second in Tomei's taxonomy. Wagner and Tuttas (2001) implemented and evaluated team learning in a process control on-line lab system. Their work indicated that distance learning experiments can lead to the same learning results as traditional lab experiments. Because observation of the lab equipment was limited to web camera views, they also found that the remote lab learners exhibited a greater level of planning in their work and precision in their operation of the lab equipment. The ABET objectives for remote lab evaluation, as listed by Rosa (2003), include (a) instrumentation, (b) models, (c) experimentation, (d) data analysis, (e) design, (f) learning from failure, (g) creativity, (h) psychomotor skills, (i) safety, (j) communication, (k) teamwork, (l) ethics, and (m) sensory awareness. The inclusion of teamwork and communication in the ABET objectives is further supported by Fakas and Gillet (2002) who indicate that collaboration provides students the opportunities to discuss, argue, and exchange information and knowledge. The act of collaborating with others on a technical problem, as defined by Qureshi, Liu and Vogel (2006) is an activity in which the individuals with complementary skills interact to create shared understanding, which would not have occurred if they were working alone. Social interaction can impact learning outcomes. The high ranking of collaboration in Tomei’s taxonomy for the technology domain, the inclusion of teamwork in the ABET list of objectives, and the findings of Wagner and Tuttas (2001) and Fakas and Gillet (2002) support the legitimacy of research on collaboration tools.

Presence

Shin (2001) frames the perception of presence, in the remote lab setting, as the degree in which a distance learner senses availability and connectedness with each lab partner.

The quantified level of presence, which Shin calls transactional presence, was found to be a significant predictor of learning outcomes. Presence consists of two interrelated phenomena, telepresence and social presence (Biocca, Burgoon, Harms & Stoner, 2001). Telepresence describes the sense of being there, while social presence concerns the sense of being together with another. Doulgeri and Matiakis (2006) refer to the remote lab user's telepresence, which is the remote operator's perception that the real lab system is being observed, not simply captured with pictures. Internet transmission time delays are a telepresence issue. Network time delays are directly related to the degree of telepresence achieved in support of the timely observation of lab equipment motion by the remote learner. Equipment safety is also related to this issue, in that slow or interrupted video updates can lead to lab equipment damage, particularly in the case of robotics and mechanical systems. Abdullah (1999) investigated social presence in on-line team conferences where only text messaging or chat was used. It was found that some students were more adept at recognizing and using social cues in their written interactions than others. These written cues can help in understanding the reactions of others when engaged in communication.

Distance education students can experience isolation from peers and instructors. Chung, Han, George, Zhang and Natarajan (2005) conjecture that such feelings come from the remote lab student not recognizing the presence of peers in the lab, and the student not knowing exactly what is transpiring in the remote laboratory as a whole. Remote lab students can also feel out of touch with the on-site instructor if they can not see him nor he them. Chung et al. define Immersive Presence as a requirement that enables cognitive, affective, and psychomotor learning objectives be integrated into the remote lab design process. Nunes, McPherson, Firth and Gilchrist (2003) posit that distance learners will benefit from Virtual Social Spaces in which peer socialization can occur. Socialization supports presence. Finally, Lucca, Romano and Sharda (2003) support the notion of Computer Supported Collaborative Learning requiring Immersive Presence (CSCLIP) which is the commonality or overlap of functions that exist where computer-supported learning, collaborative systems, and virtual reality systems intersect. The result of CSCLIP is that learners will experience stimulation of as many human senses as possible during remote lab experiences. Thus, whether referred to a transactional presence, telepresence or immersive presence, there is support for the need to heighten the remote lab user's sense of actually being in the lab, as opposed to participating as an outside viewer.

The Collaborative Remote Lab Design Process

While the development of systems that offer practical laboratory experiences from a distance have been in progress for a decade, no common-practice or generic solution has emerged for the collaborative on-line laboratory design process (Gravier, Fayolle, Noyel, Leleve & Benmohamed, 2006; Tzafestas, Palaiologou & Alifragis, 2006). Many systems have been designed on a single prototype basis with unique technical characteristics, most lacking the ability to be readily adapted to the variety of lab experiments and exercises as are required in the engineering and technology field. To the end of general specifications, Saygin and Kahraman (2004) have developed teamwork focused design requirements which are based on the set of ABET objectives for remote labs. These design constraints include: (a) Instrumentation – apply appropriate sensors and tools to make measurements and record data; (b) Models – apply theoretical and conceptual models to predict lab results; (c) Experimentation – devise an approach, specify appropriate equipment, and analyze the resulting data; (d) Design – use accepted methods for the design of the systems and the experiments; (e) Creativity – challenge the learners with real-world problem solving; (f) Data analysis – foster the research process which includes test design, data collection, and analysis; (g) Psychomotor – support activities which promote thinking and analysis, followed by appropriate action; (h) Learn from failure – include problem solving and failure analysis components in the pedagogical design; (i) Communication – support all possible levels of communication between team members and with the instructor; (j) Sensory awareness – include as much sensory feedback as is feasible, supporting virtual presence; (k) Teamwork – support learners working in collaborative groups; and (l) Ethics – foster accurate reporting of work results and responsible behavior in the lab. Also, Lin and Lin (2005) indicate that the remote lab designer should consider all aspects of the system including communications, sensors, actuators, instrumentation, and controls. The end result should be a system where the end-user can clearly observe and accurately control the experimental components of the remote lab.

Collaboration Methods Used in Remote Labs

The working group on standards for web conferencing within the Internet Engineering Task Force defines text messaging chat, voice chat and webcam with voice chat as the commonly used collaboration media types currently used (Even & Ismail, 2006). As described by Beldarrain (2006), web meetings are part of the social networking software tools that allows learners to collaborate via the Internet. Text messaging, voice chat and webcam video with voice chat are among the first-generation web tools. Second-generation web tools such as blogs, wikis and podcasts are asynchronous in nature, not suitable for real-time remote lab collaboration.

Text messaging chat supports synchronous communication between two remote partners. As defined by Downing et al. (2009), online chat refers to any kind of communication over the Internet, but primarily describes direct one-on-one chat via text-based messaging. One of the major negatives of text chat is that the conversation is not mediated with verbal or oral cues between the lab partners. This means that careful attention must be given to the flow of the text conversation to avoid the lab partners interrupting each other. In the remote lab, this added attention to the communication process distracts from the work at hand and burdens the learners with additional mental load (Hauber, Regenbrecht, Billinghurst & Cockburn, 2006). An analysis of the flow of text messaging chat conversations frequently shows some mixing of topics or thoughts. This is due in a large part to the time lag involved in composing and typing the messages and the transport time required between the user's PCs (MacDonald & Caverly, 2000). A leader-follower protocol can be used to help mitigate this problem, but that arrangement contradicts the concept of collaboration of equals between the remote lab partners.

Voice chat is the means of communicating with voice or audio through messenger or web meeting software applications enabled by the Internet. Voice chat has led to a significant increase in distant communications where two or more people can to use computers as a telephone conferencing system (Downing et al., 2009). Das, Imbertson and Mohan (2007) indicate that audio communication between lab partners is a desired step above using text messaging chat in a collaborative lab experience. The time delay between communication events involved in typing the text messages is removed when voice chat audio communication is used, noting that transport time for the audio signal across the web remains. The mental load on the lab participants for reading and processing the text messages is removed. Further, the workspace on the PC screen is also made simpler since voice chat communication can be supported with the associated web meeting software windows minimized in many instances.

A webcam is a video capture device connected to a computer. A webcam video with voice chat communication tool is simply the combination of a webcam video display with the audio capability of voice chat (Downing et al., 2009). Web cameras are often used in conjunction with audio for video telephony, permitting a computer to act as a video conferencing station. In the macro view, video-mediated communication aids in the support of social presence. More importantly, video allows for speakers and listeners to use gaze to exchange and maintain roles, to regulate turn taking behavior, to signal attention or boredom, and to give and seek feedback via short glances (Hauber et al., 2006). In voice chat and text messaging chat, a significant amount of mental attention must be focused by those communicating to extract such verbal cues by listening or reading.

Contribution to the Field

Li, Esche and Chassapis (2007) reinforce the points made previously in this Review of Literature, namely (a) that the remote lab concept has been proven to be an engaging learning environment for learners of technical subject matter, (b) that presence is an important issue in the remote lab environment, and (c) that many remote lab applications exist but no standard approach exists for the design of the lab environment or the selection of user collaboration tools. This work was performed to the end of adding to the body of knowledge involved with remote lab design, specifically in the area of on-line collaboration between lab partners during exercises which involve topics in automation.

Chapter 3

Methodology

In the distance education remote lab field no standards of practice or paradigms exist to guide remote lab designers in the selection of collaboration tools that best support learning achievement. Specific to collaboration methods that remote lab learners can use, this work adds to the body of knowledge involved in the selection and use of collaboration methods, to the end of determining which is most effective in terms of learning achievement for remote labs involving topics in automation.

Research Design

Johnson and Howell (2006) assert that experimental research is particularly well suited to web-based instructional environments. In the true experiment, research participants are randomly assigned to the treatment conditions. In certain quasi-experiment designs, treatments, outcomes measures, and experimental units can all exist, but not random assignment (Cook & Campbell, 1979). Convenience or natural occurrence selection is necessary. Thus, the quasi-experimental design approach of *repeated measures* or *with-in subjects* was used (Hoyle, 1999; Leedy & Ormrod, 2001).

All participants received all experiment treatment conditions, thus serving as their own control. This design approach, did however, have a distinct disadvantage due to the potential of a sequencing effect or multiple-treatment interference, as described by Gay and Airasian (2003). The sequencing effect was mitigated by *counterbalancing*, where the treatments were applied in different order to the participants.

Specifically, the participants worked in two-person teams, each using one of the three treatments, namely (a) text messaging chat, (b) voice chat, or (c) webcam video with voice chat, during each lesson. The two-person team member pairings for each lesson were randomly assigned. The treatments were applied in a different order from team-to-team for the six-lesson set. As the teams completed three lessons involving logic programming and three lessons involving robot programming, each treatment was experienced two times by each participant. The three logic programming lessons were completed in sequential order, as were the three robot lessons. However, the two sets of lessons were designed to be stand-alone in content. In order to further mitigate sequencing, one-half of the participants completed the robot lessons first, while the other half completed the logic programming lessons first.

Instrument Development

The instruments used for assessing learning achievement were designed by the researcher and can be found in Appendix A. Steps were taken to mitigate the issues of assessment reliability and validity and to substantiate the quality of the learning material content. First, the complete AutomationTek system was reviewed and critiqued by two subject matter experts, namely Dr. Jeffrey G. McNabb and Dr. Larry J. Heath. Dr. McNabb was a university Associate Dean, having served in a variety of roles in education for over 25 years. Dr. Heath was retired, after teaching at the university level in the field of Automation Education for 40 years. The subject matter experts reviewed the complete remote lab based learning system, noting that Dr Heath was involved in the initial design of AutomationTek in 2001. They critiqued the content of the learning materials, the operation of the remote lab equipment and the substance of the assessment and survey questions. The recommendations of Dr. Heath and Dr. McNabb were noted and incorporated. The resulting changes to the lesson materials and assessments constitute the validity analysis for the assessments (Johnson & Christensen, 2000).

Next, as outlined by McMillan and Schumacher (2006), a pre-experiment pilot run of the system was executed, as part of the grant activities involved with the design and use of AutomationTek. The first pilot run consisted of five teams, for a total of 10 ISU undergraduates who completed the six lesson sequence and the six assessments. The subjects in the pilot run were furnished with one treatment only, in order to yield better consistency (Leedy & Ormrod, 2001). The collaboration treatment used was webcam video with voice chat. The lab partners were randomly assigned for each lesson. The internal consistency of the pilot run assessments was estimated using Cronbach's Alpha model (Johnson & Christensen, 2000). As shown in Appendix B, Table 7, an estimated reliability of 0.728 was measured. McMillan and Schumacher (2006) state that a reliability of 0.8 or better is generally expected for achievement results. Hoyle (1999) indicates that larger sample sizes typically yield higher internal consistency results. Accordingly, a second pilot run was performed with an additional 10 subjects and the assessment data were appended to those of the first pilot run. Table 8 in Appendix B shows that an estimated reliability of 0.804 was achieved as a result of increasing the sample size.

In order to assure that the subjects did not have prior experience with the lesson topics, scores on a pretest were used to qualify the subjects. The validity of the pretest was substantiated by the subject matter experts. The reliability of the pretest was estimated using the test-retest method. Leedy and Ormrod (2001) indicate that for a single assessment with a relatively small number of questions (10), the test-retest method is appropriate. The 20 subjects from the first and second pilot runs were given the pretest on two occasions. The time period between the pretests was approximately one week, as suggested by D'Agostino (2005). The internal consistency of the pretest assessments was estimated using Cronbach's Alpha model (Johnson & Christensen, 2000). As shown in Appendix B, Table 9, an estimated reliability of 0.853 was measured which is acceptable (McMillan & Schumacher, 2006). Finally, the results on the pilot runs of the pretest were used to set the maximum allowable score on the pretest.

A five question survey was designed by the researcher and appended to each of the lesson assessments. This normative survey asked the subjects to rate their preference to one of the three treatments after each experience with a specified treatment. User preference data was correlated to each of the research questions. Using the guidelines of Leedy and Ormrod (2001) concerning validity in qualitative research, the survey question content was reviewed and verified by the subject matter experts. Further, a pilot test for the survey was executed using the subjects that participated in assessment pilot runs one and two. The comments of the 20 participants in the pilot runs indicated that the survey questions were clear in format and meaning.

Approach

The support of remote lab user collaboration was accomplished via Adobe® Connect Enterprise™ web meeting software. Adobe® Connect™ was selected to support remote lab user collaboration during the initial design of AutomationTek (Heath & Ashby, 2007). Adobe® Connect™ allows users to conduct online meetings, events, and seminars in which hosts can show multimedia presentations, share screens, and broadcast live audio and video to attendees in real time. Adobe® Connect™ was made available by Indiana State University for AutomationTek so that two remote lab users could enter the web meeting and use either text messaging chat, voice chat or webcam video with voice chat. The users were furnished microphone headsets and PC mounted web cameras during the remote lab sessions. The web camera was positioned to show the remote lab user's face and upper body. Depending on the treatment method (text messaging chat, voice chat or webcam video with voice chat) that was selected for use for a specific lesson by the administrators, the appropriate collaboration tool was installed on the PC and displayed in the Adobe® Connect™ meeting. For example, if text messaging chat was the selected treatment for a lesson, the text chat window was open when the users entered the web meeting via their PCs and they found their microphone and camera capability blocked. Screen shots of a typical web meeting are shown in Appendix C, along with the specifications for the version of Adobe® Connect™ that will be used.

The AutomationTek set of six lessons with remote labs was delivered as a component of four technology projects courses at ISU College of Technology. Subjects were recruited to participate from this population. Informed consent practices were accomplished. The qualifying pretest was used to disqualify subject with measurable prior knowledge, adding to the consistency and homogeneous nature of the population, as detailed by Leedy and Ormrod (2001). The scheduling of the subjects through the lesson materials, remote labs and treatments was performed to accomplish random team member pairings, different order of exposure to the treatments and different order of lesson topics. The counterbalancing of the treatments through scheduling was necessary to mitigate the sequencing effect as described by Gay and Airasian (2003). The scheduling process and the delivery of the lessons and remote labs were accomplished through a learning management system. Each lesson commenced with a presentation of the subject matter. The materials were made available for download by the learners prior to the lab sessions and required approximately thirty minutes to review. Each lab exercise consisted of step-by-step instructions consistent with the theme of the lesson, culminating with either an equipment operation exercise or a programming and debugging task. The collaboration between the lab partners was supported by a web meeting tool, preconfigured to support the treatment (text messaging chat, voice chat or webcam video with voice chat) that was scheduled for each team. One hour for completion of each the remote lab exercise was allowed. The students were scheduled to complete three lessons per week. The time-on-task allowed and the scheduling process was used during the pilot runs and approved by the subject matter experts (Johnson & Christensen, 2000). Each lesson concluded with a learning achievement assessment and a survey, completed by each team member individually. The subjects were required to complete each lesson assessment and survey before the next lab session was scheduled. The timely completion of the quantitative assessment and the qualitative survey after each treatment experience was important according to McMillan and Schumacher (2006).

Concerning sample size, Leedy and Ormrod (2001) indicate that for small populations ($N < 100$); sampling techniques are not necessary as the sample should be a census. Sixty qualified subjects participated. An $N = 60$ is generally considered adequate to produce a meaningful sampling distribution (Bartz, 1999; Gay & Airasian, 2003).

Trochim and Donnelly (2008) describe threats to validity from social interaction factors such as treatment diffusion or rivalry. Since the participants were all undergraduates at the same university and college of study, these threats were present. Actions that helped to mitigate these issues included that the study participants were from different peer groupings as they were recruited from four separate daytime and evening courses in four different undergraduate degree programs. Also, the length of the data collection period was limited, namely four weeks. Finally, the two-person team member pairings for each lesson were randomly assigned and the treatments were applied in a different order from team-to-team.

Data Collection

Since the lesson assessment data collected were of the interval type, parametric statistics were used. Analysis commenced by calculating the descriptive statistics, including mean and standard deviation for each treatment group. Analysis of variance tools were then used (Bartz, 1999; Terrell, 2004). A Levene homogeneity of variance test was performed to assure a comparable degree of variance within each of the sample groups. Next a one-way ANOVA test was employed to test for the existence of a significant difference between the groups. Significant results were obtained in the overall analysis of variance, so post hoc comparisons were conducted, namely the Tukey Honestly Significant Difference (HSD) test (Johnson & Christensen, 2000).

The statistical analysis was based on one independent variable, namely the collaboration tool used, with three levels in the independent variable (a) text messaging chat, (b) voice chat, and (c) webcam video with voice chat. Learning achievement was the single dependent variable. The data from the three independent variable treatment groups consisted of the test scores from the six assessments that accompanied the remote lab lessons. Statistical analysis was applied to these group assessment scores. In order to furnish tangential data, Likert scale data from the survey completed at the end of each lesson assessment was also collected. In a method outlined by Johnson and Christensen (2000), these data were used to track the opinion of each participant through the process of experiencing each of the treatments. Since the treatment order was known and varied for each participant, this analysis was organized on a per-subject basis. The uniformity of the survey responses, particularly after all three of the treatments had been experienced at least once, was used in drawing conclusions in support of the assessment score data. Time-on-task to complete the remote lab exercises was also recorded.

Resources

Figure 1 shows the architecture of the remote lab system that was used. AutomationTek consisted of four PLC based trainers and four educational robot trainers, along with the necessary web delivery systems. Specifically, the robots were Microbot

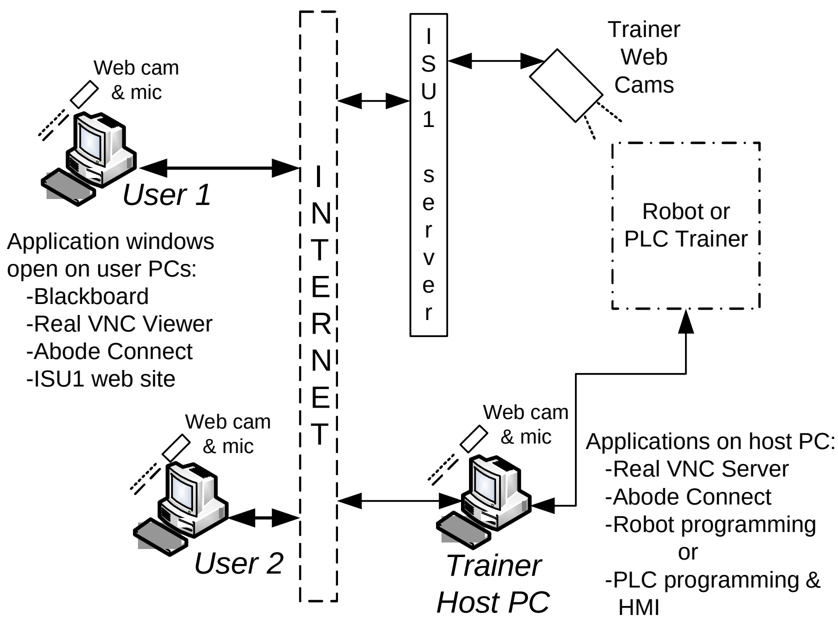


Figure 1. System architecture diagram for AutomationTek remote lab.

TeachMover brand, which support five axes of motion. The end-of-arm tooling on the Microbots consisted of a finger type gripper, suitable for pick-and-place operations. Microbot Control Center (MCC) application software located on the robot trainer host PC was used by the learners to manually operate each axis, as well as to develop and debug robot motion programs. The Microbot brand PLC trainers utilized integral input and output signal processing hardware. The input devices on the remote lab trainers included a software-based Human-Machine Interface (HMI) with two push buttons for entering discrete signals and two ten-digit thumbwheel switches for entering numeric data. Six proximity switch discrete inputs to the PLC provided status feedback of the pneumatic clamping cylinders. The output devices on the PLC trainer consisted of two panel lamps, one red-yellow-green stack light assembly and four pneumatic solenoid valves which powered the two pneumatic clamping cylinders. The application software on the PLC trainer host PC allowed for the development and debug of ladder logic programs used to operate the functions on the trainer. Pictures and specifications for the robot and machine control trainers can be found in Appendix D.

AutomationTek Learning Management System

The web portal for student access to AutomationTek was developed using the Blackboard™, Inc. learning management system. As shown in Appendix E, links to lab scheduling forms, student access portals to the learning subject matter, instructions on the use of the remote lab equipment, links to the assessments and links to the remote lab trainer systems were all available to the user in the AutomationTek Blackboard™ web site. During each on-line remote lab session the user first made a web link connection to an Adobe® Connect™ web meeting which supported either the text messaging chat, voice chat or webcam video with voice chat interface to their respective lab partner, as assigned by the schedule and configured by the lab assistants. Next the user opened a web camera link presented in the AutomationTek website, displaying three camera views of the assigned remote lab trainer. Finally a ©RealVNC virtual web connection was made to the assigned lab trainer host PC by each user. This allowed the two lab partners access to the programming software and manual operations panel HMI for the equipment on the trainer via the application software on the trainer host PC. The step-by-step lab exercise was then accomplished by the two-person lab team.

Samples of the lesson content are shown in Appendix F. The remote lab exercise titles included: (a) Moving Blocks with a Robot, (b) Stacking Blocks with a Robot, (c) Programming a Robot, (d) Automation and the PLC, (e) Developing a PLC Program, and (f) Designing and Debugging a PLC Program. The lesson material was designed for a learner with no previous experience with robots or PLCs.

Participants

The participants were undergraduate junior and senior COT majors at ISU, majoring in Electronics and Computer Engineering Technology, Mechanical Engineering Technology, Technology Education and Information Systems Technology. The demographics of these students paralleled that of ISU freshman, in that: (a) they came from middle income families, (b) were not minorities, (c) resided in small towns or rural areas, and (d) neither of their parents have a four-year college degree (Indiana State University, 2006). Based on the gender demographics of the potential participants, two percent were female. Given their academic backgrounds, the participants had the computer skills and technical background necessary to successfully participate.

Support

The researcher managed the operation of AutomationTek, along with all scheduling and coordination of data collection. Lab assistants were available to configure the Adobe® Connect™ web meeting software for each lab session, monitor the communication between the lab partners and respond to requests for assistance using the communication tool that was designated.

Research Questions

McMillan and Schumacher (2006) indicate that the purpose of developing research questions is to assist in defining the scope of the research work. To this end, the research questions are reiterated and a discussion of the work to answer the questions follows.

Research question one - *Which commonly available web communication tools best support team collaboration in a remote lab environment involving automation type lab work?* Even and Ismail (2006) established that text messaging chat, voice chat and webcam video with voice chat are the commonly used collaboration media types currently in use. These three communication methods were the treatments, the independent variables, used in this research effort. The lab exercises involved student teams working on topics in automation. The quantitative lesson assessment results and qualitative survey question results were used as indicators of the best tools to support team collaboration.

Research question two - *How do the remote lab communication approaches selected (text messaging chat, voice chat, and webcam video with voice chat) best interoperate with automation lab exercises which involve designing control language programming, downloading and debugging programs and performing analysis of results?* The participants developed, downloaded, debugged and evaluated results during the lab exercises, as evidenced by the content of the lessons. The quantitative data were collected and analyzed to the end of measuring learning achievement. Shin (2001) states that there is a significant linkage between learning achievement and the quality of collaborative processes in a distance education environment. Thus the quantitative data collected can and was linked to interoperatability. The survey questions allowed the participants to indicate preference to specific treatments, which also was linked to the quality of operation.

Research question three - *Which combination of currently available remote lab collaboration tools, namely text messaging chat, voice chat, and webcam video with voice chat, most positively impact learning outcomes in a remote lab environment involving automation type lab work?* Again the quantitative results which came from lesson assessments were used to indicate learning achievement and learning outcomes. Also the qualitative survey questions were used to indicate user preferences to collaboration tools, showing correlation between student preferences to the tools and learning outcomes (Wang, 2004).

Summary

Distance education remote lab applications are continuing to be designed, developed and deployed in the field of engineering and technology education. A standard design for the remote lab does not exist. One key pedagogical component of lab work is teaming or collaboration between lab partners. The communication tools commonly available in web meeting applications, namely text messaging chat, voice chat and webcam video with voice chat are typically those used to support remote lab collaboration. Quantitative experiments were executed and statistical analysis performed in an attempt to identify correlations between the specific remote lab collaboration tools used and learning achievement. Ancillary to the quantitative effort, surveys were used in an attempt to develop a qualitative evaluation of the effectiveness of the collaboration tools.

The intent was to add to the body of knowledge used in the design and application of remote lab technology to topics in engineering and technology education. Identification of the pedagogically best collaboration tool could be used by designers as a direction finder for the application of new technologies, as well as the improvement of the web collaboration tools that currently are being used.

Chapter 4

Results

The support of lab teams is a fundamental design requirement for remote lab systems, but remote lab teamwork is a research area that is largely unexplored. Students working in teams require effective collaboration tools which support the exchange of basic information along with social interaction, a sense of community and a feeling of presence. While this social interaction typically occurs in an unplanned and natural fashion in a traditional lab, the appropriate communication support tools must be purposefully designed and installed in the case of the remote lab.

Analysis

Collaboration plays an important role in knowledge building, particularly during lab experiences. Standards of practice or paradigms do not exist to guide remote lab designers in the selection of collaboration tools that best support learning achievement. The goal of this work was to add to the body of knowledge involving the selection and use of remote lab collaboration tools, to the end of providing distance education students with lab experiences that are equal in quality to face-to-face lab exercises. The commonly used collaboration media types currently in use in remote lab environments include text messaging chat, voice chat, and webcam video with voice chat. *Text messaging chat* refers to direct one-on-one text-based messaging, using tools such as instant messengers or web conferencing software. *Voice chat* is the means of communicating with voice or audio through messenger or web meeting software applications enabled by the Internet, where two or more people use computers as a telephone conferencing system. And *webcam video with voice chat* combines a webcam video capture device connected to a computer with voice chat. This allows for video telephony, the ability of user to view nonverbal facial gestures and expressions along with verbal exchange.

Design and Development

The effectiveness of three remote lab collaboration approaches was evaluated via quantitative and qualitative data collection and analysis. Specifically, randomly assigned two-person lab teams completed six learning modules, all involved with the topic of automation. Three lessons focused on robot programming and three on logic programming. One of the three treatments, namely (a) text messaging chat, (b) voice chat, or (c) webcam video with voice chat, was randomly assigned to the lab teams during each lesson. The support of remote lab user collaboration was accomplished via Adobe® Connect Enterprise™ web meeting software. The users were furnished microphone headsets and web cameras, where each user worked on a PC located in a different room from his or her lab partner. This forced all interaction between the lab partners to be accomplished via the assigned communication tool. Depending on the treatment method that was selected for use in a specific lesson, the appropriate collaboration tool was installed on the user's PC and displayed in the Adobe® Connect™ meeting.

A pretest was developed to assure that users did not have prior experience with the lesson topics. The reliability of the pretest was estimated using the test-retest method. At the end of each lab session, participants individually completed a learning assessment and a normative survey where they were asked to rate their preference for the communication treatment. The instruments used for assessing learning achievement were designed by the researcher. Steps were taken to mitigate the issues of assessment reliability and validity, which included reviews by subject matter experts and two pre-experiment pilot runs where internal consistency was estimated.

The six learning modules with remote labs were delivered to undergraduate junior and senior ISU College of Technology majors as a component of technology projects courses. Based on the size of this population, a census sampling of $N = 60$ was selected.

Implementation

The pretest was used to disqualify subjects with measurable prior knowledge. The results of the pretest pilot runs were used to set the disqualification point at any score over 30%. Six study subjects were disqualified and six replacement subjects were added to maintain an initial $N = 60$.

The scheduling of the subjects was performed to accomplish random team member pairings, different order of exposure to the treatments and different order of lesson topics. The scheduling of the lessons and remote labs was accomplished through a learning management system, namely Blackboard™. Each lesson commenced with the download of the subject matter reading material. One hour was allowed for each lab exercise, which consisted of step-by-step instructions, culminating with either an equipment operation exercise or a programming and debugging task. The assessments and surveys were delivered via the learning management system as well. Participants were required to complete the assessments and surveys for each lab session before progressing to the next lesson. Lab attendants were available to answer questions about use of the collaboration equipment as well as the robots and logic trainers, communicating via the collaboration tool selected for each specific lab team.

The subjects performed the lab work during a four week period of day and evening scheduled sessions. Sixty participants were scheduled to complete six lessons each for a total of 360 assessments and surveys. Due to issues such as students dropping classes and missing scheduled lab sessions, the data for seven students were removed from the analysis. This resulted in an N = 53 for a total of 106 assessment scores and survey results for each of the three treatments.

Evaluation

First, the quantitative results were evaluated. The descriptive statistics, including mean and standard deviation were computed for the assessment scores, as shown in Table 1. The mean and standard deviation data preliminarily suggested that the use of voice chat only produced the highest mean assessment scores and the lowest standard deviation.

Table 1
Quantitative Results - Descriptive Statistics of Assessment Scores

Treatment	Mean	*N*	Std. Deviation
Text Chat	75.3774	106	15.92689
Voice Chat	82.6415	106	10.98067
Webcam w. Voice Chat	80.7547	106	12.16538
Total	79.5912	318	13.50860

A one-way ANOVA was used to test for the existence of a significant difference between the groups. Specifically, the one-way ANOVA tests the null hypothesis that all three means are equal. As shown in Table 2, the *p* value ($p = 0.000$) indicates that the null hypothesis is rejected. The large value of the *F* ratio (8.651) provides further evidence against the null hypothesis. These results indicate that a statistical significance existed between the treatment assessment scores. The *Effect Size* of the outcome (eta) was 0.228.

Table 2
Quantitative Results - One-way ANOVA Analysis of Assessment Scores

	Sum of Squares	*df*	Mean Square	*F*	*p*	eta
Between Groups	3011.950	2	1505.975	8.651	.000	.228
Within Groups	54834.906	315	174.079			
Total	57846.855	317				

Leech, Barrett and Morgan (2008) state that this eta value is at the typical or medium guideline value for interpretation of the strength of the relationship that the analysis indicates.

Post hoc comparisons were then conducted, namely the Tukey Honestly Significant Difference (HSD) test. Table 3 shows all possible comparisons between the three treatment groups. The differences between pairs of means are in the column labeled

Table 3
Quantitative Results - Tukey Honestly Significant Difference Test of Scores

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Standard Error	*p*	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-7.26514	1.81232	.000	-11.5319	-2.9964
2	3	1.88679	1.81232	.552	-2.3809	6.1545
1	3	-5.37736	1.81232	.009	-9.6451	-1.1096

Mean Difference (I-J). Noting that the mean difference is significant between Treatment 1 (text messaging chat) and Treatments 2 (voice chat) and 3 (webcam video with voice chat) confirms that the use of text messaging chat as a communication tool negatively impacted learning achievement. Since the mean difference between assessment scores for Treatments 2 and 3 is not significant at the .05 level, then it is concluded that the somewhat higher mean shown in Table 1 for voice chat over webcam video with voice chat was not significant.

After each lesson assessment the subject was asked to assign a Likert scale preference rating to the communication treatment method he had just used. The Likert scale ratings were (a) 1 = *Strongly Not Preferred*, (b) 2 = *Not Preferred*, (c) 3 = *Neutral*, (d) 4 = *Preferred*, and (e) 5 = *Strongly Preferred*. To commence the analysis, descriptive statistics were used; specifically the mode was calculated. The data in Table 4 shows that the most frequent survey response to the use of voice chat was *Not Preferred* (47.2%), to Voice Chat was *Strongly Preferred* (55.7%) and to use of the Webcam with Voice Chat communication tool was *Preferred* (50.9%). The Kruskal–Wallis test was then used to

Table 4
Quantitative Results - Mode Statistical Analysis of the Likert Survey Data

Likert Scale Responses	**Text Chat Percent**	**Voice Chat Percent**	**Webcam w. Voice Chat Percent**
(1) *Strongly Not Preferred*	26.4	0	0
(2) *Not Preferred*	47.2	.9	1.9
(3) *Neutral*	22.6	5.7	25.5
(4) *Preferred*	2.8	37.7	50.9
(5) *Strongly Preferred*	.9	55.7	21.7

calculate the mean rank and the Chi-Squared statistics. Table 5 shows that the Voice Chat communication tool had the highest rank and the null hypothesis was rejected as indicated by the large Chi-Squared value and the p = 0.000 value.

Table 5
Quantitative Results - Kruskal-Wallis Analysis of the Likert Survey Data

Treatment	***N***	**Mean Rank**	**Chi-Square**	***df***	***p***
Text Chat	106	62.58	202.117	2	.000
Voice Chat	106	231.49			
Webcam w. Voice Chat	106	184.42			
Total	318				

Finally, the subjects were asked at the end of each lesson survey to post comments about their experience with the assigned remote lab communication tool. A summary of the quantity of responses and the categories of the comments is shown in Table 6. A tabulation of the responses is listed in Appendix G. Of the 177 comments recorded,

Table 6
Qualitative Results - Summary of Comments about Communication Tools

	Negative to Text Chat	Positive to Voice Chat	Positive to Webcam w. Voice Chat	Other - (unrelated to treatments)	Total
Comments (% total)	47%	17%	19%	17%	100%

those concerning text messaging chat were universally negative, accounting for 47% of the total responses. There were more affirmative comments (19%) about the use of a web camera for communication and presence than those who indicated that a webcam view of their lab partner was not needed or effectively used (17%). As detailed in Appendix G, comments directly related to the positive aspects of presence issues accounted for 8% of the responses. A total of 7 comments (4%) were made indicating that at the beginning of the session the lab partners used the web camera to establish a relationship, then as the work of the lab commenced they used verbal communication and paid little attention to their lab partner's web camera image.

Summary

A total of 53 ISU COT students completed six lessons and remote labs on topics in automation. The subjects worked in randomly assigned two-person teams. An assessment and a normative survey were completed by each subject at the end of each lesson, resulting in a total of 318 data samples. The quantitative and qualitative results were analyzed. The quantitative statistics indicate that text messaging chat as a communication tool negatively impacted learning achievement. There was not a statistical difference in assessment scores between learning modules where the subjects used voice chat verses those who used webcam video with voice chat. The Likert scale survey showed that the voice chat communication tool had the highest rank in user preference. To the end of the qualitative data, a total of 177 comments were posted by the study subjects where the text messaging chat treatment received universally negative comments. Affirmative comments concerning the use of a web camera for communication and presence were of note, as were comments about not needing a web camera, but to a lesser degree.

Chapter 5

Conclusions, Implications and Recommendations

Real experiments are indispensible in engineering and technology education for developing skills with physical processes and equipment. In order to offer such experience in the distance education learning environment, web based remote laboratories are being developed. The conversion of hands-on lab equipment, development of web ready systems and the interface of associated web applications to the equipment holds potential for the development of some engaging learning environments. However much work remains to design, construct and support pedagogically sound instructional processes, particularly where the delivery environment is the dynamic Internet.

Conclusions

The research questions, which guided the study, are used as a framework to discuss the findings. The first research question was: *Which commonly available web communication tools best support team collaboration in a remote lab environment involving automation type lab work?* As developed in the literature review, text messaging chat, voice chat and webcam video with voice chat are the commonly used collaboration media types currently used in remote labs. The statistical results of the Likert scale preference survey indicate that the use of voice chat was the preferred remote lab communication tool. In the general comments which were collected, a slightly higher number of affirmative responses were noted concerning the use of a web camera for communication and presence than for voice chat. Text messaging chat ranked statistically last in the preference survey and a large number of negative comments were posted by users after completing lab work using text messaging chat. Thus, in reference to this research question, voice chat and webcam video with voice chat best support collaboration in automation type remote lab work.

The second research question was: *How do the remote lab communication approaches selected (text messaging chat, voice chat, and webcam video with voice chat) best interoperate with automation lab exercises which involve designing control language programming, downloading and debugging programs and performing analysis of results?* As indicated in the first research question, the statistical results of the Likert scale preference survey indicate that the use of voice chat was the preferred remote lab communication tool while user comments suggested some users preferred webcam video with voice chat. A small number of comments, as shown in Appendix G, refer to issues involved with the amount of information required to be in view on the user's PC screen in order to accomplish the lab work. A virtual connection PC window was required by users to access the application software for the robots or logic trainers, along with another window for the two or three web camera views of the lab equipment. This arrangement of PC windows is shown in Figures 4 and 6 of Appendix D. If the user additionally wanted to view chat text or their lab partner's image, the Adobe® Connect™ window also had to be arranged on the PC screen. In contrast, to support voice chat, the web meeting software had to be open but could remain out of focus behind the other windows, not consuming screen space. This issue was the stated reason for the comments posted in support of voice chat. Thus, specific to the AutomationTek remote lab hardware and software system, voice chat appears to be the best communication tool to support the interoperation of automation lab work, supported by the qualitative statistics and explained by the user comments.

The final research question was: *Which combination of currently available remote lab collaboration tools, namely text messaging chat, voice chat, and webcam video with voice chat, most positively impact learning outcomes in a remote lab environment involving automation type lab work?* This question was partially addressed by the results of the quantitative data analysis. The statistical analysis of the assessment scores indicated that the use of text messaging chat as a communication tool negatively impacted learning achievement. However, the quantitative findings did not produce a definitive ranking between the voice chat and the webcam video with voice chat treatments. The qualitative data involved preference, which could not be related specifically to learning achievement. Thus, in reference to the third research question specific to the AutomationTek remote lab hardware and software system, text messaging chat was a detriment to learning achievement and either audio voice chat or webcam video with voice chat will equally support learning achievement.

Implications

The quantitative data collected in this effort indicates that for this particular remote lab system (AutomationTek), using text messaging chat as a communication method for two lab partners will negatively impact learning achievement. Additionally, the analysis of the qualitative data indicates that users did not prefer text messaging chat. The findings of this work leads to the inference that the use of text messaging chat is an undesirable communication method in remote lab work, and can be detrimental to learning achievement.

The form and function of automation labs parallel that of many engineering and technology lab systems. In these cases, there is a large amount of information that must be present on the PC screen, again as evidenced by Figures 4 and 6 of Appendix D. Also, 9% of the survey comments, as detailed in Appendix G, indicated that information arrangement on the PC screen was problematic. Thus, available space on the screen is a problem and space consumed by any web communication tool compounds the issue. These considerations lead to the conclusion that the best communication tool would be one that does not take space on the user's PC screen nor distract from the lab work.

The qualitative data suggest that the subjects were nearly equally divided on preference to voice chat verses webcam video with voice chat. The ability to exercise personal preference is an important feature in application software, allowing users to select their favorite tools and features. To the end of designing a remote lab environment and selecting collaborative communication tools involving automation equipment, the results of this work points to making voice chat the default method of communication. But, the webcam video with voice chat option should also be available as a configurable or selectable option, allowing users to arrange the work space and features to fit their needs at any time during the lab experience.

Recommendations

Standards do not exist for the development and implementation of remote lab equipment. At this time, web meeting software applications are the commonly available means of supporting remote lab communication. While Adobe® Connect™ was used in AutomationTek, there exists a number of web meeting software applications that can be used. Development work and research is needed involving the comparison of web meeting products and their associated features. Also, custom communication tools designed specifically for remote lab use could and hopefully will be developed in the future, allowing for a more transparent and efficient way of supporting communication between lab partners.

While not directly related to lab partner communication, the issue of information overload and the need for more efficient ways to present the remote lab software applications and tools on the user's PC screen did surface during this project. As remote labs continue to transition from single user, single experiment stations to those that support a range of experiments, program debug and testing capabilities and lab partner collaboration, issues involving the management and presentation of on-screen information are expected to increase in frequency and importance. A great amount of design and research work will be needed in this area.

Finally, as detailed in the literature review, the most complete set of remote lab design objectives currently available have been developed by ABET. These include (a) instrumentation, (b) models, (c) experimentation, (d) data analysis, (e) design, (f) learning from failure, (g) creativity, (h) psychomotor skills, (i) safety, (j) communication, (k) teamwork, (l) ethics, and (m) sensory awareness. Many of the objectives can be satisfied by directly transferring the applied technologies of face-to-face labs to remote lab designs. However the objectives of communication, teamwork and sensory awareness require special technology considerations. These needs are directly related to collaboration and presence. Research, design and innovation involving collaboration and presence need to continue. The benchmark for success will be to realize distance education remote lab experiences that are equal in quality to face-to-face lab exercises.

Summary

Practical lab work is an essential part of engineering and technology educational programs. The need for laboratory experiences in on-line science, engineering, and technology programs is being fulfilled using a number of approaches, with varying degrees of success. The remote lab approach allows learners to access traditional laboratory facilities through on-line digital portals which use Internet interfacing technology. Remote labs possess the interactive nature of simulations, yet deliver the reality of working in a traditional lab with real equipment. Collaboration, namely students working in teams on lab exercises, is a key ingredient in creating an effective learning environment. Small group collaboration enhances learning outcomes through the process of discussing technical issues and through social interaction. Another important area of concern in the design of remote lab delivery systems is the fostering and support of virtual or social presence. The primary tools available to support Internet based remote labs include web cameras, audio equipment, web conferencing software tools and the specialized interfaces required to allow remote operation of lab equipment. Due to the variety and complexity of laboratory equipment, along with the breadth of educational topics and needs, a standard approach for remote lab system architectures does not exist. The majority of remote labs developed to date suffer from a lack of support for collaborative group work.

The problem identified for investigation was that no standards of practice or paradigms exist to guide remote lab designers in the selection of collaboration tools that best support learning achievement. The goal was to add to the body of knowledge involving the selection and use of remote lab collaboration tools, to the end of providing distance education students with lab experiences that are equal in quality to face-to-face lab exercises. Text messaging chat, voice chat and webcam video with voice chat are the commonly used collaboration types currently used as social networking software tools. These are also the tools used by learners to collaborate via the Internet and form the basis for remote lab communication methods.

Experimental research was conducted where the participants received all experiment treatment conditions. Specifically, the participants worked in two-person teams, each using one of the three treatments, namely (a) text messaging chat only, (b) voice chat, or (c) webcam video with voice chat, during each lesson. The two-person team member pairings for each lesson were randomly assigned and the treatments were applied in a different order from team-to-team, for a six-lesson set of remote lab experiences involving topics in automation. The teams completed three lessons involving logic programming and three lessons involving robot programming. The participants were undergraduate technology majors, who had the computer skills and technical background necessary to successfully complete the remote lab based lessons. The researcher managed the operation of the remote labs, along with all scheduling and coordination of data collection. Lab assistants were available to respond to requests for assistance using the communication tool that was designated.

The remote lab equipment consisted of four programmable logic controlled (PLC) based trainers and four educational robot trainers, along with the necessary programming software and web delivery systems. The web portal for student access was developed using a learning management system. During each on-line remote lab session the user first made a web link connection to a web meeting which supported either the text messaging chat, voice chat or webcam video with voice chat interface to their respective lab partner. Next, the user opened a web camera link, displaying three camera views of the assigned remote lab trainer. Finally, a virtual web connection was made to the assigned lab trainer host PC by each user. This allowed the two lab partners access to the software tools involved with the lab equipment. The step-by-step lab exercise was then accomplished. Fifty three students completed the six lessons involved in the study, resulting in a total of 106 assessment scores and survey results for each treatment.

Quantitative instruments used for assessing learning achievement were designed by the researcher. Steps were taken to mitigate the issues of assessment reliability and validity and to substantiate the quality of the learning material content, which included the review of the learning system, assessments and surveys by two subject matter experts. Two pre-experiment pilot runs were then executed to validate the reliability of the instruments. In order to assure that users did not have prior experience with the lesson topics, scores on a pretest were used to qualify the subjects. A five question survey was also designed by the researcher and appended to each of the lesson assessments to collect qualitative data. This normative survey asked the subjects to rate their preference to one of the three treatments after each lesson experience.

Analysis commenced by calculating the descriptive statistics for the quantitative data. The mean and standard deviation of the quantitative data preliminarily suggested that the use of voice chat produced the highest mean assessment scores and the lowest standard deviation. A one-way ANOVA test resulted in a low significance level (p = .000), indicating that the null hypothesis was rejected. The large value of the F ratio (8.651) provided further evidence against the null hypothesis. These results indicated that a statistical significance existed between the treatment assessment scores. Post hoc comparison, namely the Tukey Honestly Significant Difference (HSD) test, was executed. The HSD test confirmed that the use of text messaging chat as a communication tool negatively impacted learning achievement. Also, concerning the assessment score analysis, there was not a statistical difference in assessment scores between learning modules where the subjects used voice chat verses those who used webcam video with voice chat. After each assessment the subject was asked to assign a Likert scale preference rating to the communication treatment method they had just used. The results indicated that voice chat was the preferred remote lab communication tool.

Next the qualitative data were evaluated. The subjects were asked to post comments about their experience with the assigned communication tool. Of the comments received, those related to using text messaging chat were universally negative. There were more affirmative comments about the use of a web camera for communication and presence than those who indicated that the webcam was not needed or effectively used. Four percent of the comments indicated that at the beginning of the session the lab partners used the web camera to establish a relationship, then as the work of the lab commenced they used verbal communication and paid little attention to their lab partner's web camera image.

The findings of this work leads to the inference that the use of text messaging chat is an undesirable communication method in remote lab work, and can be detrimental to learning achievement. Next, due to the large amount of information that must be present on the PC screen during remote lab work, the available space on the screen is a problem and space consumed by any web communication tool is unwelcomed. These considerations, which were supported by user comments in this work, led to the conclusion that a desirable communication tool would be one that does not take space on the user's PC screen nor distract the user from the lab work.

The subjects were nearly equally divided on preference to voice chat verses webcam video with voice chat. To the end of designing remote lab collaborative communication tools involving automation equipment, the results of this work points to making voice chat the default method of communication; but the webcam video with voice chat option should also be available as a configurable or selectable tool.

Standards do not exist for the development and implementation of remote lab equipment. Development work and research is needed involving the comparison of web meeting products and their associated features. Also, custom communication tools designed specifically for remote lab use hopefully will be developed in the future. The most complete set of remote lab design objectives currently available have been developed by ABET. The design objectives of communication, teamwork and sensory awareness require special technology considerations. These needs are directly related to collaboration and presence. Research, design and innovation involving collaboration and presence should continue. The benchmark for success will be to realize distance education remote lab experiences that are equal in quality to face-to-face lab exercises.

Appendix A

Assessment Instruments

Pretest

Add Question Here

Question 1 **Multiple Choice** **10 points** Modify Remove

Question A PLC is ....

Answer
- a computer.
- designed for use in industrial applications.
- programmed using ladder logic.
- ✓ all of the above - a, b & c.

Add Question Here

Question 2 **Multiple Choice** **10 points** Modify Remove

Question

Robots possess multiple axes which allows for complex motion. The number of axes on a robot is called ....

Answer
- the motion capability index.
- the robot axis application number.
- ✓ the number of degrees of freedom.
- the robot poistioning sequence number.

Add Question Here

Question 3 **Multiple Choice** **10 points** Modify Remove

Question What is the most common application of robot technology in use today?

Answer
- ✓ Industrial applications.
- Medical applications.
- Personal assistance.
- Education.

Add Question Here

Question 4 **Multiple Choice** **10 points** Modify Remove

Question What is the purpose of the robot *teach pendant*?

Answer
- The robot teaches the user where positions exists by displaying them on the teach pendant.
- ✓ The teach peadant is used for manual control of the robot.
- The teach pendant is used for automatic control of the robot programs.
- Robots do not have teach pendants.

Add Question Here

Question 5 | **Multiple Choice** | **10 points** | Modify | Remove

Question Can robots have digital I/O?

Answer
- ✓ Yes. Most robots support hardware inputs and outputs.
- No. Robots do not have I/O. If you have I/O you need a PLC.
- Robots only support analog signals, not digital I/O.
- I/O is not digital.

Add Question Here

Question 6 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is ladder logic?

Answer
- A robot programming language.
- ✓ A graphical programming language widely used for PLCs.
- A graphical PLC programming language that was used 50 years ago, but not now.
- A text based PLC programming language.

Add Question Here

Question 7 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is a normally open contact, in the context of relay logic?

Answer
- ✓ A contact that is open or false when the relay is de-energized.
- A contact that is closed or true when the relay is de-energized.
- Relays do not have contacts.
- Normally open means that the relay contact remains open for a time period after the relay coil is powered, then it closes.

Add Question Here

Question 8 | **Multiple Choice** | **10 points** | Modify | Remove

Question In a robot program, what does the command Move x = 5.0 mean?

Answer
- The 5 indicates that the 5th axis will be moved.
- Move commands are not part of robot programs.
- The Move command is the 5th positon command in the robot program.
- ✓ This shows the x axis position of the robot coordinates.

Add Question Here

Question 9 | **Multiple Choice** | **10 points** | Modify | Remove

Question What type of machine would most likely be found performing an automated welding application?

Answer
- A PLC.
- ✓ A Robot.
- A movable welder.
- None of these.

Add Question Here

Question 10 | **Multiple Choice** | **10 points** | Modify | Remove

Question How many states can a digital or discrete logic element have?

Answer
- 1
- ✓ 2
- 3
- The number depends on the range of the signal.

PLC Logic Programming Lesson 1 Assessment

Add Question Here

Question 1 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is the purpose of the PLC on the trainer?

Answer
- a. The PLC is used to program the PC on the trainer.
- ✓ b. The PLC controls the trainer devices by executing a program.
- c. The PLC has no real use on the trainer.
- d. The PLC is a junction point for the device wires on the trainer.

Add Question Here

Question 2 | **Multiple Choice** | **10 points** | Modify | Remove

Question A PLC is........

Answer
- a. a computer.
- b. designed for use in industrial surroundings.
- c. programmed using ladder logic.
- ✓ d. all of these - a,b&c..

Add Question Here

Question 3 | **Multiple Choice** | **10 points** | Modify | Remove

Question Which of these devices are connected as PLC *inputs* on your trainer?

Answer
- ✓ a. The push buttons (thru software on the host PC).
- b. Indicating lamps.
- c. The pneumatic (air) cylinders.
- d. All devices on the trainer are connected as PLC inputs..

Add Question Here

Question 4 | **Multiple Choice** | **10 points** | Modify | Remove

Question

Which of these devices are connected as PLC *outputs* on your trainer?

Answer
- a. The push buttons (via software) on the host PC.
- ✓ b. Indicating lamps.
- c. Thumbwheel switches.
- d. All devices on the trainer are connected as outputs from the PLC.

Add Question Here

Question 5 | **Multiple Choice** | **10 points** | Modify | Remove

Question

The steps in a PLC scan .....

Answer
- a. Jump from reading inputs to writing outputs as needed.
- ✓ b. Are: read inputs, solve the logic program, write outputs and communicate with the PC.
- c. Are turned on and off by special outputs.
- d. Are: solve logic, write outputs and communicate with the PC.

Add Question Here

Question 6 | **Multiple Choice** | **10 points** | Modify | Remove

Question How is communication accomplished between the PLC and the host PC on your trainer?

Answer
- a. They are connected by Ethernet.
- ✓ b. They are connected by a serial communication cable.
- c. There is no connection.
- d. Floppy disks or flash drives are required to accomplish file transfers.

Add Question Here

Question 7 **Multiple Choice** **10 points** Modify Remove

Question What does *on-line* mean (or what is accomplished during on-line connection) in terms of the PLC?

Answer

a. We are downloading a logic file to the PLC from the PC.
b. We are monitoring a logic address and the ladder in the PLC.
c. The PC and the PLC are communicating over the serial cable.
✓ d. All of these: a,b&c.

Add Question Here

Question 8 **Multiple Choice** **10 points** Modify Remove

Question

Once the PLC programming software indicates it is connected to the PLC (on-line), are we viewing the logic that is in the PLC?

Answer

a. Yes. Once we establish communication with the PLC we are viewing it's logic.
b. You never view the actual logic in the PLC.
✓ c. At the time of connection, if the logic in the PLC exactly matches the logic in the PC file we have open, then connection will take place. If the on-line and off-line files do not match, you must download the Disk or PC file version.
d. None of the above answers are correct.

Add Question Here

Question 9 **Multiple Choice** **10 points** Modify Remove

Question When a PLC input (push button for example) changes from Off to On, how long before the resulting PLC logic takes affect?

Answer

a. There is a one second delay between the reading of inputs and the setting of outputs.
b. There is absolutely no delay between the change of an input and the resulting output.
✓ c. The PLC scan controls this. The PLC reads inputs, solves logic and sets outputs, about 40 times each second.
d. Inputs are faster than outputs.

Add Question Here

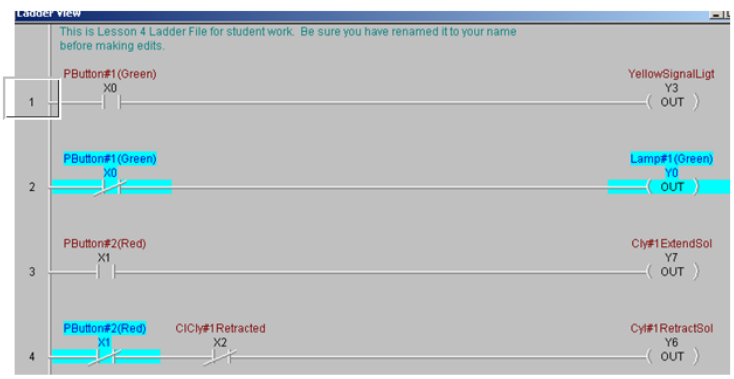
Question 10 **Hot Spot** **10 points** Modify Remove

Question

The attached image shows four PLC ladder rungs. Click on the rung number to enter your answer to the question.

Answer

Four rungs of PLC logic are shown. Which rung (1,2,3 or 4) energizes the Yellow Signal Light? Click on the rung number (number at left of rung) to indicate your answer.



PLC Logic Programming Lesson 2 Assessment

Add Question Here

Question 1 | **Multiple Choice** | **10 points** | Modify | Remove

Question The PLC scan has 4 steps. What happens during the second step?

Answer
- a. The inputs are read.
- b. The outputs are set.
- c. The PLC alwats skips step 2.
- ✓ d. The ladder logic is scanned and solved.

Add Question Here

Question 2 | **Multiple Choice** | **10 points** | Modify | Remove

Question What are logic elements?

Answer
- a. The ladder rungs.
- b. The scan steps.
- c. Any logic symbol that is on a rung.
- ✓ d. None of these.

Add Question Here

Question 3 | **Multiple Choice** | **10 points** | Modify | Remove

Question Which direction does the PLC scan the ladder?

Answer
- ✓ a. Always top to bottom.
- b. Always bottom to top, just like a person climbs a ladder.
- c. The direction is determined by the program.
- d. Step three of the scan sets the direction.

Add Question Here

Question 4 | **Multiple Choice** | **10 points** | Modify | Remove

Question

How are I/O addresses assigned on your trainer PLC?

Answer
- a. Outputs start with X, inputs start with Y and the numbering starts with 1.
- ✓ b. Inputs start with X, outputs start with Y, numbering starts at 0 and the numbers 8 and 9 are always skipped.
- c. Input X0 abd output Y0 do not exist.
- d. You number the I/O anyway you want in the PLC program.

Add Question Here

Question 5 | **Multiple Choice** | **10 points** | Modify | Remove

Question

PLC output Y5 is connected to an orange lamp. If you have program logic which turns On output Y5 on ladder rung#2 and you also have ladder program logic which turns Off output Y5 on rung#21, what will be the state of the orange lamp?

Answer
- a. The orange lamp will be On.
- ✓ b. The orange lamp will be Off.
- c. The state of the orange lamps depends of the scan direction.
- d. The orange lamp will flash.

Add Question Here

Question 6 | **Multiple Choice** | **10 points** | Modify | Remove

Question We refer to *normally* open and *normally* closed logic elements. What does *normal* mean?

Answer
- a. Normal means before the logic is scanned.
- b. Normal means before the machine operates.
- c. Normal always means Off.
- ✓ d. Normal refers to when no one has touched the logic device and it is sitting on the self in the store.

Add Question Here

Question 7 **Multiple Choice** **10 points** Modify Remove

Question How many states can a PLC logic elements or device have?

Answer
- a. Many.
- b. One.
- c. The number of logic states for logic elements and devices differ.
- ✓ d. Two. Either On or Off.

Add Question Here

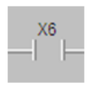
Question 8 **Hot Spot** **10 points** Modify Remove

Question

Click on the best answer.

Answer

Select the best response (a,b,c or d) that describes this ladder logic programming symbol:



- a. A NC logic element.
- b. A NO logic element.
- c. A push button.
- d. A separator.

Add Question Here

Question 9 **Hot Spot** **10 points** Modify Remove

Question Click on the best answer.

Answer

Select the best response (a,b,c or d) that describes this ladder logic programming symbol:

- a. A NC logic element.
- b. A NO logic element.
- c. A push button.
- d. A divider.

Add Question Here

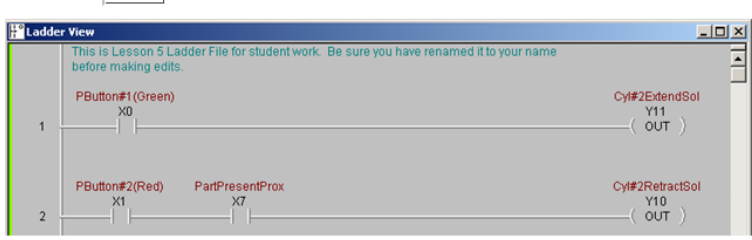
Question 10 **Hot Spot** **10 points** Modify Remove

Click on the best answer (a,b,c or d).

Answer

For the ladder logic rungs shown below monitoring a PLC program that is running, if input X1 is true and input X7 is On:

- a. Output Y11 must be Off.
- b. Output Y11 must be false.
- c. Output Y10 will be false.
- d. Output Y10 will be true.



PLC Logic Programming Lesson 3 Assessment

Add Question Here

Question 1 **Multiple Choice** **10 points** Modify Remove

Question For the PLC ladder logic shown, could the red signal light Y4 and the sounder Y5 ever both be On at the same time?

Answer

- ✓ a. Yes.
- b. No.
- c. It depends on the C0 seal-in.
- d. Y5 will never turn On.

Add Question Here

Question 2 **Multiple Choice** **10 points** Modify Remove

Question For the PLC ladder logic shown, what kind of I/O device is C0?

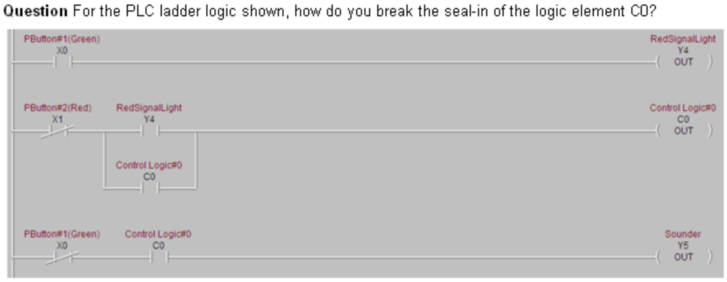
Answer

- a. A PLC input.
- b. A PLC output.
- c. A counter.
- ✓ d. A control logic programming element.

Add Question Here

Question 3 **Multiple Choice** **10 points** Modify Remove

Question For the PLC ladder logic shown, how do you break the seal-in of the logic element C0?



Answer

- ✓ a. Press PB#2.
- b. Press PB#1.
- c. Output Y5 will turn Off C0.
- d. Output Y4 will turn Off C0.

Add Question Here

Question 4 | **Multiple Choice** | **10 points** | Modify | Remove

Question

For the PLC ladder logic shown, how do the red signal light and the sounder logically operate?

Answer

a. The red light and the sounder are always on at the same time.

✓ b. The red light turns On because someone pressed PB#1. Once PB#1 is released, the sounder turns On and stays On until someone presses PB#2.

c. If the sounder is On, then someone is pressing PB#2.

d. The sounder will never operate in this logic configuration.

Add Question Here

Question 5 | **Multiple Choice** | **10 points** | Modify | Remove

Question

For the PLC ladder logic shown, what happens if you press PB#2 and hold it?

Answer

a. The red signal light will never turn On.

b. The sounder will never turn Off.

✓ c. The sounder will never turn On.

d. The red light will flash.

Add Question Here

Question 6 | **Multiple Choice** | **10 points** | Modify | Remove

Question

When programming the TMR logic instruction:

Answer

a. The TMR box must always be placed on the far right end of a rung.

b. All logic elements on the left of the TMR must be true to cause the timer to start.

c. The K value is the timer present value.

✓ d. All these - a,b,c &d.

Add Question Here

Question 7 | **Multiple Choice** | **10 points** | Modify | Remove

Question Which is the proper K vaue for a one minute time delay?

Answer

a. 10.

b. 6.

c. 60.

✓ d. 600.

Add Question Here

Question 8 | **Multiple Choice** | **10 points** | Modify | Remove

Question How do you trun Off or reset a TMR logic element?

Answer
a. Use the TMR Off instruction.
b. Change the K value.
✓ c. Turn Off any of the logic elements to the left of the TMR box on the rung.
d. None of these.

Add Question Here

Question 9 | **Multiple Choice** | **10 points** | Modify | Remove

Question

For the PLC logic shown, which answer (a,b,c or d) best describes the operation of timer #0.

Answer
a. Timer #0 will not operate if output Y4 is On.
b. Timer#0 causes the green signal light to illuminate after 6 seconds.
✓ c. After timer#0 has been enabled for 60 seconds, the green signal light will seal-in if the yellow signal laigh is Off.
d. After timer#0 has been tining for 60 seconds the red signal light will turn Off because the green signal light will seal-in in the true condition.

Add Question Here

Question 10 | **Multiple Choice** | **10 points** | Modify | Remove

Question Which timer identification number is not allowed in your trainer PLC instruction set?

Answer
a. T0
b. T5
c. T10
✓ d. T9

Robot Lesson 1 Assessment

Add Question Here

Question 1 | **Multiple Choice** | **10 points** | Modify | Remove

Question Which of the following are robot applications are in use today?

Answer
a. Industrial robots that stack boxes.
b. Industrial robots that weld.
c. Military robots.
✓ d. All of the above; a,b & c.

Add Question Here

Question 2 | **Multiple Choice** | **10 points** | Modify | Remove

Question The gripper on your Teachmover robot is also called:

Answer
a. Shoulder
b. Base
✓ c. End of arm tooling
d. Extender

Add Question Here

Question 3 **Multiple Choice** **10 points** Modify Remove

Question What is the purpose of the Rotate button on the teach pendant?

Answer
✓ a. Rotate turns or twists the gripper
b. Rotate turns the base of the robot
c. Rotate closes the gripper mechanism
d. Rotate is not used on the Teachmover

Add Question Here

Question 4 **Multiple Choice** **10 points** Modify Remove

Question What is the difference between manual and auto mode on our robot?

Answer
a. In manual mode the pendant is used to move the robot and in auto mode the pendant causes pre-programmed moves
✓ b. In auto mode pre-programmed robot motion commands are executed while in manual mode the robot moves based on your control of the pendant buttons
c. There is no auto mode on the Teachmover
d. There is no manual mode on the Teachmover

Add Question Here

Question 5 **Multiple Choice** **10 points** Modify Remove

Question Why is Home position used?

Answer
a. Home closes the gripper fingers, nothing else
b. Home retracts all of the axes
✓ c. Home defines the beginning position for the robot so it can repeat moves
d. Home has no real purpose on the Teachmover

Add Question Here

Question 6 **Multiple Choice** **10 points** Modify Remove

Question Why is the pendant called a *Teach Pendant*?

Answer
a. The robot teaches the user where pre-programmed reference exist.
✓ b. Robot programs are often written off-line and the pendant is used to *teach* the robot where desired position exist in space
c. All manual mode operations involve *teaching* the robot
d. The pendant allows the user to *teach* the robot the maximum travel or reach in the work area

Add Question Here

Question 7 **Multiple Choice** **10 points** Modify Remove

Question What is the purpose of the Base button on the teach pendant?

Answer
a. Base applies to all robot motions, centering them
b. Base tells the robot to go to the Home position
✓ c. Base rotates the first axis to turn right or left
d. Base rotates the gripper

Add Question Here

Question 8 **Multiple Choice** **10 points** Modify Remove

Question What is the purpose of the Pitch button on the robot pendant?

Answer
a. Pitch is not a pendant function
✓ b. Pitch raises or lowers the gripper angle
c. Pitch causes the robot base to tilt
d. Pitch causes the teachmover shoulder to move

Add Question Here

Question 9 **Multiple Choice** **10 points** Modify Remove

Question How are the teachmover axes powered?

Answer
✓ a. Electric stepper motors
b. Pneumatic (air powered) actuators
c. Hydraulic actuators
d. Both electric motors and air power actuators

Add Question Here

Question 10 **Multiple Choice** **10 points** Modify Remove

Question In manual operations, does the computer in the robot track axis position?

Answer
✓ a. Yes
b. No - never
c. No, only during programmed moves
d. This is a one axis robot, so asis position does not apply

Robot Lesson 2 Assessment

Add Question Here

Question 1 | **Multiple Choice** | **10 points** | Modify | Remove

Question Isaac Asimov's 1939 writings about robots:

Answer
a. are based on scientific principles that still apply today.
✓ b. were science fiction that presented the three laws of robotics.
c. were science fiction that now serve as basic definitions for robot axis naming used today.
d. defined how robots should be applied.

Add Question Here

Question 2 | **Multiple Choice** | **10 points** | Modify | Remove

Question In the technical definition of a robot, it:

Answer
✓ a. indicates that robots typically have several re-programmable axes.
b. states that robots are built to single purpose applications.
c. states that robots can be manually conbtrolled.
d. none of the above.

Add Question Here

Question 3 | **Multiple Choice** | **10 points** | Modify | Remove

Question The space in which a robot gripper can move with no limitations in travel other than those imposed by the joints is called .....?

Answer
a. Degrees of Freedom.
b. Repeatability.
c. End of arm tooling design.
✓ d. Work envelope.

Add Question Here

Question 4 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is the difference between manual and auto mode on our robot?

Answer
a. In manual mode the pendent is used to move the robot and in auto mode the pendant causes pre-programmed moves.
✓ b. In auto mode pre-programmed robot motion commands are executed while in manual mode the robot moves based on your control of the pendant buttons.
c. There is no auto mode available.
d. There is no manual mode available.

Add Question Here

Question 5 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is the purpose of the Step-by-Stpe lab indicating you should plan your axes moves?

Answer
a. Manual mode block stacking is difficult.
b. All axes must be homed before stacking blocks.
✓ c. This lab is an introduction to swriign and downloading a motion program.
d. The TeachMover gripper does not have the degrees of freedom required.

Add Question Here

Question 6 | **Multiple Choice** | **10 points** | Modify | Remove

Question The TeachMover has how many degrees of freedom?

Answer
a. 4
✓ b. 6
c. 12
d. 1

Add Question Here

Question 7 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is the purpose of the Base button on the teach pendant?

Answer
a. Base applies to all robot motions, centering them.
b. Base tells the robot to go to the Home position.
c. Base rotates the gripper.
✓ d. Base causes the robot base or first axis to turn right or left.

Add Question Here

Question 8 | **Multiple Choice** | **10 points** | Modify | Remove

Question What is the purpose of the Pitch button on the robot pendant?

Answer
a. Pitch is not a pendant function.
✓ b. Pitch raises or lowers the gripper angle.
c. Pitch casues the robot base to tilt.
d. Pitch casues the TeachMover shoulder to move.

Add Question Here

Question 9	Multiple Choice	10 points	Modify	Remove

Question What types of jobs do robots typically do?

Answer
- a. Most robots weld.
- ✓ b. Jobs that are dirty, dangerous, difficult or dull.
- c. High tech jobs.
- d. Jobs that are easy for humans but can be accomplished by a robot.

Add Question Here

Question 10	Multiple Choice	10 points	Modify	Remove

Question What is the paypload of your TeachMover?

Answer
- a. The maximun weight of objects that the robot can lift at the center of the work envelope.
- b. The physical dimensions of the work enveolpe related to the size of the item the gripper can accept.
- ✓ c. The maximun weight of objects that the robot can lift and move in the work envelope.
- d. None of these answers.

Robot Lesson 3 Assessment

Add Question Here

Question 1	Multiple Choice	10 points	Modify	Remove

Question Why is homing the robot important?

Answer
- a. Home closes the gripper fingers, nothing else.
- b. Home retracts all of the axes.
- ✓ c. Home defines the beginning position for the robot so it can repeat moves that involve other objects.
- d. Home has no real purpose on the TeachMover.

Add Question Here

Question 2	Multiple Choice	10 points	Modify	Remove

Question What is the purpose of the MCC software?

Answer
- a. To monitor the robot.
- ✓ b. To allow the user to read, change and save robot programs.
- c. To check the robot home position.
- d. MCC software is not used on the TeachMover.

Add Question Here

Question 3	Multiple Choice	10 points	Modify	Remove

Question How does the Move command affect the robot when a prgram is being executed?

Answer
- a. The Move command tells one TeachMover axis a new desired position.
- b. The Move command indicates current robot position.
- ✓ c. The Move command tells the robot to move each of the six axes to a new positon, as indicated for that Move command in the program.
- d. The Move command records the axis positions.

Add Question Here

Question 4	Multiple Choice	10 points	Modify	Remove

Question In the MCC software, under the Controller pull-down menu item, the Write Program command:

Answer
- a. Compares the program in the TeachMover with that in the MCC software.
- b. Starts the program.
- c. Transfers the program in the TeachMover to the MCC software on the PC.
- ✓ d. Transfers the program on the PC as shown in the MCC software to the TeachMover.

Add Question Here

Question 5 **Multiple Choice** **10 points** Modify Remove

Question If you make a change in the robot prorgam on the PC, what must be you do to affect that change on the TeachMover robot?

Answer
✓ a. Download the program using the Write command.
b. Upload the program from the robot.
c. Home the robot.
d. Nothing - program changes on the PC are on-line with the robot.

Add Question Here

Question 6 **Multiple Choice** **10 points** Modify Remove

Question In a robot program in a Move command, what does "x=5" mean?

Answer
a. x is the symbol for the first axis or base of the TeachMover and indicates the base is at the 5 degree position.
✓ b. This shows the x coordinate of the x-y-z position of the gripper in space.
c. x=5 means this is the 5th move in the robot program.
d. This means the robot axis "x" is at the 5 degree position.

Add Question Here

Question 7 **Multiple Choice** **10 points** Modify Remove

Question In a robot program Move command, what does "g=2.5" mean?

Answer
✓ a. Since g=0 means the gripper is closed, g=2.5 means it is opened.
b. The g value is not used in programming the TeachMover.
c. The "g" applies to end-of-arm tooling, but not the gripper.
d. The gripper is at a 2.5 degree pitch from vertical.

Add Question Here

Question 8 **Multiple Choice** **10 points** Modify Remove

Question Why is repeatability important in robot programming and operation?

Answer
a. Repeatability doesn't matter but positioning accuracy does matter.
b. Repeatability only applies to axis positions, not gripper positions in space.
✓ c. If the robot does not return to the same position in space each time a position is programmed, the robot can not do accurate work.
d. Repeatability determines the number of decimal places required for programming positions.

Add Question Here

Question 9 **Multiple Choice** **10 points** Modify Remove

Question What are the steps involved in programming a position?

Answer
a. Jog the robot into position and press the Update Display button.
✓ b. Select a program line number, press Insert, select a command, jog to the desired gripper position in space and press Insert.
c. Select a program line number, press record, select a command, jog to the desired gripper position in space and press Insert.
d. Jog the robot into position and press Record.

Add Question Here

Question 10 **Multiple Choice** **10 points** Modify Remove

Question What is an advantage and a danger in using the Jump command?

Answer
a. Jump allows the program to move backwards but this takes PC time.
✓ b. You can reuse sets of commands in a subroutine fashion, but you must be careful not to prgram a loop that the program can not exit.
c. Jup works great, no dangers involved.
d. Jump allows for selecting other programs by program name, but it is a problem if you try to jump to a program that doesn't exist.

Survey Questions

Five survey questions were appended to each of the six lesson assessments. The same survey questions were used in each case. The first question was used to confirm that the treatment utilized matches that planned. The last question allowed the users to make comments on their experience with the tool used.

Add Question Here

Question 11 **Multiple Answer** **0 points** Modify Remove

Question Which technology did you use to communicate with your lab partner during this remote lab lesson?

Answer

1. Chat only (text messaging).
2. Audio only (PC mics).
3. Audio and video (mic with web camera view of your partner).

Add Question Here

Question 12 **Opinion Scale/Likert** **0 points** Modify Remove

Question If you did NOT use chat (text messaging) during this remote lab, please skip to the next question. If you did use chat (text messaging), please rate your preference for using chat, instead of audio or audio with video.

Answer

✓ 1. Strongly Not Preferred
2. Not Preferred
3. Neutral
4. Preferred
5. Strongly Preferred

Add Question Here

Question 13 **Opinion Scale/Likert** **0 points** Modify Remove

Question If you did NOT use audio only during this remote lab, please skip to the next question. If you did use audio only, please rate your preference for using audio only, instead of chat or audio with video.

Answer

✓ 1. Strongly Not Preferred
2. Not Preferred
3. Neutral
4. Preferred
5. Strongly Preferred

Add Question Here

Question 14 **Opinion Scale/Likert** **0 points** Modify Remove

Question If you did NOT use audio with video during this remote lab, please skip to the next question. If you did use audio with video, please rate your preference for using audio with video, instead of chat or audio only.

Answer

✓ 1. Strongly Not Preferred
2. Not Preferred
3. Neutral
4. Preferred
5. Strongly Preferred

Add Question Here

Question 15 **Short Answer** **0 points** Modify Remove

Question Do you have any comments on your experience using the remote lab communication tools (chat, audio or audio with video) during this lesson?

Answer

Appendix B

Pilot Study Results

Results of the Reliability Estimate Analysis for Pilot Run Number One

In pilot run number one, ten subjects (*N* = 10) completed the six lesson assessments. Table 7 shows the results of the statistical analysis.

Table 7
Reliability Statistics for Pilot Run Number One – Cronbach's Alpha

Cronbach's Alpha	*N* of Items
.728	6

Results of the Reliability Estimate Analysis for Pilot Run Number Two

In pilot run number two, ten additional subjects (*N* = 20) completed the six lesson assessments. Table 8 shows the results of the statistical analysis based on the assessment scores combined from pilot runs one and two.

Table 8
Reliability Statistics for Pilot Run Number Two – Cronbach's Alpha

Cronbach's Alpha	*N* of Items
.804	6

Results of the Reliability Estimate Analysis for the Pretest

The ten subjects in pilot run number one and the additional ten subjects in pilot run number two (N = 20) completed the pretest using the test-retest method. Table 9 shows the results of the statistical analysis.

Table 9
Reliability Statistics for the Pretest – Cronbach's Alpha

Cronbach's Alpha	*N* of Items
.853	2

Appendix C

Collaboration Tool Examples and Specifications

Collaboration Tool Example

Figure 2, along with the annotations, show how the Adobe® Connect™ web meeting tool was used for collaboration.

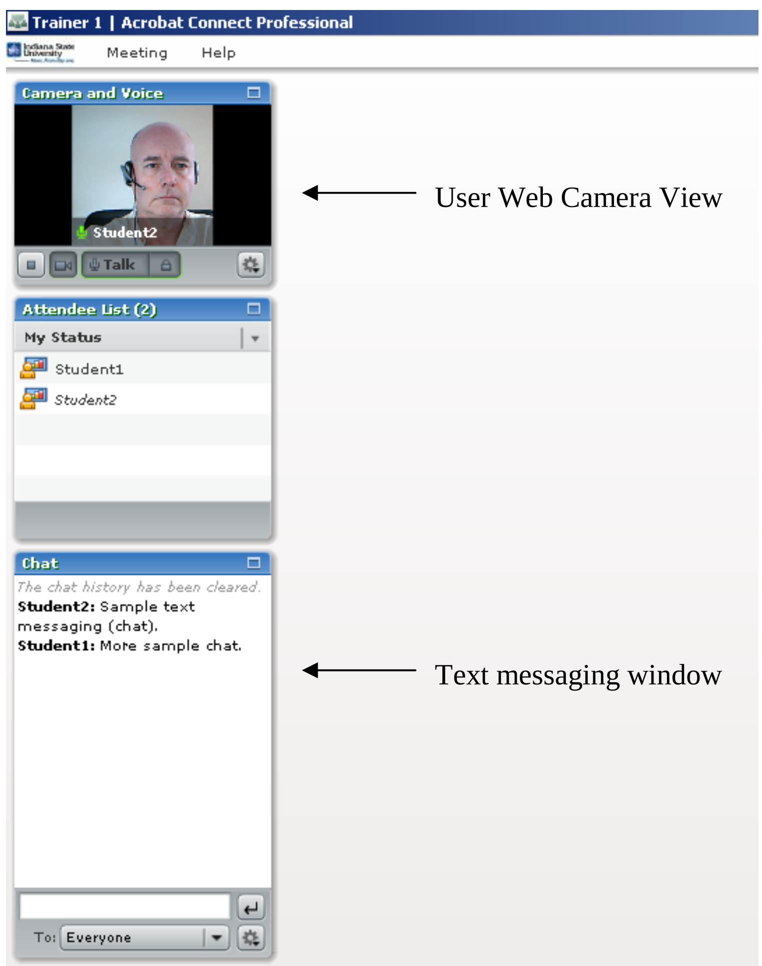


Figure 2. Example of Adobe® Connect™ window viewed by users.

Collaboration Tool Specifications

The Adobe® Connect™ server, Enterprise Version 7.0, resided on the ISU computer network.

Appendix D

AutomationTek Remote Lab Trainer Specifications

PLC Trainer Stations

The PLC trainers were Microbot model V-1 units. Each used an AutomationDirect D06 PLC with 16 discrete inputs and 10 discrete outputs. All of the I/O is powered by a 24 Volt Direct Current (DC) power supply. The PLC trainer station is shown in Figure 3. The web cameras used to generate the video images of the trainer actions were DLink

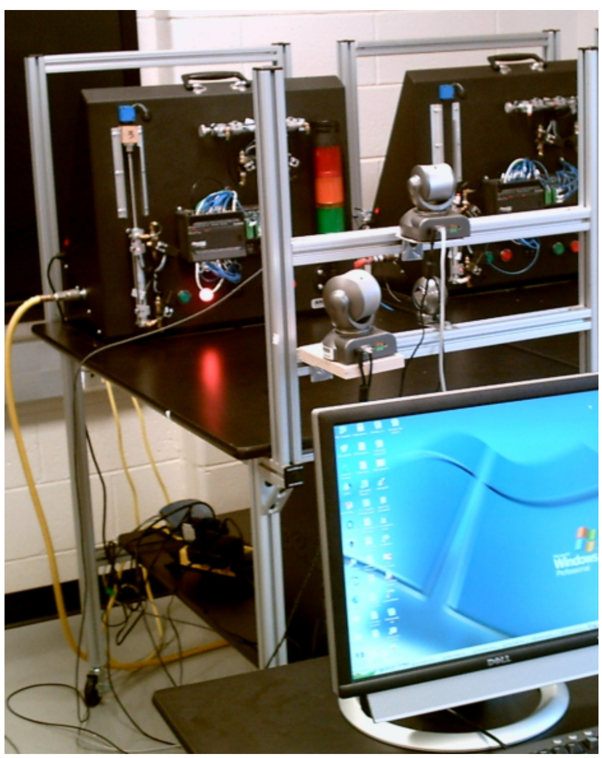


Figure 3. A view of a PLC trainer station.

model DCS5300 webcam units. Three web cameras were used on each trainer.

PLC Programming Software

Each PLC trainer station had a host PC which supported the software required for the station. The ladder logic programming software was AutomationDirect DirectSOFT32, version 3.0. The HMI software used to support the operator station was AutomationDirect LookoutDirect, version 2.5. A screenshot of the host PC with the PLC programming software, along with the web camera views is shown in Figure 4.

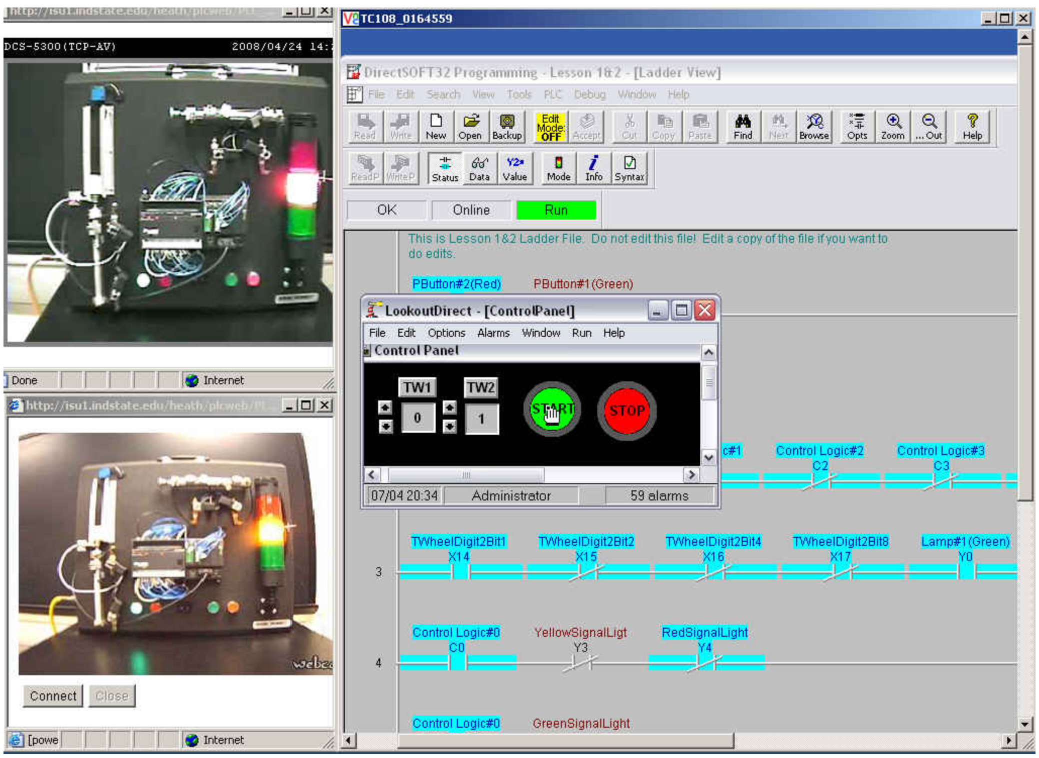


Figure 4. A screenshot of a user’s PC with a PLC remote lab in operation.

Microbot TeachMover Stations

The TeachMover, shown in Figure 5, had five revolute axes and an integral hand. The axes were electrical stepper motor driven via open loop control. The teach pendant

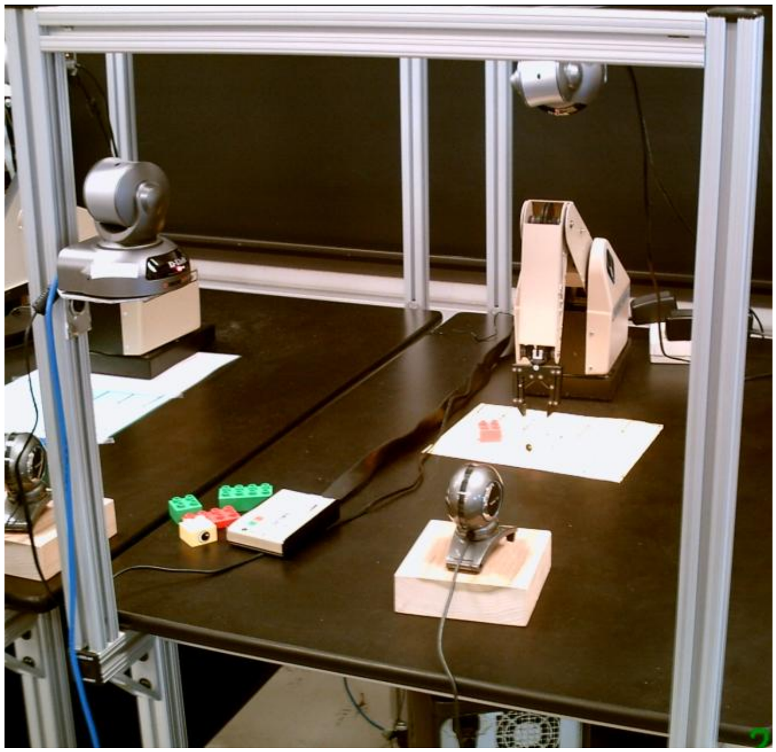


Figure 5. A view of a TeachMover robot trainer station.

had three operational modes and 13 function keys. The payload of the TeachMover was 1.0 pounds with a resolution of 0.011 inches on each axis and a positioning accuracy of +/- 0.030 inches. The overall reach of the robot was 15.5 inches. The maximum speed for a coordinated move was 7.0 inches/sec. The web cameras used to generate the video images of the trainer actions were DLink model DCS5300 units. Three web cameras were used on each trainer.

TeachMover Programming Software

The robot programming software was Microbot MCC, version 7.0. A screenshot of the host PC with the MCC programming software in operation, along with the web camera views is shown in Figure 6.

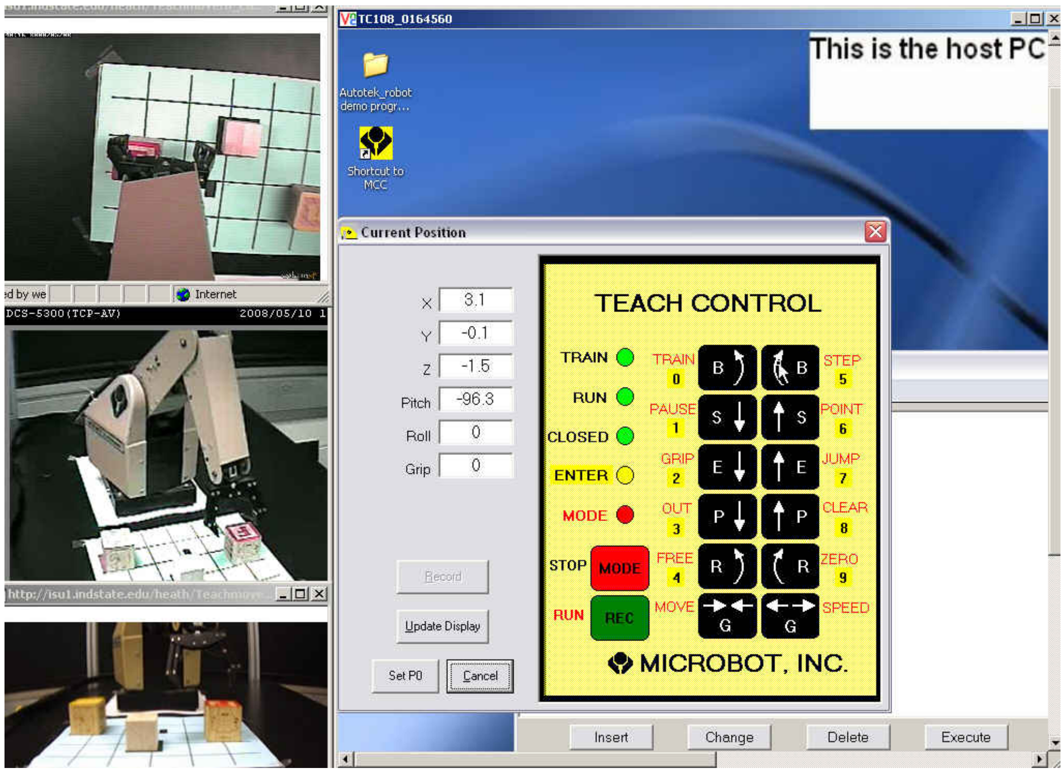


Figure 6. A screenshot of a user's PC with the robot remote lab in operation.

©RealVNC

The virtual connection software application ©RealVNC was used to support the virtual control of the software on the host PC by the remote user. Both the ©RealVNC Server which operates on the host PC and the ©RealVNC Viewer which operates on the user's PC were Free Edition Version 4.1.

Appendix E

AutomationTek Learning Management System Details

The delivery of the ancillary activities associated with AutomationTek including the lesson content delivery, remote lab scheduling and the assessments were accomplished using the Blackboard™ learning manage system, Release 7 Application Pack 3. The AutomationTek Blackboard™ pages were hosted on an ISU server. Participants had access to Blackboard™ via their COT courses and were enrolled in AutomationTek through Blackboard™ utilities by the researcher. A navigation map of the AutomationTek Blackboard™ site is shown in Figure 7. Sample content is shown in Figure 8 and Figure 9.

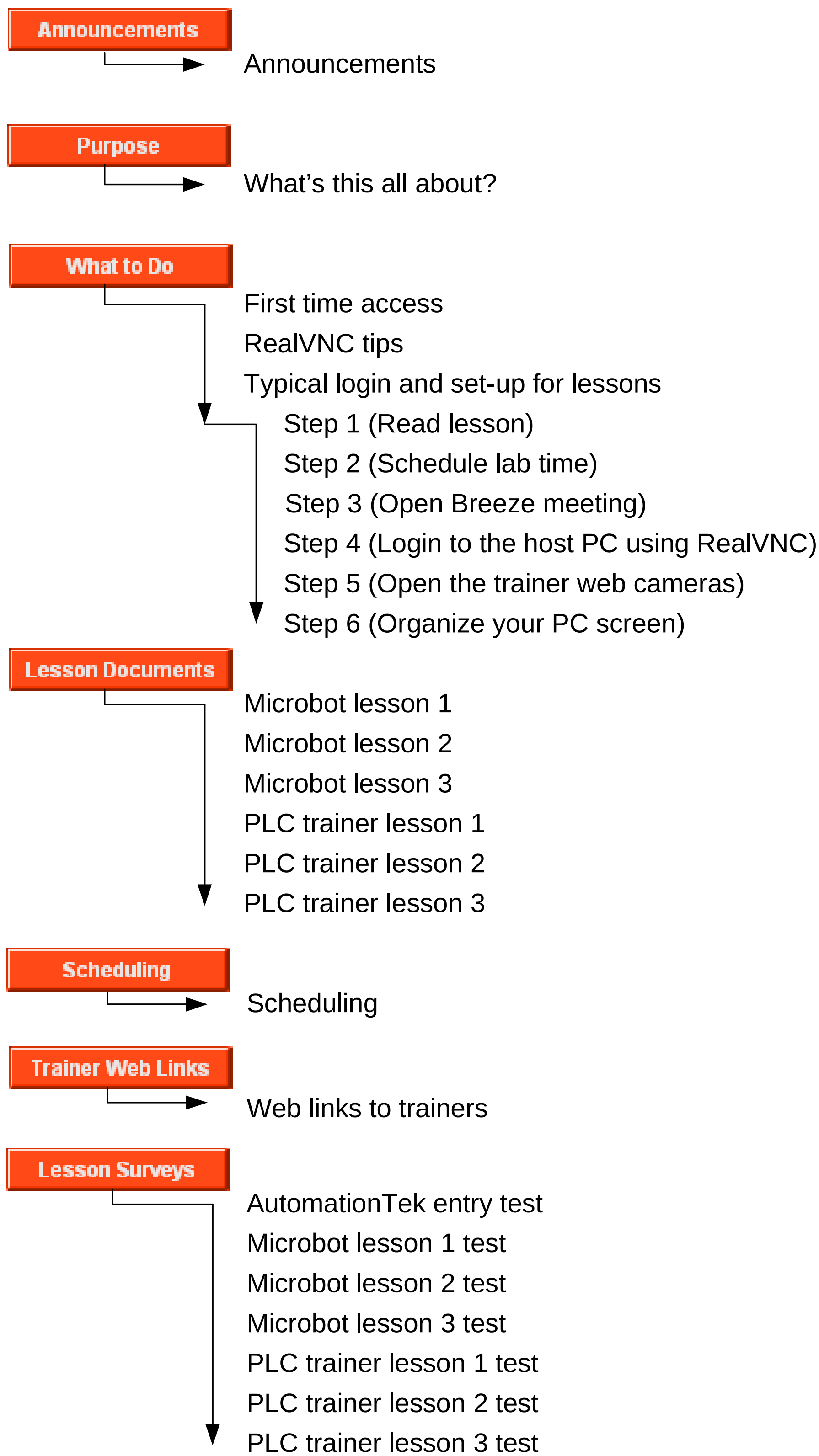


Figure 7. Navigation map of the AutomationTek Blackboard™ site.

Step 4 (Log-in to the host PC using RealVNC) - Again click on the: Trainer Web Links button and scroll to the links of the trainer you have scheduled. Now open RealVNC from your PC's start menu and enter the IP address and password of the trainer you wish to control.

If you have logged into a PLC trainer, your RealVNC virtual view should look like this:

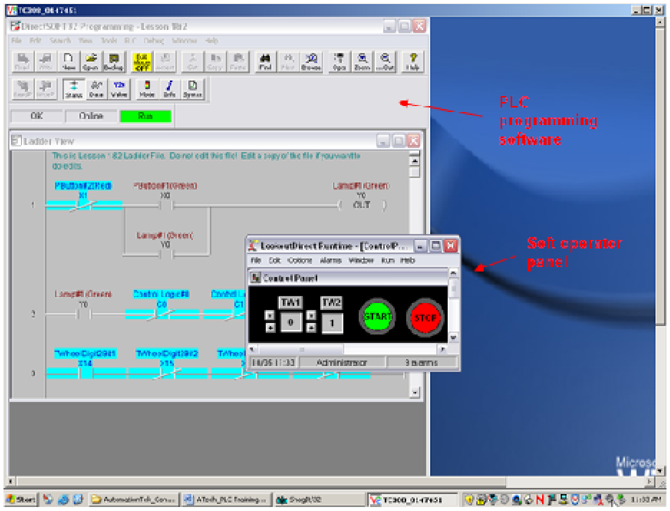
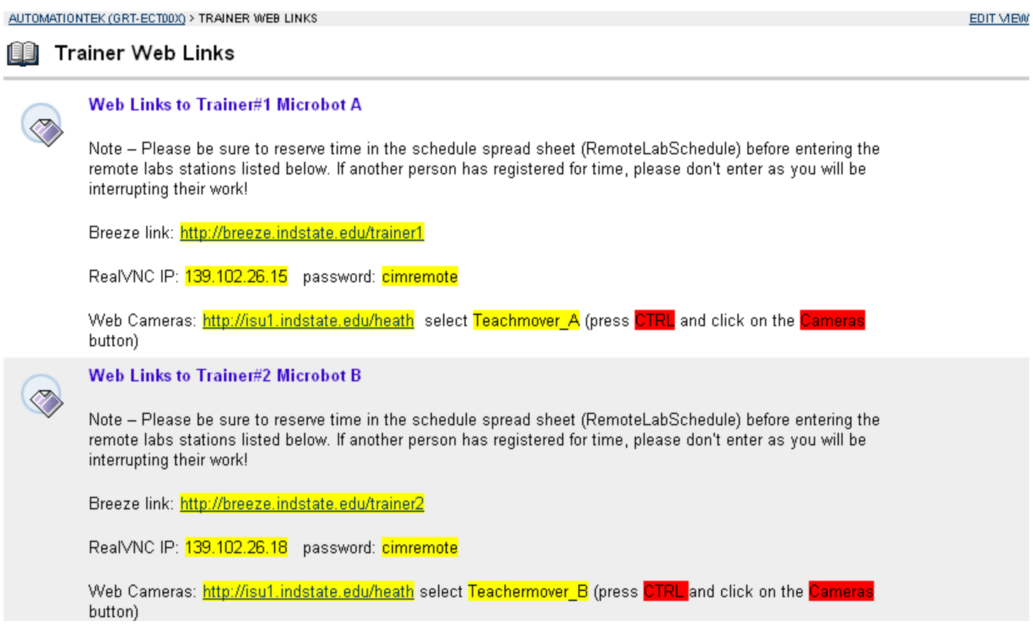


Figure 8. Typical content from the AutomationTek Blackboard™ site.



AUTOMATIONTEK (GRT-ECT00X) > TRAINER WEB LINKS EDIT VIEW

Trainer Web Links

Web Links to Trainer#1 Microbot A

Note – Please be sure to reserve time in the schedule spread sheet (RemoteLabSchedule) before entering the remote labs stations listed below. If another person has registered for time, please don't enter as you will be interrupting their work!

Breeze link: http://breeze.indstate.edu/trainer1

RealVNC IP: 139.102.26.15 password: cimremote

Web Cameras: http://isu1.indstate.edu/heath select Teachmover_A (press CTRL and click on the Cameras button)

Web Links to Trainer#2 Microbot B

Note – Please be sure to reserve time in the schedule spread sheet (RemoteLabSchedule) before entering the remote labs stations listed below. If another person has registered for time, please don't enter as you will be interrupting their work!

Breeze link: http://breeze.indstate.edu/trainer2

RealVNC IP: 139.102.26.18 password: cimremote

Web Cameras: http://isu1.indstate.edu/heath select Teachermover_B (press CTRL and click on the Cameras button)

Figure 9. Typical content from the AutomationTek Blackboard™ web links instructions.

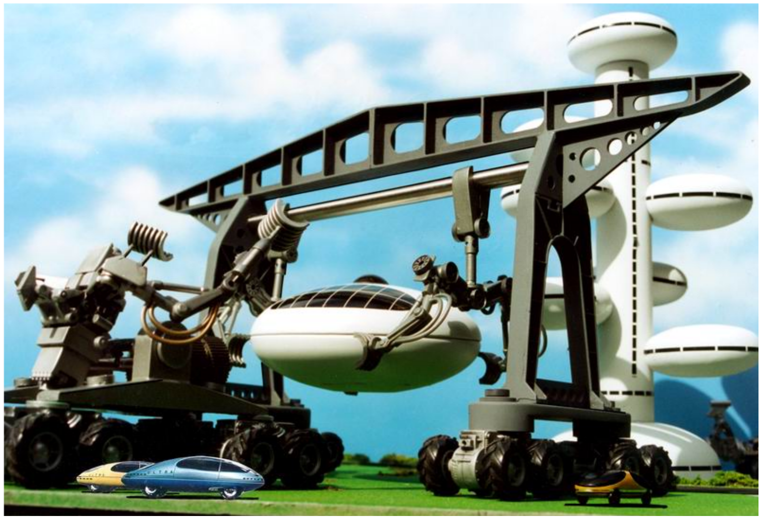
Appendix F

Sample Lesson Content

PLC Trainer Lesson 1 Sample Content

Lesson 1. Automation and the PLC - Running a PLC program

What is automation? Why is automation important to us? What does automation have to do with the equipment we are going to use in the course? Let's discuss these questions and explore possible answers.



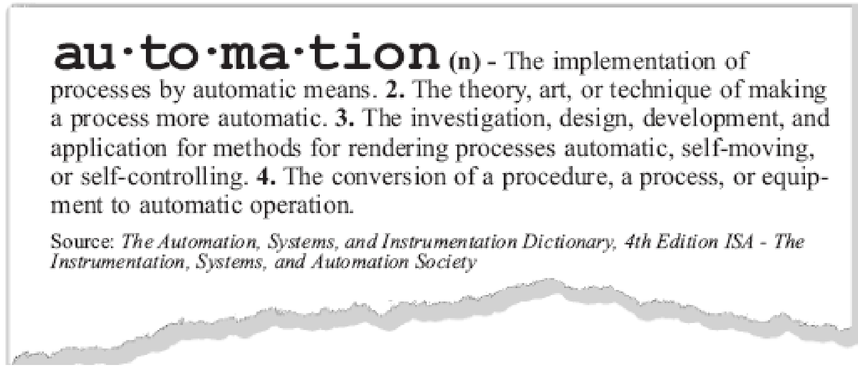
Objectives

When you finish this module you will be able to:

1. Understand the term "automation".
2. Be able to explain how automation is used.
3. Operate the devices on the trainer via the Internet.
4. Understand the term "PLC".
5. Know about the parts of a PLC.
6. Understand what the lights on the front of the PLC mean.
7. Download any PLC program.

What is Automation?

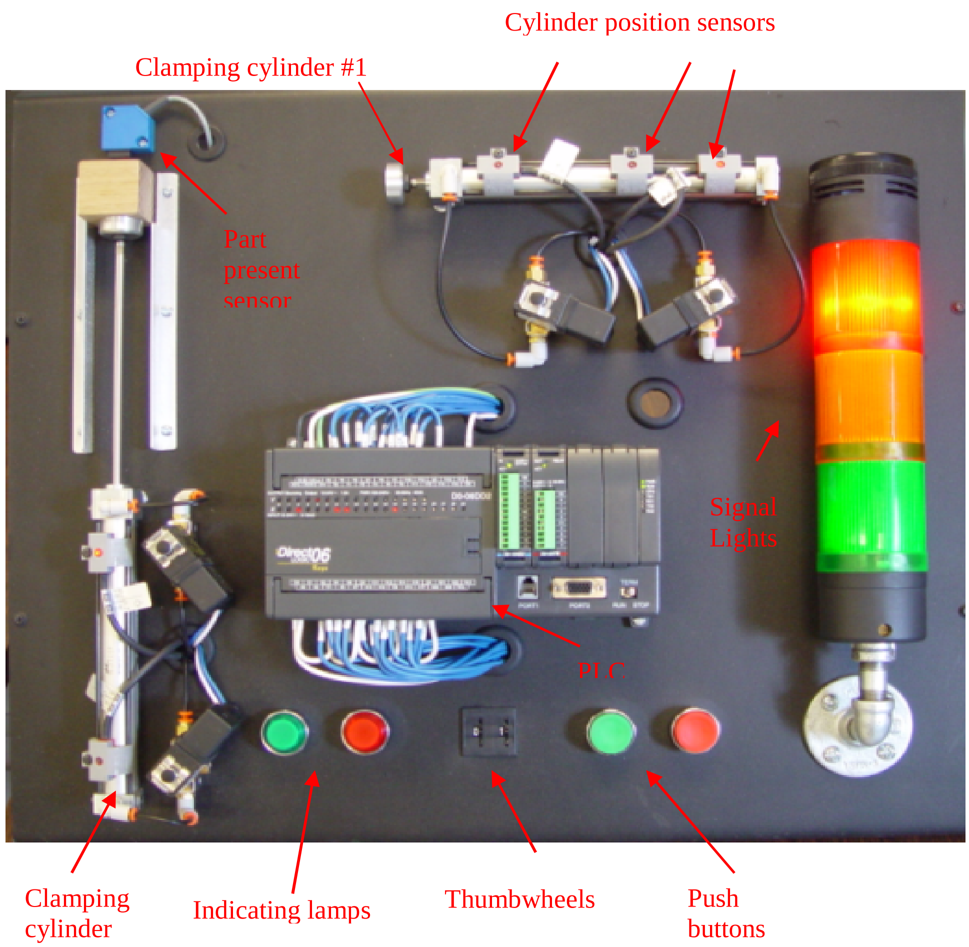
In the days before electronics and computers, most manufacturing machines were manually operated. A person inserted manufacturing parts in machines by hand, operated machines in manual modes, and assembled goods by hand. The ability to build machines that are self-controlled came with the invention of electronics and computers. An automated system is a collection of machines or machine operations working together to accomplish a task or produce a product.


au·to·ma·tion **(n)** - The implementation of processes by automatic means. **2.** The theory, art, or technique of making a process more automatic. **3.** The investigation, design, development, and application for methods for rendering processes automatic, self-moving, or self-controlling. **4.** The conversion of a procedure, a process, or equipment to automatic operation.

Source: *The Automation, Systems, and Instrumentation Dictionary, 4th Edition ISA - The Instrumentation, Systems, and Automation Society*

Automation trainer equipment

Your trainer is loaded with components that are used in automated systems. These include push buttons, indicating lamps, signals lights, valves for operating the cylinders and a programmable logic controller (PLC).



What is a PLC?

A programmable logic controller (PLC for short) is a computer which has been designed for use in industrial surroundings and to be programmed by an industrial technician. The PLC is the brain of an automated machine or group of machines that may operate in an automated cell. The PLC is programmed with a language called ladder logic, which is like blueprints that technicians use.

How do PLCs control machines?

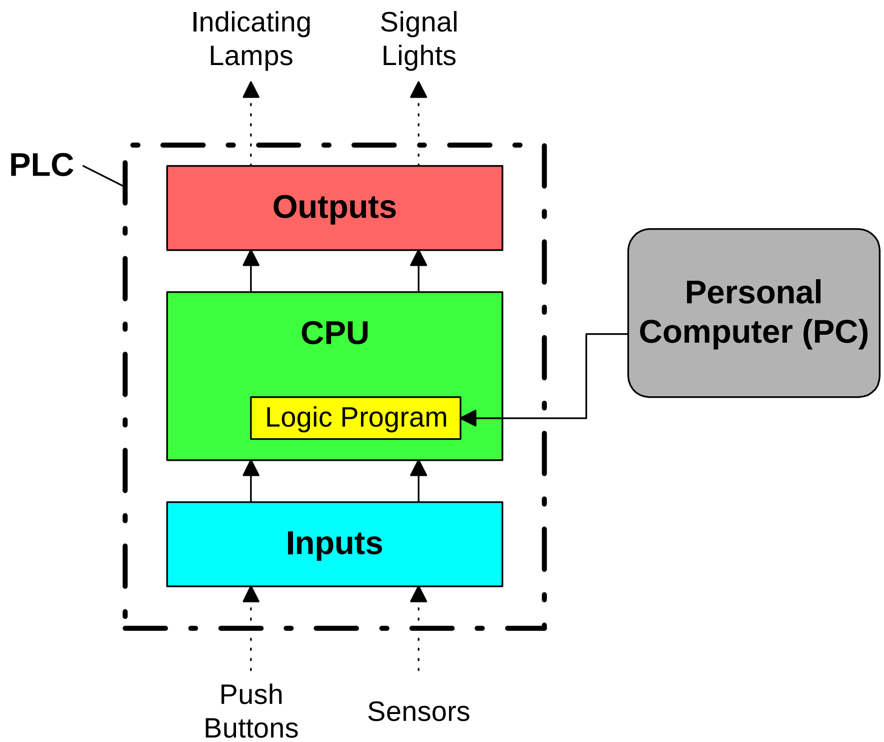
In most automation systems or machine cells, each machine has its own PLC. Again, the PLC is the *brain* that controls the machine. Our trainer also has a PLC, shown here.

While the PLC is a computer housed in a single box, it has several parts. These parts include:

a) The computer itself, called the Center Processing Unit or CPU
b) Inputs to the PLC, which receive incoming signals
c) Outputs from the PLC, which are outgoing signals
d) The logic program, which turns outputs on or off, based on the status of the inputs and the logic of the program
e) The PC, where the logic program is developed and sent (downloaded) to the PLC

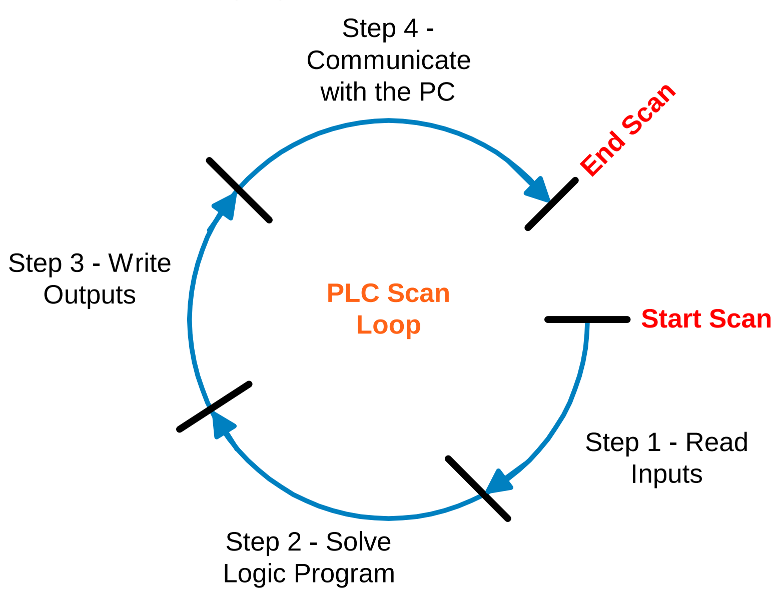
The diagram below shows how the PLC parts fit together on our trainer. A personal computer, PC for short, will be used to download the logic program to the PLC. We will call the PC that physically resides in the lab at ISU as the *host PC*. You are working in a remote lab environment, where you will connect to the PLC trainer station via your local PC, and perform the PLC programming and operation tasks. Specifically you will take virtual control of the host PC, where the host PC desktop will appear on your PC. The lab in this lesson covers that process in step-by-step detail, so stand by for more.

Inputs, such as the push buttons and sensors on our trainer are wired to the *input* terminals on the PLC. Output devices, such as the indicating lamps and signal lights, are wired to the PLC *output* terminals. The PLC will turn the outputs on or off, based on the condition of the inputs and what the logic program indicates.



How does the PLC execute the logic program?

The PLC operates on a very simple method called scan. The PLC *scan* operation can be viewed as a set of simple operations or steps that happen over-and-over. The scan steps are shown in the following figure.



In the first step, the PLC reads the input signals. In step two the PLC solves the logic program that you have written and downloaded to the PLC. In the third step the PLC turns outputs on or off, based on the input states and the logic written in the program. In the final step the PLC communicates with the PC when it is connected to the PLC. The scan then ends, and the next scan starts. Note that the PLC performs the scan very fast. By fast we mean about 40 scans per second! So, as you can see, the scan process is very simple. The simple design helps to make the PLC operate well in the rugged industrial world.

What are the lights on the front of our trainer PLC?

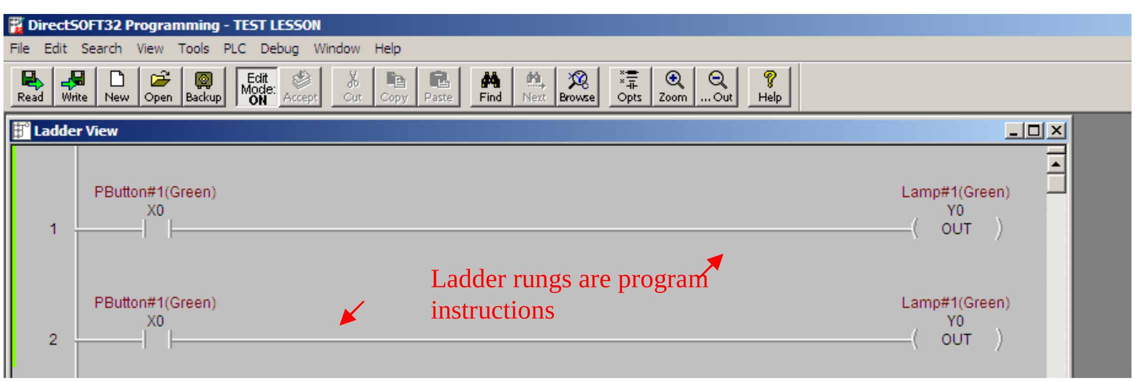
As we said, inputs are signals that come into the PLC. Outputs are signals or commands for action that come out of the PLC. The red lights, shown in the picture below, indicate when input and output points are on or off. When the red light is on, that input or output is on.

Each input and output on any PLC has a number connected to it. This number is called an address. We will learn much more about address in Lesson 5. On our PLC, input signals are identified by addresses like X0, X1, and X2 and so on. Outputs are identified by Y address numbers like Y0, Y1, and Y2 and so on.

How do we use the programming software?

In subsequent lessons sections we will be showing you what the items in a PLC program look like, what they mean, and how they are used. The purpose of this lesson is to give you experience in downloading a logic program to the PLC from the PC, using the menu items in the DirectSOFT32 software.

The logic program that runs in the PLC looks like a ladder, as shown in the picture here.

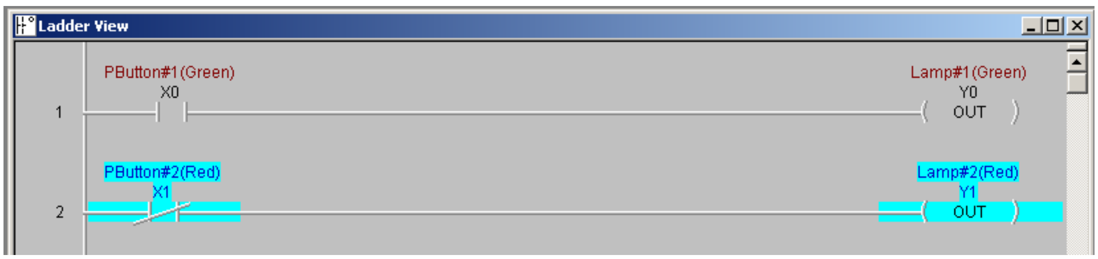


Each rung on the ladder means one instruction to the PLC. For now, just know that this is the logic program. You will be an expert at reading and even writing your own logic programs as you progress.

What is the monitoring all about?

Once you have downloaded a file to the PLC and it is running, you can monitor or watch the logic in operation. You will use monitoring to test the logic you will write in later lessons and fix the problems in the logic. Only truly genius programmers can write computer programs that work right the first time. The rest of us must debug our programs. Debugging means to see what doesn't work correctly and make logic changes to fix the problems.

The picture shown below has monitoring turned on. The logic parts shown in light- blue mean that they are On. Do you see any addresses that match the red lights on the front of our PLC on the trainer?

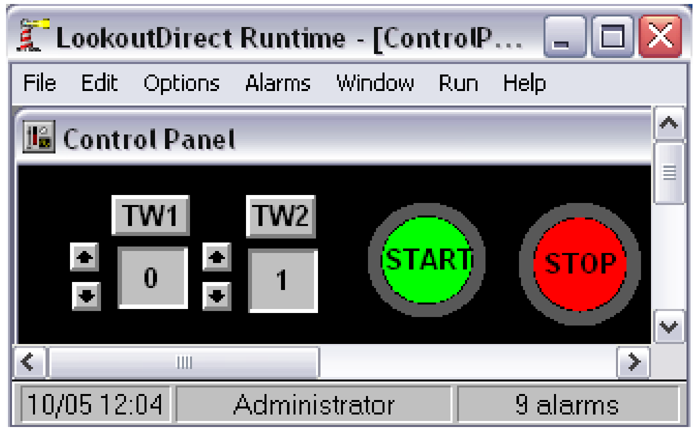


Now work through the step-by-step procedures. 1-1 will show you how to operate the various functions on the trainer and the trainer host PC through Internet access. In 1-2 you will work on identifying some of the PLC I/O addresses on the trainer. Finally in 1-3 we will go through the process of download and running a PLC program.

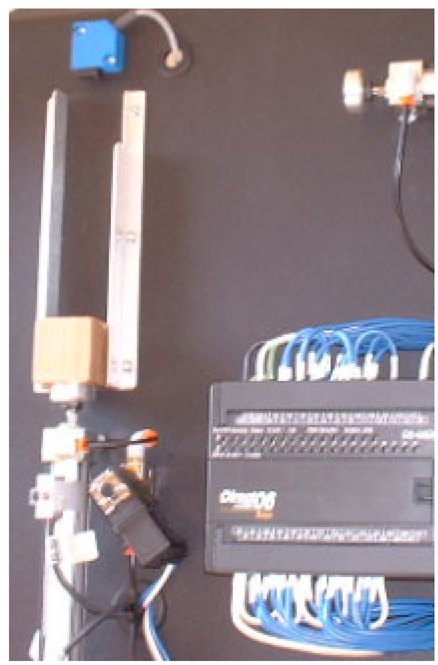
Step-by-step A-1

The PLC should have the file *Lesson 1&2.PRJ* already loaded. If things do not operate as detailed in the procedure, ask for help by speaking to the lab assistant. In later lessons you will learn how to load programs into the PLC and develop your own programs. For now, just follow the steps carefully listed below, to learn how to manipulate control of the trainer remotely and operate the devices.

______1. The trainer has been programmed to operate in five different ways. Each different way of operating is called a mode. Modes can be changed by using the right thumbwheel switch and the push buttons on the soft operator panel shown here. To change modes, do the following:



A. Set a number on the right hand thumbwheel switch between 1 and 5. The picture here shows the number *1* selected on the thumbwheel #2 switch. Use the up and down arrows to select different numbers.
B. After selecting a mode number, press the green start button. The green indicating lamp should turn on, indicating that the mode has been selected.
C. To change modes, press the red stop button. The red indicating lamp should turn on when the stop button is pressed.



______2. Select mode #1 and start the trainer. The signal lights should operate in the order green, yellow, red. This will happen over and over.

______3. Now stop mode #1 operation with the red stop button and select mode 2. In mode #2, clamping cylinder #1 should extend.

______4. Now select modes #3 and #4 and watch what trainer functions happen

______5. Mode #5 shows the clamping operation.

______6. Now try to operate the trainer using the numbers 6 through 9 on the right thumbwheel switch.

PLC Trainer Lesson 2 Sample Content

Lesson 2. Developing a PLC program, Understanding I/O & Normally open / normally closed logic

Objectives

When you finish this lesson you will be able to:

1. Understand how to read ladder diagrams.
2. Understand how PLC scan applies to ladder diagrams.
3. Know where to place your logic in the ladder.
4. Know how to do basic rung edits.
5. Know how to read ladder logic diagrams.
6. Know where to place the logic you develop for the trainer.
7. Know how to make basic logic program changes.
8. Use I/O addressing in a PLC program.
9. Understand PLC I/O numbering.
10. Use inputs and outputs in a PLC program.

PLC Trainer Lesson 3 Sample Content

Lesson 3. The seal-in, Timers & Designing and debugging a PLC program

Objectives

When you finish this lab you will:

1. Know how the seal-in logic works.
2. Know how to use program control logic elements.
3. Realize that other logic element types exist in additional to inputs and outputs.
4. Use timer logic elements in PLC programs.

Robot Lesson 1 Sample Content

WELCOME to AutomationTek

LAB 1 – Moving blocks with a robot

This is a unique opportunity for you to learn about technology over the web with hands on activities. Lab assistants are ready to help you learn the details about technology and see if this is something you want to do. For the best experience you will want to have a webcam and microphone to talk to the lab assistant and/or a lab partner!

Introduction

Robots are used throughout industry to weld, move parts, paint and many other manufacturing tasks. Newer robots are becoming very humanoid and may soon be serving you at McDonalds. The military has all kinds of robots. The common element to all these systems is that robots are computer controlled devices.

The little TeachMover robot that you will be operating in this lab has a computer in the base that drives six stepper motors. The computer keeps track of how far each motor moves so it can repeat sequences of moves. The HOME location is wherever the counters are reset to zero. The motors are connected by gears and cables to the parts of the arm and the gripper so you can pick up the blocks.

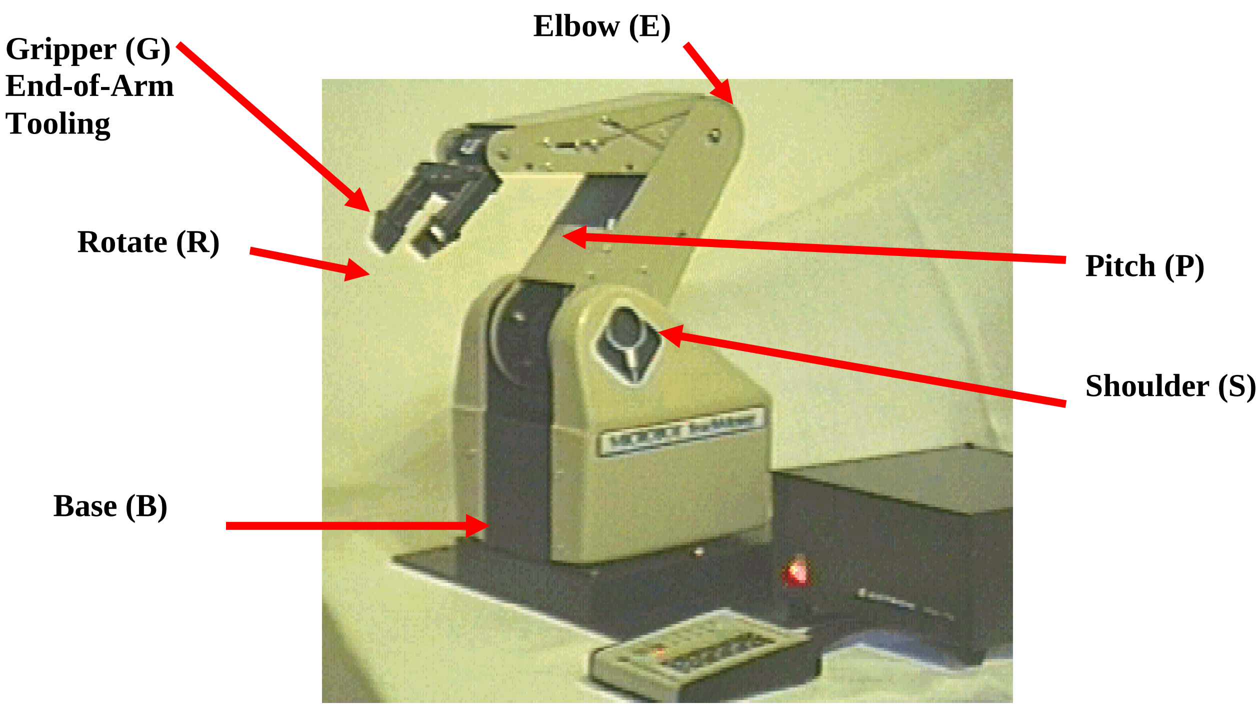
Objectives

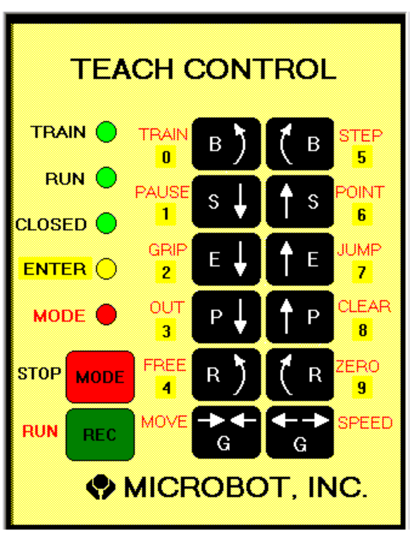
When you finish this lab you will be able to:

1. use the teach pendant to move blocks with the TeachMover robot to specified locations.
2. identify the TeachMover axis designations
3. understand the Home positioning process.

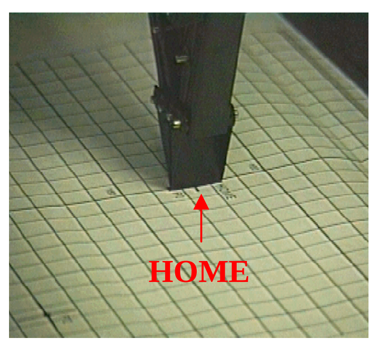
Step-by-step

Per the picture that follows, hold the mouse down on each axis of the teach pendant that you wish to move. An axis is one joint on the robot. Hold it and watch the robot move. Don’t leave it down for very long until you get a feel for how long you have to hold it to move the robot a given amount. This takes some practice do to the video delay over the internet.





Base(B)
Shoulder(S)
Elbow(E)
Pitch(P)
Rotate(R)
Gripper(G)



_____ 1. Move each of the robot axes in both directions to become familiar with the direction and action of each axis.

_____ 2. Now move the robot so the fingers are closed and the fingers are just above, or touching, the BAR marked as the HOME position. This is not critical for this lab but it is a good habit to build for later labs. This defines the beginning position for the robot so it can repeat moves that involve other objects.

_____ 3. Press the (up) S key to move the shoulder of the robot up and away from the table. Move it so it is above a block that is on the table. Make the rest of the moves necessary to move the block to the other side of the work area from where it was to when you started. (The G keys open and close the gripper).

_____ 4. Now move another block in the same manner to the opposite side from where it started.

_____ 5. Leave the robot above the last block, not touching anything (2 or 3 inches above the table.)

Robot Lesson 2 Sample Content

LAB 2 - Stacking blocks with a robot

Objectives

When you finish this lab you will be able to:

1. use the teach pendant to stack two blocks and return them to their original locations,
2. plan the moves for a robot program.

Sony's QRIO robot. (about 24" tall)

Robot Lesson 3 Sample Content

LAB 3 - Programming the robot

Objectives

When you complete this lab you will be able to:

1. use the MCC Editor to develop, upload, download and operate robot programs
2. use the editor to insert and delete commands
3. save programs to a hard drive on the host PC

Appendix G

Tabulation of Survey Responses

A total of 318 remote lab sessions were completed. The participants completed a survey after each lesson assessment where they used a Likert scale to indicate their preference to the treatment they had used. Also, they were asked, "Do you have any comments on your experience using the remote lab communication tools (text messaging chat, voice chat or webcam video with voice chat) during this lesson?" In 177 cases (56% of the surveys) comments were posted. The comments have been categorized into like groups, and include a) negatives of text messaging chat, b) prefer voice chat alone, c) prefer webcam video with voice chat, d) mentioned webcam video with voice chat and presence, e) used webcam video with voice chat at the beginning of the lab, and f) other comments. Interspersed within the responses are comments concerning problems with information arrangement on the user's PC screen, specifically that too much information was required on a screen to execute some of the lab work. Nine percent of the comments collected made reference to this issue. Table 10 lists the categories along with 10 sample comments that are representative of the responses in each category.

Table 10
Tabulation of Survey Comments

Negatives of text messaging chat - 83 instances (47% of total comments)

1. The text messaging took too much time.
2. We spent more time on the texting than with the PLC software.
3. Using chat was horrible on robot lesson 3.
4. I don't like chat.
5. Text chat takes up screen space. We had to switch back and forth to read the text.
6. Why use text messaging if you can use mics?
7. Chat is NOT preferred.
8. We just gave up on text chat and just took turns operating the robot.
9. I prefer audio over chat.
10. Do we have to use chat messaging again?

Prefer voice chat - 23 instances (13% of total comments)

1. I liked audio on PLC lesson 2.
2. Audio is the best way to communicate.
3. We preferred audio over text chat. Simple to use and we didn't have to position the chat or webcam windows on the PC screen.
4. Using the mics worked good.
5. The web cameras are nice but just having audio works well.
6. I didn't find seeing my lab partner very helpful. Using just audio allowed for no space taken on my PC screen and we communicate easily.
7. Audio only takes up no computer screen real estate and works OK.
8. With audio all you need to do it talk.
9. Audio is much better than chat. Also using the web cams takes time to position on the screen and doesn't add much.
10. Audio is my preference. It works well and doesn't clutter up the PC screen with a web cam view of my lab partner.

Prefer webcam video with voice chat - 19 instances (11% of total comments)

1. I liked seeing my lab partner.
2. The web cam view of lab partners is good.
3. It was helpful to see my lab partner.
4. Facial expressions are good to see when talking with your lab partner.
5. I like the web cam view of my lab partner.
6. Seeing my lab partner is good.
7. I prefer using the web cam.
8. The web cam view is helpful.
9. Video with audio is my choice.
10. We prefer using the web cam over audio only.

Table 10 (continued)
Tabulation of Survey Comments

Webcam video with voice chat and presence - 14 instances (8% of total comments)

1. Video views of lab partners made us feel more like a team.
2. Personal web cams make the lab more realistic.
3. In this lab I felt we were a lab team working together.
4. We liked being able to see each other.
5. It took time to get the web camera view of my lab partner on the screen but it was helpful when discussing the work.
6. We used the web cameras along with the voice audio.
7. The web cam with audio is the best approach.
8. Seeing my lab partner made the lab more personal.
9. My preference is using audio with a web camera.
10. The web cam helped me connect with my lab partner.

Used web cam at the beginning of the lab, then ignored it - 7 instances (4% of total comments)

1. The web camera is nice for seeing what your lab partner looks like, but after we started working, I didn't look at it again.
2. We initially said Hello and looked at each other at the beginning of the lab, then didn’t use the web cams after that.
3. The web camera view of my lab partner was helpful in getting to know him, after that the little window was in the way.
4. I liked being able to see my lab partner at the beginning of the lab, but after that the webcam took up space on the screen.
5. Once we got into the lab, we never looked at the web camera windows.
6. It is nice to see your lab partner at the beginning of the session so you have an idea of who you are working with.
7. The web camera view of your lab partner is needed so you get to know or confirm who you working with in the case of this lab.

Other comments - 31 instances (17% of total comments)

1. Robots are fun.
2. We had trouble getting the robot to repeat home position.
3. Using the web cams is difficult when you are picking up blocks.
4. We needed more than 1 hour on robot lab 3.
5. I liked the robots better than the PLCs.
6. This stuff is pretty cool.
7. I liked PLC programming better than the robot programming.
8. The PLC programming is hard.
9. The PLC trainers are really interesting, particularly the clamps.
10. The sound of the PLC trainer is delayed.

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