On The Use Of Students For Developing Engineering Laboratories

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ABSTRACT

This paper describes a unique and innovative approach that solved the dual problem of starting up a new engineering instructional laboratory in a timely manner, and for teaching engineering students advanced skills in Automatic Data Collection. Students enrolled in a special pilot course were used to develop and startup an Automatic Data Collection laboratory. These students were assigned individual Automatic Data Collection technologies of interest and given total responsibility for the successful startup of the laboratory. The organization and structure of the course modeled the typical team oriented project development efforts in industry. Feedback from students showed the course to be better than a typical lecture/laboratory/demonstration type course in the following ways: 1) students believed they had greater amount of contact with equipment; 2) their experience on the project was more realistic than more traditional courses; 3) they believed they gained a more thorough understanding of the technology under study; and 4) they believed they improved their professional skills making them more marketable to potential employers. With respect to the laboratory itself, startup time was reduced from an estimated 18 months to 14 weeks with the help of the student teams.

I. INTRODUCTION

Development of state-of-the-art engineering laboratories is becoming an increasing problem in the University environment. Due to the greater variety and increased complexity of much state-of-the-art hardware and software, the cost and cycle time for development and startup of a modern engineering laboratory can be excessive. This, together with decreasing budgets for technician support experienced by many engineering departments, often hamper efforts to develop new laboratories for engineering instruction.

In addition to this problem, the complexity of the technology itself associated with many advanced computerized technologies (e.g., computer-aided-design, computer-aided-manufacturing, computer network design, automatic data collection) make it more difficult to give students sufficient skills to enable them to adequately apply these technologies after graduation. Courses designed to educate students on these technologies usually contain a lecture component, practical demonstrations of the technology, and laboratory exercises which present the student with a series of experiments, each having a narrowly defined objective and a limited set of expected results.[1,2] Although this approach is practical in many domains of engineering, sometimes more realistic educational experiences are necessary to give the student more robust proficiency.

This paper describes a unique and innovative approach that helped resolve both of these problems. The authors used this approach to instruct undergraduate and graduate industrial engineering and manufacturing engineering students in concepts and skills in a relatively new engineering technology—Automatic Data Collection (ADC). In addition, these students served as a "start-up" team for development of the laboratory. This enabled students to not only acquire skills in ADC technologies, but also in real-life 'project management'.

Students enrolled in a special pilot course were used to independently develop and startup an ADC laboratory. These students were assigned individual ADC technologies of interest and given total responsibility for the successful startup of the laboratory.

II. PREVIOUS WORK

Although students have been informally used by universities for many years to aid laboratory development, there is little documentation in the published literature using laboratory development as a means for training students. For example, in reference 3 the authors describe a laboratory containing scaled working models of Flexible Manufacturing Systems. These machines were fabricated and assembled by graduate students with a minimum of technician support. However, as the focus of this paper was in the description of the laboratory itself, no detailed discussion or formal assessment of students' experience in this process was described.

In reference 1 the authors describe an approach for training Computer Engineering students. As part of a Senior Design Laboratory, students are presented with a product specification of a design problem (e.g., design and construction of a microcomputer based board game). Students work in teams to build a product that meets these specifications. Students provide laboratory demonstrations of important milestones, give oral and written reports of their project, and provide a final product demonstration. Industry representatives have given this course positive feedback in that it teaches students to meet enforced due dates and enhances both their oral and written communication skills.

III. Purpose Of Research

We describe the startup of an engineering laboratory to train students in the design and implementation of advanced ADC technology. This idea met complementary goals. Students in the Industrial Engineering Department had expressed an interest in acquiring more hands-on, realistic experience with ADC than what would be typically available in the lecture/demonstration/lab course they had experienced with other computerized technologies. In turn, the authors, as principal investigators of the laboratory, had the desire to make the ADC Laboratory functional for instruction in the shortest time possible.

To meet these complementary goals, we used students to expedite laboratory development. In turn, we assessed the value of laboratory development as a mechanism to teach advanced ADC concepts and skills. This idea was implemented in a pilot course entitled "ADC Projects".

This paper describes the need for an ADC laboratory to train industrial engineers, the goals for the pilot course, the methods used to educate students in ADC skills, results of the students' experiences, and results of the laboratory development effort.

IV. The Need For ADC Trained Engineers

The demand for trained engineers to implement such Automatic Data Collection technologies as barcode, Radio Frequency (RF), magnetic stripe, machine vision, and voice recognition has "exploded" in recent years. These technologies have been incorporated in such diverse industries as banking, manufacturing[4-6], food processing[7], retail garments, health care[8-10], and even the gaming industry.[11,12] At least 87 different industry standards in ADC currently exist and will need support. American businesses have found that these technologies are critical to competitiveness in the global marketplace. Although the U.S. currently leads in development of ADC technologies, good engineers are critical to maintain this lead.

The diverse range of applications of ADC technologies is analogous to the variety of environments in which Industrial Engineers work. These technologies are typically used to develop sophisticated information systems to reduce costs, control inventory, and provide timely, accurate information.[13]

Due to the lack of a laboratory, undergraduate engineering curricula currently do not provide in depth education on ADC technologies. At an introductory level, students are unfamiliar with barcode or magnetic symbology standards, print quality analysis methods, and ADC database design. At the advanced level, students are unaware as to how to design, select and install ADC systems, or how to develop advanced applications such as material tracking, labor tracking, or defect reporting. We believe that these skills are essential to the graduating engineer since the usage of these technologies is universal in industry today.

To meet the need for engineers skilled in ADC, the Automatic Data Collection Laboratory was founded by a grant from the National Science Foundation.[14] The purpose of this laboratory is to provide an environment for engineering students to gain knowledge and skills in state-of-the-art ADC technologies. It will also equip these students to successfully utilize these technologies in the workplace.

V. Course Method Overview

The ADC Projects course was administered over a 14-week period. The course syllabus is illustrated in Figure 1. From an instructional design viewpoint, the goals of the course were to: a) provide a more realistic educational experience than with the traditional lecture/demo/lab structure; b) provide more direct contact with ADC equipment; c) increase the depth of understanding of the technology and equipment; d) impact the professional development of the student; and e) provide an overall rewarding experience for the student. From a project management viewpoint, the goal was to decrease the cycle time for startup of the laboratory from that possible with the single technician currently assigned to the laboratory.

Five major components comprised the course and were designed to impact the stated objectives. Each component is described below.

1. Technology Position Papers. Students were required to develop Technology Position Papers to acquire basic knowledge on a particular ADC technology and to provide a single source of educational material and documentation on each technology for future students.

2. Product Installation/Startup. Students were required to install and startup one or more ADC products within one of several different ADC technology areas.

3. Laboratory Experiment Development. Within an assigned ADC technology area, students developed laboratory experiments that would be used as learning exercises for teaching introductory concepts on ADC in future courses.

4. Demonstrations/Presentations. At regular intervals, students demonstrated the status of their products and experiments to others, including students in the course, instructors, and visitors from industry.

5. Weekly status meetings/reports. To develop professional skills of the students, weekly status meetings with progress reports supplanted traditional lectures.

The pilot course consisted of 15 students from the Industrial Engineering Department and the Manufacturing Systems Program at the University of Pittsburgh. Eight students were undergraduates, while seven were graduate students. Undergraduate students were at the Junior and Senior Level. There were no formal prerequisites for the course. Students in the course had no specific skills except for basic computer skills that are taught in typical freshman and sophomore level courses. None of the students had any previous experience in ADC technology.

Available equipment from an ADC technology area such as: a) Barcoding, b) Radio Frequency Data Collection (RF/DC), c) Radio Frequency Identification (RD/ID), d) Magnetic Stripe, e) Voice, f) Computer Vision, g) Material Tracking, and h) Response Time Simulator was assigned to pairs of students. Table 1 lists the equipment and software made available through the National Science Foundation (NSF) grant for the Laboratory. Attempts were made to assign equipment to students based on their individual interest areas. To compensate for differences in educational levels of undergraduate vs. graduate students, more difficult applications (e.g., material tracking software, RF/DC, RF/ID, vision) were assigned to the graduate students, while simpler technologies (e.g., barcode printing/verification, magnetic stripe reading/encoding) were assigned to undergraduates.

An electronics technician was made available to the students on a consulting basis for approximately 10 hours per week. The technician had skills in basic computer hardware connectivity and software installation, but had no particular skills in any ADC area. The role of the technician was to provide advice to the students on possible solutions to equipment/software troubleshooting problems that the students were experiencing.

Students were told that they would work on projects with a defined goal. Students were also informed that the methodology of the course was unstructured compared to other courses they had taken in their collegiate experience. Students were then informed of the course objectives, the course structure, and the requirements. Students were told that they would have complete responsibility for the development of their particular technology, although technician support would be made available to students on a minimal basis. Support from ADC vendors could be used if they could solicit such help. To keep students on schedule for development, deadlines for sections of the position papers and laboratory experiments were made known on the course syllabus. At the end of the course, students were given a questionnaire to assess their subjective evaluation of the course format with respect to the stated objectives. Criteria for grading included the comprehensiveness of the technology position paper, relevance and completeness of the laboratory exercises, and the successful installation and startup of the ADC equipment and software.

VI. Technology Position Papers

Currently, there are no comprehensive textbooks on ADC technology. Therefore, there is no single source that one may reference to learn the very basics of each ADC technology area. To overcome this problem, students were required to conduct a literature search in their assigned technology area and to write a 40 to 50 page technical paper that described this technology. This information would provide future students a single source of documentation to which they could refer to learn the basic concepts of each technology. To aid students in the literature search, the Technical Information Center from AIM^USA (the ADC industry trade organization located in the Pittsburgh area) was made available to them.

There was a position paper for each one of the ADC technology areas including Barcodes, Magnetic Stripe, RF/DC, RF/ID, Machine Vision, and Voice Recognition. In addition, a graduate student team undertook the effort to develop a position paper on Ma-

IE1059: AUTO IDENTIFICATION PROJECT

Textbook: Palmer, *The Barcode Book*

Grading:		
	Project	45%
	Position Paper	45%
	Laboratory Usage	10%

TENTATIVE SCHEDULE

Date	**Project**	**Position Paper**
5/13	Introduction	Introduction
5/18	Assign Projects Begin Manual Reading	Assign Position Paper /Begin Lit. Review
5/25	Equipment Handout	Continue Literature Review
6/1	Roundtable Discussions	Continue Lit. Review/Begin Draft Outline
6/8	Roundtable Discussions	Draft Outline DUE/Begin Introduction
6/15	Roundtable Discussions	Introduction DUE/Begin Technology Desc
6/22	Roundtable Discussions	Continue Technology Desc.
6/29	Roundtable Discussions	Technology Desc. DUE Begin Available Hardware/Applications
7/6	Roundtable Discussions	Continue Available Hardware/Applications
7/13	Lab Demos	Available Hardware DUE/Continue Applic.
7/20	Lab Demos	Applications DUE Begin Conclusions/Begin Exercises
7/27	Project Presentations/Conclusions/Exercises DUE	
8/3	Project Presentations/Lesson Plans DUE/POSITION PAPERS DUE	
8/10	Project Presentations	

Figure 1. ADC Projects course syllabus.

BARCODE EQUIPMENT:

Terminals -

- Hand-held with scanner, spread spectrum RFDC
- Base station / controller for RFDC
- Fixed location
- Fixed location, moving beam with frontal scanner

Readers -

- Hand-held, non-contact, wedge reader
- Hand-held, contact, wedge reader
- Point of Sale CCD scanner
- Swipe reader

Printers -

- Thermal
- Thermal transfer
- Laser
- Barcode printing software

Verifiers

- hand-held verifier

MAGNETIC STRIPE EQUIPMENT

Readers -

- Point of Sale type swipe reader

Encoders -

- Standard encoder, swipe style

Media

- Cards
- Tickets

RADIO FREQUENCY EQUIPMENT:

Readers & Terminals -

- RF Reader
- RF Antenna
- RF Module

Encoders -

- RF programmer with tag programming software

Media -

- Identification Tags (Active & Passive)

VISION EQUIPMENT:

- Black & White 1024 Camera
- 13" RGB Analog Monitor
- Image Processor
- Object Code Library with image processing software
- Cable Assembly

VOICE RECOGNITION EQUIPMENT:

- Fixed-station voice recognition system
- Portable voice-recognition system (voice communication)
- Application software

APPLICATION SOFTWARE

- Quality assurance
- Inventory control
- Time and attendance
- WIP tracking
- Lot tracking
- Integrated data collection
- Communications software

Table 1. NSF funded laboratory equipment and software.

terial Tracking System Design that included requirements for data, functionality and hardware connectivity. This task of developing a technical position paper served several purposes: It provided students an astute understanding of their particular technology area. It also served to develop students' technical writing skills, as sections of these papers were reviewed throughout the course by the instructors. In addition, the resultant position paper would serve as a single source document on a particular technology that could be used by future students in a planned introductory course on ADC.

VII. Product Installation/Startup

In the second week of the course, students were assigned an ADC technology area. Eight teams were formed with most teams comprised of two students. The teams undertook installation of the following types of equipment and software:

- Barcode Printing Systems
- Computer Vision Systems
- RF/DC Systems
- RF/ID Systems
- Magnetic Stripe Systems
- Voice Recognition Systems
- Barcode Material/Labor Tracking Systems
- ADC Network Design/Response Time Simulation

Product installation and startup served to improve the students' technical skills in their technology area as well as their professional skills. In this task, students were required to install all software for their product and to physically connect all peripherals. The major obstacle experienced by all students in this task was the initial establishment of communications (e.g., the "handshake"). All ADC equipment requires integration of a vendor's hardware (e.g., RF terminals, barcode terminals, magnetic stripe readers, barcode printers) with the computer system. To successfully accomplish this task requires knowledge of appropriate cable requirements, pin configurations, and communication settings on computers.

The procedure for completing this task typically took the following form: Students would begin by reviewing technical manuals and following these instructions for connection and installation. If the product would not respond as expected, students would repeat the installation/connection steps to ensure they had not made an error. If success could still not be achieved, they would review the manuals further including any troubleshooting guidelines that may have been provided. Following this activity, students would consult with the technician and would carry out his recommendations. Finally, product vendors would be consulted.

VIII. Laboratory Experiments

Each team was required to develop several laboratory experiments pertinent to their ADC technology area. The purpose of these experiments was twofold: 1) to provide students with skills in ADC application development; and 2) to provide a compendium of experiments that could be used to educate students in ADC technology for an introductory course planned for the coming academic year. Table 2 describes experiments developed by students for each technology area.

To ensure the quality of these experiments, teams had to obtain pre-approval from the instructor for each laboratory exercise. At the end of the term, students delivered a comprehensive laboratory report that included a) the title of each laboratory experiment, b) its objective, c) detailed instructions of how to setup the experiment, d) instructions on how to carry out the experiment; and e) expected solutions for the experiment. In addition, students were to have detailed appendices to this report that documented critical information such as necessary cabling, communication settings, pin configurations, pertinent reference manuals, startup instructions, names and phone numbers of key technical contacts, and so forth.

Students were graded by instructors on this task based on the completeness of the laboratory project report and the instructors' ability to easily setup and carry out the laboratory experiments.

IX. DEMONSTRATIONS/PRESENTATIONS

To improve the presentation skills and provide industry contacts to students for potential employment after graduation, regular presentations and demonstrations were done by the teams. Throughout the term, students demonstrated the status of their products and laboratory experiments with the instructors. Periodically, tours by ADC vendors and industry managers interested in applying ADC technology were arranged. Over the 14-week period, several students presented their technologies and demonstrated their products to seven corporations that toured the facility.

Voice Recognition	1. Train the system on the user's voice. 2. Carry out a paint inspection program 3. Carry out application integrating voice with barcode technology
Material Tracking Systems	1. Write an IRL program for a simple work-in-process tracking system 2. Write an IRL program for a simple labor tracking system.
Magnetic Stripe	1. Read information from credit cards 2. develop a program to encode a blank magnetic stripe card 3. Read the card just encoded 4. Make up a mock ID badge card for a company.
Barcode Symbology and Printing	1. Decode three labels given three different symbology standards. 2. Encode two labels using 2 of 5 and Code 93. 3. Create barcode labels to support a work-in-process tracking system. 4. Compare/contrast different types of barcode readers for receiving 25 packages at a receiving dock within a 15 minute period.
Response Time Calculation	Assess expected response times of given network configuration parameters using a response time calculator.
Machine Vision	1. Using the program provided, measure the dimensions of the steel samples provided and compare them to given specifications. 2. Use image enhancement capabilities of the vision system to perform a defect analysis of the steel samples.
RF/ID	1. Read and write an ID number to and from a tag. 2. Measure the optimum orientation of the given tags within the capture area. 3. Determine the three dimensional capture area between a tag and the antenna
RF/DC	Develop a program that reads a barcode from the hand-held RF reader, and provides instructions to the user in response to the scanned barcode.

Table 2. Sample of experiments for each technology area.

X. Weekly Status Meetings/Reports

To develop professional skills of the students and to aid them in overcoming any problems they may be experiencing with their projects, weekly status meetings with progress reports replaced traditional lectures. These meetings were conducted in the laboratory itself. Students met with instructors once per week for a two-hour meeting. The first hour was a group meeting, while the second hour was devoted to one-on-one discussions with each team. In the group meeting, each team presented to the instructors and the other teams a one-page status report of their project that described their accomplishments for the week, problem areas, how they planned to resolve those problem areas, and goals for the following week. This time was also used by the instructors to give technical direction to each team, and to provide pertinent information to the students such as lab policies, contacts for technician support, and dates and times of industry visitors.

The one-on-one discussions with each team were typically carried out at the team's workstation. This time was devoted to demonstrations of each teams work, as well as detailed discussions and demonstrations of the technical problems the team may be experiencing at the moment.

XI. Results

To evaluate the effectiveness of the course in meeting its stated objectives, a questionnaire was devised. A copy of this questionnaire is included as Appendix A. The questionnaire was administered to the students at the end of the course. The intention was to assess students opinions of the format of the course compared to a more traditional course (e.g., lecture/lab/demos) that would have been used to teach ADC concepts and skills.

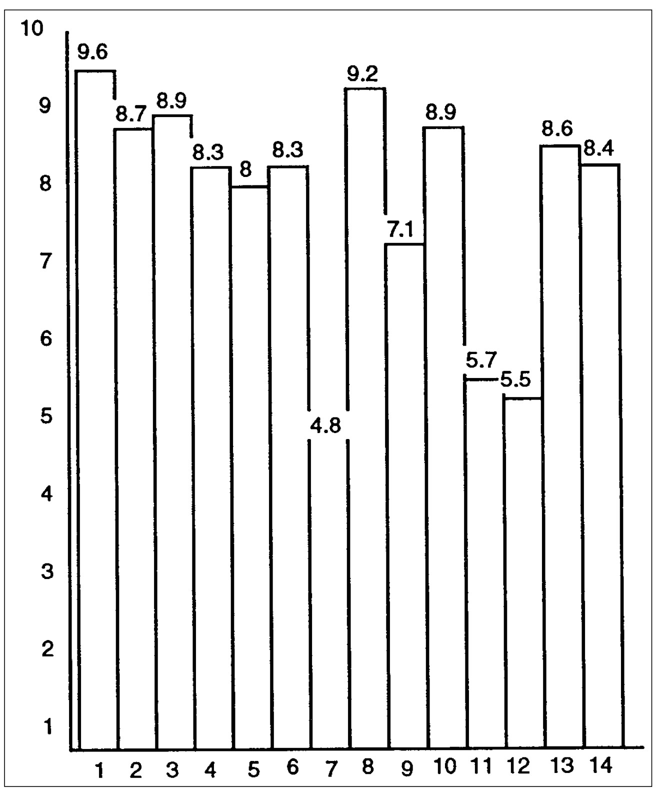

Figure 2. Average responses of course effectiveness.

It consisted of 14 questions assessed through 10-point Likert scales with 1 being a poor rating and 10 being an excellent rating. The 14 questions assessed student's impressions of: a) equipment contact, b) realism, c) depth of knowledge/skills in a particular ADC technology, d) breadth of knowledge/skills across different ADC technologies, e) students' perception of professional development, and f) students' overall educational experience.

14 students completed the questionnaire. Figure 2 illustrates the results which represents the average score on each question. Students' comments are described in the following sections.

A. Equipment Contact

Question 1 assessed students' impressions of Equipment Contact compared to a traditional course consisting of lecture, a two-hour weekly laboratory, and demonstrations. Students saw this as a major advantage of the new course format. Students believed they were given much greater access to the equipment than they would have been allowed in a more traditional 2-hour laboratory. The equipment was made available to them in the laboratory for approximately 60-hours/week. The type of equipment contact was also very different. Students believed they were not constrained by narrow objectives and exercises typically allowed in traditional laboratory projects. They commented on how much they liked the total availability of equipment from the point they removed it from boxes, through installation, establishment of communications, startup and laboratory development.

B. Realism

Question 2 addressed the realism of the course structure in teaching ADC as compared to realism of the more traditional format. Students believed the structure to provide a more realistic education on ADC than what would normally have been available. Aside from equipment contact as described above, students liked the idea that the products were the same as those used in industry (as opposed to scaled physical models). They also liked the idea of making contact with vendors and technicians to support their efforts in that this was what they would normally do in a job setting. Other comments included the ability to develop new applications; to assemble, test and run a product from 'scratch' (as this is how products would arrive to them in industry); and the ability to identify and resolve 'real life' problems associated with equipment installation that would not normally arise in a laboratory exercise setting.

C. Depth of Knowledge

Questions 3 through 6 addressed depth of knowledge and skills in ADC that could be attributed to the course format. Question 3 assessed a students' opinion of in-depth understanding of their ADC area comparing the current format with the traditional approach. In response to this question, all students believed that they had a much more in-depth understanding of their ADC technology using the current approach. Several students commented that their motivation to become highly proficient in their assigned technology was increased by the responsibility they felt for successfully starting up and developing their projects.

Question 4 assessed the value of the position paper in understanding the ADC technology. Overall, students felt that the position paper was critical in obtaining an understanding of the basic principles upon which the ADC technology was based. For example, the team working with magnetic stripe technology used the equipment to learn how to startup and operate hardware and software for magnetic stripe encoding and decoding; but, it was through the position paper that they learned the basic technology of how a magnetic bar is read and encoded. Students felt that both approaches were necessary—the position paper to learn the theory of ADC; and the equipment contact to apply the theory.

Question 5 assessed the value of the product installation and startup in understanding their ADC area. Responses were similar to those of Question 3 and were overwhelmingly positive. Students felt that learning a product beginning with its installation was the best way to learn this technology. The detail necessary for successfully completing this task was an experience that most students felt they would not have had in a more narrowly defined laboratory exercise. Students stated that they believed that installation and startup would be their primary responsibility in a job where they would work with ADC technology.

Question 6 assessed the value of the laboratory exercise development as an aid to learning. Students felt that exercise development helped enhance their learning experience in ADC that was begun with the equipment installation and position paper. Through development of applications, they could ensure the system was functioning correctly, and develop common applications used in industry. For example, the material tracking team was surprised at the ease in which labor and work-in-process tracking systems could be developed. Before this class, the team had the impression that these applications were overly complex and difficult to develop.

D. Breadth

Question 7 assessed how well the course allowed students to learn different ADC technologies. Average scores on this measure were expectedly low. Although they believed the course provided a forum to learn one technology very well, the students did not believe this structure was useful for learning a variety of ADC technologies. The weekly meetings which served to update other teams on the status of each project provided only a superficial understanding of a technology different from that with which a team was assigned. Recommendations included the need for 'mini' lectures throughout the course on the various ADC technologies.

E. Professional Development

Questions 8 through 12 assessed students' impressions of enhancement of their professional skills as potential engineers. These questions address their perception of their own confidence in working with ADC technology for a company (Question 8), value of the weekly meetings and progress reports (Question 9), perceived marketability of their skills (Question 10), opportunity the course provided to meet potential employers (Question 11), and value of demonstrations to their professional development (Question 12).

Students had a high perception of their own confidence in using ADC with a potential employer. All students felt that they could successfully apply this technology for a corporation as a result of the course format. With respect to the weekly meetings and progress reports, students saw these of some value in the course. They stated that these mechanisms aided them in setting and meeting weekly goals, keeping the project on course, and obtaining helpful feedback and recommendations from the instructors and other students.

Students stated that they felt that the course format would make them much more marketable to potential employers. They believed that the hands-on experience would enable them to obtain a greater number of job interviews, and to give a better interview by a more thorough explanation of the ADC technology in which they worked.

Students did not feel that the demonstrations added much value to their professional development. The reason is that very few students actually performed the demonstrations for the outside visitors. Some students that did do demonstrations for visitors felt that visitors were more curious about the technology than any active interest in potential employment of students after graduation.

F. Overall Experience

The last two questions addressed the students' perception of their overall experience with the course format as compared to other courses they have had in the School of Engineering (Question 13) and with other more traditionally structured courses (Question 14). With respect to both of these questions, the students believed that the course format was much better and more enriching than other courses and other course formats. Comments such as "the opportunity to work with the technology from start to finish", "the hands on experience", "communications with vendors", "the challenge of the project", and "potential for employment because of the 'start-to-finish' experience (e.g., installation, wiring, application development)" all contributed to this experience.

The average score for these two questions would have been better if the outcome was different for the one team that could not successfully complete their project at the time the evaluation was administered. We are happy to report that shortly after the questionnaire was completed, this team was able to successfully startup their product and complete the project on time.

XII. Status Of Laboratory Development

In addition to enrichment of the students' learning experience, startup time of the laboratory was drastically reduced. At the end of the 14-week term, seven of the eight ADC technology areas were installed and running. In addition, demonstrations and experiments were completed and documented. The technician assigned to the laboratory estimated that, working alone, it would have taken him approximately 18 months to bring the laboratory to the same level of development as was done by the students in the 14-week period.

XIII. Conclusions

The use of students for laboratory startup was a "win-win" situation. The authors were able to make the most of valuable technician time by using this person as a consultant. Students were able to gain valuable technical educational skills through "hands-on" experience with equipment, and "first-hand" experience with problem solving and project management.

Given the findings from the questionnaire described above, student perceptions of the approach are that it is highly effective in teaching engineering concepts. However, throughout the course the most obvious limitation of such an approach was the lack of breadth a student gains on various ADC technologies. Although students became highly skilled in their own technology area, they learned very little about other technologies.

To overcome this limitation, the department has decided that the ADC Projects course will be the second in a two-course elective series on ADC for undergraduate engineering students. The first course will be introductory in nature. It will cover the breadth of different ADC systems and will utilize the lecture/2-hour laboratory/demonstration format. The second course will be the ADC Projects course and will be similar to the format described in this paper. This course is intended to give future students the same depth of understanding in an ADC technology of interest as acquired by those students in the pilot course. This will be accomplished through installation and startup of new equipment as the laboratory continues development over the next several years. In addition, students will be allowed to initiate special projects where they can use the laboratory for application development for industry as well as for research.

At the completion of the course, three of the 15 students graduated. Within one month of the course, all three students were employed by companies, and are currently working on ADC related projects for these corporations. Indeed, the employer of one of these students was one that visited the laboratory during the conduction of the course. This situation would not have been possible without both the laboratory and the well trained students that resulted from the course experience.

The use of students in this approach can be a valuable experience for those developing new laboratories in engineering disciplines. We believe the approach can be extended to modernize existing laboratories. In the end, the approach appears to solve multiple objectives: decreasing the lead time for laboratory development, while providing a deeply enriching educational experience for engineering students.

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Appendix A

ADC Project Questionnaire

Equipment

1. To what degree do you feel you had contact with equipment as compared to a traditional approach (lecture/2-hour lab/demo)

1 2 3 4 5 6 7 8 9 10

much less contact — about the same — much more contact

Explain:

Realism

2. Compared to a traditional approach to instruction, to what degree do you feel that your experience with the equipment was more realistic

1 2 3 4 5 6 7 8 9 10

much less realistic — about the same — much more realistic

Explain:

Depth

3. Compared to a traditional approach, to what degree to you feel you learned the equipment and technology to which you were assigned?

1 2 3 4 5 6 7 8 9 10

very superficial understanding — about the same — much more indepth understanding

Explain:

4. To what extent was the position paper of value in understanding your ADC technology?

1 2 3 4 5 6 7 8 9 10

of no value — some value — of great value

Explain:

5. To what extent was the product installation and startup of value in understanding your ADC technology?

1 2 3 4 5 6 7 8 9 10

of no value — some value — of great value

Explain:

6. To what extent was the laboratory experiments of value in understanding your ADC technology?

1 2 3 4 5 6 7 8 9 10

of no value — some value — of great value

Explain:

Breadth

7. Compared to a traditional approach, to what degree do you feel you learned about a variety of ADC technologies.

1 2 3 4 5 6 7 8 9 10

fewer variety — about the same — greater variety

Explain:

Professional Development

8. Compared to a traditional course format, how confident do you feel that you could successfully bring up your ADC technology for a company?

1 2 3 4 5 6 7 8 9 10

Not confident at all — about the same — very confident

Explain:

9. To what extent were the weekly meetings and progress reports of value in helping you with your project?

1 2 3 4 5 6 7 8 9 10

of no value — some value — of great value

Explain:

10. Compared to a tradtional course format, to what degree do you feel that the structure of this course will make you more marketable to potential employers?

1 2 3 4 5 6 7 8 9 10

Not at all — about the same — much more marketable

Explain:

11. Compared to a traditional format, to what degree does this course structure provide an opportunity to meet potential employers (e.g., demos to visitors)?

1 2 3 4 5 6 7 8 9 10

No benefit at all — great benefit

Explain:

12. If you met any visitors to the lab or gave demos to visitors, to what degree was this of benefit to you?

1 2 3 4 5 6 7 8 9 10

No benefit at all — great benefit

Explain:

Overall Experience

13. Overall, how would you rate your educational experience with this course compared to other courses?

1 2 3 4 5 6 7 8 9 10

Total waste of time — about the same — highly enriching

Explain

14. To what degree was the structure of this course better or worse than a more traditionally structured course?

1 2 3 4 5 6 7 8 9 10

much worse — about the same — much better

Explain: