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Interdisciplinary Facilities that Support Collaborative Teaching and Learning

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It has become widely accepted that the computer is an indispensable tool in the study of science and technology. Thus, in recent years curricular programs such as Industrial Technology and associated scientific disciplines have been adopting and adapting the computer as a tool in new and innovative ways to support teaching, learning, and research. Industrial Technology is a management-oriented technical curriculum built upon studies from a variety of disciplines related to manufacturing technology. Included are a sound knowledge and understanding of material and production processes; principles of distribution; and concepts of industrial management and human relations. The importance of readily available technology and supporting software, which has flexibility in design and usage, has become an integral component of technology curriculums. The flexibility of these computer systems and their peripherals provides opportunities for interdisciplinary studies that extend well beyond the traditional technology curriculum into broader areas of science and mathematics. The facilities and curriculum described in this article support the ongoing collaborative work of students and faculty from the disciplines of computer science, chemistry, mathematics, physics, and industrial technology.

The undergraduate program in Industrial Technology and the graduate program in Integrated Science and Technology (ISAT) at Southeastern Louisiana University (Southeastern) have initiated a joint project of curricular programs with shared computing facilities, which provide interdisciplinary educational opportunities for their majors. A newly developed lab is used in interdisciplinary courses that emphasize virtual instrumentation. An existing automated systems laboratory that emphasizes system integration is in use. In addition, an existing computer-aided design (CAD) lab has been refurbished to support courses that emphasize industrial design, solid model ideation, and, most recently, rapid-prototyping and computer-aided inspection. Finally, a state-of-the-art computer-integrated manufacturing laboratory has been developed around existing and recently acquired equipment and facilities modifications.

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INTERDISCIPLINARY STUDIES

At Southeastern, the Department of Industrial Technology is an integral part of a new Master of Science degree in the Integrated Science and Technology (ISAT). This program emphasizes advanced studies in mathematics, science, and technology. The departments of Computer Science, Mathematics, Chemistry, and Physics offer this advanced degree in conjunction with the Department of Industrial Technology as a career enhancement degree. This degree prepares students for the workplace by giving them experience in applying their knowledge of mathematics, science, and technology to projects that are relevant to business and industry. Technology students gain more in-depth knowledge of the physical sciences and mathematics that is foundational to their field of study. Students learn problem solving and critical thinking skills through a core of interdisciplinary project-oriented courses that extend and broaden training in each of these academic areas. In addition, students from the disciplines of computer science, chemistry, mathematics, and physics become acquainted with the latest in the applications of technology that are applicable to the needs of business and industry.

Educational institutions are constantly addressing the challenges of meeting the needs of an increasingly diverse workforce for the future and preparing them to function in an increasingly technology-driven and information-intensive society. The clustering of students from various disciplines into working teams is one method of addressing this problem. Numerous authors have addressed the importance of working in teams from an interdisciplinary perspective (Erb & Doda, 1989; Katzenbach & Smith, 1993; Flowers, Mertens, & Mulhall, 1999). Most nonacademic, real world projects are interdisciplinary in nature. Consequently, this demands that educational curriculums address diversity through appropriate content and experiences. In this article, the authors propose that traditional laboratory infrastructures can be modified to support data acquisition, data analysis, and subsequent dissemination of information in undergraduate and graduate studies involving science and technology. Further, it is suggested that appropriate technology infrastructures can assist discipline specific as well as interdisciplinary scientific research.

The project focuses on the creation of an integrated, interdisciplinary, design-oriented, lower-division curricula that emphasizes broad concepts, student discovery, cooperative learning, problem-solving processes, and design ideation. These changes have also influenced associated upper-division restructuring. Undergraduate research projects are linked to graduate studies through shared facilities, collaborative work on research projects, and integrated program goals. For example, undergraduate and graduate students from industrial technology, mathematics, computer science, physics, and marketing are currently collaborating on the Department of Defense's Defense Advanced Research Projects Agency (DARPA) project to build a totally autonomous vehicle. Program goals seek to develop a sense of community during the graduate and undergraduate experience, with attention focused on student/student, student/faculty, and faculty/faculty relations.

INTEGRATED SYSTEMS

Integrating systems allows for the improvement of communication and control of information flow to all aspects of an enterprise. Integration aims to improve the operation of an enterprise by using a combination of people and technology to bring products to market that are equal or superior in

quality to those produced elsewhere, timely in delivery, competitive in price, and able to meet the customer's need for a pleasing and attractive appearance. Consequently, the development of new approaches, designed to support the continuous improvement of processes, allows quality products and services to be delivered. This project uses computer-integrated facilities and equipment that introduce students to state-of-the-art technologies in areas such as real-time data acquisition on system variables, data processing, and information dissemination. Integrated systems may also be used in courses that emphasize computer-aided design and manufacturing, computer-controlled systems, robotics, and real-time physical systems. Although computer integrated manufacturing is not a new concept, the interdisciplinary and outreach concept as illustrated here is innovative. This interdisciplinary collaboration is supported by laboratory designs that satisfy the basic needs of various departments and is synergistic in nature, improving the educational opportunities beyond the mere sum of its parts.

An integrated system approach is important to a variety of business areas from planning, purchasing, and customer support for a product. This concept can also be applied to areas in a manufacturing enterprise (or even the service sector of businesses), where sharing information between people can be improved through the use of computer tools. Computer tools, for example, virtual instrumentation, when combined with the appropriate network infrastructure permits communications between applications, processes, and users. This systems approach can be implemented in varying degrees of complexity through progressive stages of development. This improvement will be realized by performing continuous evaluation and subsequent control of processes with a goal of improving efficiency and quality. Managing the process and focusing on quality reduces total needed resources. As Pecan, Salim, & Zora (2004) note “. . . precision instrumentation control and reliability in data acquisition is imperative to the today's manufacturing systems. Appropriate techniques may cause major impacts on results and outcomes” (p. 3).

The need for integration develops as a result of growth in both the size and complexity of operations. The need to share information between people and machine functions is met by the use of computer tools. The availability of computers, for example, the widespread use in industry of CAD systems, databases, and numerically controlled (NC) machines have made the efficient sharing of information both practical and essential. Communication of data is made possible by networks that connect computers, data collection

devices, prototyping equipment, and NC machine tools. For business and industry interfacing these devices is often made easier by working with a consultant specializing in system integration. Companies are in need of employees with skills in areas necessary for the development and evolution of integrated systems. Consequently, developing these skills is of utmost importance to science and technology students and a primary objective of this program. It is also an objective of this project to foster creativity and enhance student productivity using design automation and multimedia technology. This project includes an electronic network and a resource rich virtual network component resulting in an effective distribution point for the proper dissemination of information.

To accomplish these objectives, a laboratory was developed that integrates computer hardware, instrumentation, interfacing, computer-controlled systems, real-time systems, and integrated manufacturing. Program goals focus on the students' need to gain hands-on experience with the fundamental hardware building blocks of computing machinery and the integration of these components with software to develop computing systems. These laboratories also provide students with facilities for experimentation, development, and running real-time software support for a physical system.

LABORATORY DEVELOPMENT AND USATION PLANS

A refurbished Industrial Technology automated systems laboratory supports lab activities in upper level undergraduate courses in Industrial Technology, Computer Science, and the ISAT graduate program. This lab is developed around computer-numerical-control (CNC) equipment that is integrated with robotic equipment. Two additional laboratories have been developed to support interdisciplinary and collaborative course delivery and research projects. These labs provide students with product simulation software and rapid-prototyping equipment. The challenge is to teach students critical thinking through design ideation, modeling and testing, and the associated manufacturing requirements using computer systems. It is the aim of the program to impart hardware principles to future computer scientists/software engineers and technologists. ISAT graduate students use the same labs for computer-aided product design and analysis. In addition, computer-aided manufacturing (CAM) projects, graphical modeling, and rapid prototyping allow students the opportunity to fully integrate the roles of designer and

engineering analyst. Programmable logic controls (PLC) used in conjunction with virtual instrumentation creates fully automated and integrated manufacturing system controls and data collection.

A virtual instrument (VI) consists of an industry-standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-in boards, and driver software, which together perform the functions of traditional instruments. VIs represent a fundamental shift from traditional hardware-centered instrumentation systems to software-centered systems that exploit the computing power, productivity, display, and connectivity capabilities of popular desktop computers and workstations. Finally, VIs are appropriate for general purpose applications such as network communications, database development, and data analysis programs. Although the PC and integrated circuit technology have experienced significant advances in the last two decades, it is software that truly provides the leverage to build on this powerful hardware foundation to create VIs.

PARAMETRIC MODELING AND RAPID PROTOTYPING LAB

Rapid prototyping is not a new idea to the field of engineering design. However, Walker and Cox (1999) found that rapid prototyping is on the increase because there is “an abundance of new [affordable] technology for rapidly developing prototypes” (p. 3). These prototypes, when developed around a common database, decreased the number of engineering changes in a product or an industrial design (Paul, 1995). CAD software programs such as Pro-Engineering provide the tools for parametric modeling that allows for concurrent input from designers, testing, and prototype developers. For example, many companies desire to improve communications between engineers and manufacturing. Improved communication can be achieved through the process of parametric design. In this process designers and manufactures share a common database which is continually updated as design ideation is altered.

In the last year students and faculty, using the concepts of parametric design, have collaborated with a regional maritime museum on the reconstruction of a full size replica of the Civil War submarine the *Pioneer*. The original 35 foot submarine was built and tested in New Orleans in 1862

before being scuttled prior to the Union Army's invasion of the city (Ragan, 1999, p. 50). Students who worked on the project were required to integrate knowledge and skills from technology courses with mathematics, physics, and history. Solid modeling with CAD software and the production of prototypes on the 3-dimensional (3-D) printer helped determine the physical and mechanical constraints of the submarine. The original *Pioneer* submarine was predecessor to and built by the same designers of the infamous *Hunley*. Parametric modeling and 3D modeling played a significant role in the collaboration among the university, museum, and industry that resulted in the reconstructing the submarine. The project was completed and is on display at the Lake Pontchartrain Basin Maritime Museum in Madisonville, Louisiana.

In a second project students from the department of Industrial Technology work together to develop alternate design ideation and computer-aided inspection of mechanical crane booms. Prototype development is completed on a 3-dimensional printer. Multiple parameters such as part orientation during buildup, scaling factors to account for treatments, and parts built in assembly as opposed to individual components affect output. Rifeschneider (2000) claimed that "...product designers are assuming part of the role of engineering analysts. Streamlined engineering analysis programs that can be used by non-specialized designers running CAD on standard PC platforms" (p. 4). Again, students not only had the ability to create the designs but also to perform design on the various prototypes.

After prototype development, parts are subjected to fatigue testing with variations in load amounts, duration, and repeatability. Tests that are conducted on design ideas are controlled by the virtual instrumentation developed by ISAT graduate students. Data on the tests is recorded and analyzed with software. At the same time, all design ideas are saved as artifacts that can be accessed if needed. In this program industrial design projects were developed by undergraduate students in the IT program and tested with equipment designed by graduate students in the ISAT program. Virtual instrumentation programs written by ISAT graduate students drive the control and statistical databases for testing.

CAD AND RAPID PROTOTYPING EQUIPMENT

The CAD software packages that students use for design and development are Pro-Engineering, AutoCad's solid modeling, and AutoCad's Inventor. General features include high precision drawing and importing/exporting in DXF and STL formats to third party software programs. Both Master Cam and BobCad milling software packages are used to convert CAD drawings into CNC code.

For rapid prototyping the system developed by Z-Core's 3D printer the Z-400 was selected. The Z-Core printer works with either starch-based or plaster-based powders building up two-dimensional cross-sectional layers from .004 to .010 of an inch in thickness. Clearance fits for finished mating parts is .010 of an inch. The printer can construct flexible, hardened, or snap-together parts. Parts can be constructed as individual components or assemblies. The advantage of rapid prototyping parts allows for review of possible design flaws as well as giving considerations to manufacturing requirements (Walker & Cox, 1999). Simulation and rapid prototyping teaches important lessons about product failure and provides opportunities to modify designs at greatly reduced costs (Wigotsky, 1997).

COMPUTER INTEGRATED MANUFACTURING (CIM) LAB

The equipment in the computer integrated manufacturing lab supports the use of "smart" robotic systems, that is, robots that have on-board microprocessor systems and the ability to be controlled from a teaching pendant. These characteristics provide an opportunity for teaching students the fundamentals of stepper motors and digital control of such motors in a physical system. The authors teach students to use the computer to control the operation of a variety of manufacturing equipment. This would cover concepts and procedures associated with virtual instrumentation and associated software. Students also explore the role of such equipment in larger industrial systems that use the concept of control systems, numerical control (NC), and computer numerical control (CNC) technologies used in today's manufacturing industries. The students learn about automated system processes in which machine tools follow an ordered sequence of operations under the control of a set of coded instructions. This requires theoretical and practical knowledge of automated systems and their programming requirements.

Program goals include instruction on the electronic and mechanical constraints of varying types of industrial, personal, and educational robots. In addition, coverage is given to industrial and engineering applications as well as the economic and human factors of robots in manufacturing systems. The robotics equipment previously mentioned provides for quick “start-up” time for students to become familiar with the system by learning to guide, control, and store trajectory programs for the robot system’s manipulator arm, thus, learning the fundamentals of this new type of I/O system.

COMPUTER INTEGRATED MANUFACTURING EQUIPMENT

For the robotic and computer integrated manufacturing concepts, the authors chose several systems manufactured by Eshed, Robotec, and Amatrol. The program uses a number of Point-to-Point Robot Systems. These consist of a highly reliable mechanical arm and multi-function controller. The manipulator arms are an open, vertically articulated structure. The manipulator arms have five axes plus gripper with optical encoders on all axes.

There are also a number of Continuous Path robot systems. This is a fast, accurate, flexible, and reliable robotic system designed for laboratory applications, research, and/or training. This manipulator arm also has an open structure and is vertically articulated with five degrees of freedom (plus gripper). A variety of grippers allows for a wide range of flexibility. This controller is a stand-alone, real-time, multitasking controller that allows for simultaneous and independent operation of several programs, grouping of axes for multiple device control and editing programs while others are running. The basic controller is configured with eight axes of control, is expandable to 11 axes and is capable of handling both 16 inputs and outputs.

Continuous path control robot systems offer an exceptional working volume and absolute speed/time between control points. This is an essential component for experiments in which students expect the robots to perform in a very efficient and accurate manner. Consequently, the continuous path system enables functions such as design spraying or dispensing exercises. Due to the high repeatability factor of these systems, students will be able to design sorting, palletizing, loading/unloading CNC machines or other material handling application and expect high quality results. Since these

robots have open or closed loop control with various velocity profiles (parabolic, trapezoid, free running, acceleration, and deceleration) and proportional-integral-differential control, the difference between the fine tuned control and insufficient gain, overshoots, position, and error speed can all be demonstrated. The lab has machine vision systems, which includes an updated version software package, with a real-time frame grabber (512 x 512 pixels, 256 gray levels) and multiframe/multicamera capabilities. Multiple vision parameters (such as camera gain/offset, threshold, etc.) can be set for each application. Explicit shape analysis and measurements can be conducted.

VIRTUAL INSTRUMENTATION LAB

The virtual instrumentation lab is used to enhance student learning in applied mathematics, science, and technology. The configuration of the facility provides faculty members and students with a convenient meeting place to exchange ideas and develop collaborative activities in a student-centered layout. This facility also supports research projects that use virtual instrumentation techniques for control of machinery, data gathering, and analysis. This platform allows students to exercise their imaginations to create circuits and simulations and then measure and evaluate them using National Instrument's Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW). National Instrument's Educational Laboratory Virtual Instrumentation Suite (ELVIS), which is a set of programmable instrumentations, is also used to control and monitor PLC's, CAD/CAM and CIM arrangements. ELVIS provides a link between the virtual/software and the physical world. To achieve this, students are provided with a series of interfacing and control exercises and experiments that build on the fundamental hardware principles including machine interface and remote control of equipment. Curriculum applications include electronics design, communications, controls, instrumentation, and data acquisition. The technology and classroom arrangement allows for hands-on activities and exploratory learning of a collaborative nature that is essential to all occupations. Pecun et al. (2004) repeated Franz and Travis' claim that "National Instrument's LabView™ data acquisition hardware and software module has become one of the most widely used tools to capture, and view process controls, instrumentation, and power system data both in academia and the industry" (p. 1).

Applied research is conducted in this lab to develop, test, and validate the ISAT student's thesis or research projects. Beyond this, students also have the ability to conduct applied research as a team. The team approach adds the dimension of synergy to learning. Applied learning in teams, as Senge (1990) reported, becomes "...a commonality of purpose, a shared vision, and understanding of how to complement one another's efforts" (p. 234). For example, students in the graduate and undergraduate programs are required to generate multiple approaches to solving problems that are based on current business and industry-driven practices such as work-study analysis or developing manufacturing controls using PLC's. These topics provide students with the opportunity to explore research topics that represent current business and industrial standards. These projects often continue over a two or three semester period. The ease of repeatability of experimental setups in a virtual instrumentation lab allows students to maintain experiments and continue their study over an extended period of time. Consequently, the development of a virtual instrumentation lab, which supports research from diverse scientific fields, will enhance a seamless transition between theoretical research and application.

Data acquisitions, statistical analysis, and presentations on research projects are required in the ISAT curriculum. It is the nature of the ISAT program to be cross-disciplinary in its studies. It is imperative that students have the advantage of virtual instrumentation that can perform with cross-functionality. Laptops in the lab also function as platforms from which students will use software for implementing efficient data storage and analysis. This includes but is not limited to programs such as Mat Lab, Derive, MathMatica, and Microsoft's Excel and Access. The virtual instrumentation lab supports research in chemistry, computer science, industrial technology, physics, and mathematics without major modification to the equipment or loss of integrity to the study's validity. Because research in scientific fields is often an outgrowth of prior research, longer-term studies can be completed as research setup configurations and findings are saved as electronic files.

The program uses National Instrument's Data Acquisition system ELVIS. This system includes; a full development system of LabVIEW, a termination breadboard, and a Data Acquisition (DAQ) interface card. LabVIEW is a graphical programming system for data acquisition and control, data analysis, and data presentation. This package provides an alternative to cumbersome text-based programming by providing an innovative programming methodology in which the user graphically assembles software

modules called virtual instruments (VIs). With LabVIEW different types of PLC hardware and associated software can be used. A series of exercises are planned in which students will learn to build address decoders, scan and input external data from sensors and instrumentation, provide latching and control, and then provide scanned output after processing the input data.

CONCLUSION

With a commitment to cooperative teaching and learning, student/student interaction, and student/faculty interaction will change dramatically. Responsibility for learning shifts to students organized into teams. As a facilitator instead of a lecturer, the faculty member emphasizes positive interdependence among team members and individual accountability. This program has increased use of new technology-enabled methodologies. High technology classrooms and multimedia laboratories are implemented throughout the curricula as appropriate.

Given the large percentage of students in technology, computing, and sciences seeking graduate degrees, the authors believe that it is increasingly important to introduce students to collaborative activities in the curriculum. Likewise, we believe that interdisciplinary settings in which students are taught the fundamentals of good practice and policy in science and technology will enhance and improve the use of this tool to advance these areas. Thus, students need to be able to use sophisticated, real-world equipment. The work described in this article is an effort to afford our students the fruit of these beliefs.

Educators face a great challenge in trying to integrate the products and services associated with new technologies into their curriculums. This brings with it many exciting promises. It is hoped that the experience that students will gain from this project will prepare them for becoming members of systems development teams consisting of both scientists and technologists. At this writing, some of the work described in this article is in the developmental stages. The authors plan to report an update of this project's progress in future conferences.

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