2006-265: SHOW THEM NAND GATES AND THEY WILL COME

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Jerry C. Hamann received the B.S. in Electrical Engineering with a Bioengineering Option from the University of Wyoming in 1984. He then worked for the Loveland Instrument Division of Hewlett-Packard before returning to the University of Wyoming to complete the M.S. in Electrical Engineering in 1988. Sharing time as a lecturer and National Science Foundation Graduate Fellow, he completed the Ph.D. in Electrical Engineering at the University of Wisconsin in 1993. As a faculty member at the University of Wyoming since 1993, Jerry has pursued research interests in applied robotics and control, signal processing, and higher education teaching and learning. He currently directs the University of Wyoming Hewlett Foundation Engineering Schools of the West Initiative, which is focused upon enhancing the recruitment, retention and quality of undergraduate engineering students.

Dennis Coon, University of Wyoming

Dennis N. Coon received a BS in Ceramic Engineering from the New York State College of Ceramics at Alfred University in 1979, an MS in Ceramic Science from the Pensylvannia State University in 1984, and a Ph.D. in Ceramic Science from the Pennsylvannia State University in 1986. He was employed at the Idaho National Environmental and Engineering Laboratory from 1985 through 1988 where his primary interest was in the devlopment of advanced materials for high temperature engines. He was a member of the development team that was awarded a R&D 100 award by Research and Development Magazine for development of ceramic joining method. Since 1988 he has been a member of the Mechanical Engineeirng Faculty at the University of Wyoming. Coon has been involved with the Engineering Summer Program since 1991, and has served as Director since 2004. Coon has been the Coordinator of the NSF funded Computer Science, Engineering, and Math Scholarship Program at the University of Wyoming since 2003. Coon’s research interests include composite materials and reliability of advanced materials in high temperature, high stress environments.

Paul Crips, Laramie Middle School

Paul M. Crips received his B.S. degree from the University of Wyoming in 1978 in Industrial Technology. He received a M.S. degree from the University of Wyoming in 2001 in Natural Science. Crips has spent the last 28 years as a teacher of junior high school aged students teaching both industrial technology and science. His most recent assignment is teaching seventh graders physical science, which includes classical physics and biological adaptation. Crips is an Amateur Radio operator holding an Extra Class FCC license (KI7TS). He is the advisor of two after school clubs, the Carey Junior High School Amateur Radio Club (KC7OEK) and the

Society of Student Astronomers. He is also the co-founder of the statewide "Women in Science Forum" that promotes gender equality in science, mathematics and technology. Crips is a Milken Family Foundation teacher of the year for Wyoming, 1999, Walt Disney Corporation American Teacher Awards Honoree for middle grades science, 1999, Arch Coal Teacher of the Year, 2004, U.S. West Teacher of the Year for Wyoming, 1996, STARDUST Mission Fellow, NASA, 1999-2006, Christa McAuliffe Fellow for Wyoming 1994. He is also a Maury Project Trainer for the U.S. Naval Academy and the American Meteorological Society on oceanography. Crips is also a military veteran serving honorably three years in the United States Naval Reserve and 17 years, Wyoming Army National Guard.

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John W. Pierre received the B.S. degree (1986) in EE with a minor in economics from Montana State University. He also received the M.S. degree (1989) in EE with a minor in statistics and the Ph.D. degree (1991) in EE from the University of Minnesota. He worked as an electrical design engineer at Tektronix before attending the University of Minnesota. Since 1992, he has been on the faculty in the Electrical and Computer Engineering Department at the University of Wyoming where he is currently a professor. He was a UW NASA Space Grant Faculty Fellow and a Department of Energy AWU Faculty Fellow during the summers of 1994 and 1995, respectively. His research interests include signal processing education, statistical signal processing, system identification, and signal processing applications to power systems. He is an active member of IEEE and ASEE Societies.

"Show Them NAND Gates and They Will Come"

Abstract

Many universities and colleges are faced with declining numbers of potential engineering students. In Wyoming, this is due to a declining number of high school graduates as well as potential students not being aware of the engineering career field. We have met this challenge with a variety of awareness and recruiting programs. A common thread in these efforts is a hands-on laboratory program in digital design fundamentals. This program exposes students to the exciting world of engineering, Boolean logic, and fundamental design principles. This low cost program consists of a series of theory modules coupled with a hands-on laboratory component. We have purposely developed laboratory modules using low cost, readily available components and test equipment. This approach has been used for the past five years with a middle school girls program, science and engineering summer programs for high school juniors and seniors, K-12 teacher enrichment programs, and also freshmen orientation to electrical and computer engineering programs. In this paper we will describe the modular approach, the low cost laboratory exercises, and also the success of using this approach to attract students to careers in the engineering and science.

Overview

Many colleges and universities are faced with declining numbers of graduating high school seniors. This body of students is the primary source of future undergraduate engineering students. At the University of Wyoming, there are many different programs to attract students to the university as well as the study of engineering. A brief summary of each of these programs are provided below.

- **Summer High School Institute (HSI):** The mission of HSI is to provide a place where some of Wyoming's most intellectually talented high school sophomores can gather before their junior and senior years, living and studying in an environment with no pressure for grades, and sharing ideas and friendship with other gifted students. The primary purpose of the program is to annually draw 100 talented high school sophomore students to the university for an intensive examination of unanswered questions and unresolved challenges. Among the areas that are probed include: world hunger, plants and people, knights and cowboys, drama, ethics and society, communicating with computers, understanding cultural development, pharmacy, fundamentals of computer design and programming, and the links between life and the arts. The goal is not to require students to learn another body of knowledge and pass yet another test. It is, rather to challenge imaginations, focus diverse disciplines on specific issues or problems, and integrate various individual talents into a larger perspective. In the process it is hoped that the selected high school students achieve their academic and personal potential by cultivating their leadership capabilities; to expanding their horizons, developing their adaptability, creativity, and critical thinking abilities, and to heighten their sensitivity to future possibilities for themselves, Wyoming society; and to stimulate and reward excellence in Wyoming schools [Adapted from 1].

- **Engineering Summer Program (ESP):** The College of Engineering and the Wyoming Engineering Society, in conjunction with the J. Kenneth & Pat Kennedy Endowment Endowment and the University of Wyoming College of Engineering Hewlett Foundation Engineering Schools of the West Initiative offer high school juniors an opportunity to participate in a summer program of hands-on experiences in various engineering fields. For example, students may design and build a digital circuit, study solutions to an environmental issue, test the aerodynamics of a tennis racket or model rocket, fabricate advanced composite materials, or design timber trusses. Laboratory sessions provide basic instruction and give students the opportunity to put new found knowledge to the test. ESP participants work one-on-one with faculty members and advanced students. This two week program is designed to expand student horizons, develop creative thinking and problem solving skills, and challenge imagination [Adapted from 2].

- **Computer Science, Engineering and Math (CSEM) Middle School Girls Camp:** The CSEM Middle School Girls Camp offers a variety of learning experiences for girls who have completed 6th, 7th or 8th grade and have an interest in broadening their knowledge about computer science, engineering and mathematics. The camp, directed by Professor Jerry Hamann of the Department of Electrical and Computer Engineering, is part of the Engineering Schools of the West Grants Initiative provided by the William and Flora Hewlett Foundation. The camp focuses on educational, hands-on study to increase and maintain interest in science and mathematics. This one-week camp offers experimentation and exploration in the area of robotics, graphical programming, 3-D design prototyping, and applied mathematics. In addition, there are several social activities such as picnics, swimming, climbing and field trips to nearby engineering and natural resource sites. All activities are provided by faculty from the College of Engineering and College of Arts and Sciences with assistance from graduate and undergraduate students in the disciplines [Adapted from 3].

- **EE1010 Introduction to Electrical and Computer Engineering:** The university's Electrical and Computer Engineering Department has initiated a new course, Introduction to Electrical and Computer Engineering, which is now in its fourth year. The purpose of the course is to expose freshmen to the discipline through a laboratory experience. Students perform both hardware and computer laboratory exercises in a wide range of areas of electrical and computer engineering. The course is only one credit hour and meets in a laboratory once a week for two hours. We make it a hands-on overview course with both hardware and some computer components. The individual topics covered attempt to expose students to the breadth of ECE and give the students a broader appreciation for the field and just how diverse the discipline is. The course comprises a series of laboratory modules (each 1-3 weeks long) in different areas of ECE. The workload of the course is intended to be minimal; the point is to motivate them and expose them to ECE, not to burden their already heavy class load. Although the course is not a prerequisite for other ECE courses, we feel that being exposed to the course motivates the students in the ECE courses that follow. The course is taught in the second semester of the Freshman year. While the course does not require a textbook, a number of textbooks, including [4] and [5], are available for such a course. Associated with [4] is a laboratory manual available on the internet describing a series of experiments.

- **Thinking and Doing Mathematics:** Engaging today's youth in mathematics and science is the foundation for sparking their future interest in the fields of engineering and science. This is the motivation for "Thinking and Doing Mathematics," a program that helps teachers learn more hands-on approaches to teaching mathematics through engineering and science. Participating teachers attend a ten day workshop at the university. The university's colleges of Engineering, Education and Arts and Sciences host the workshop for elementary, middle school and high school teachers who would like to partner with university faculty members to enhance K-12 mathematics and science courses. Interactive settings, hands-on projects, discussion groups and innovative teaching that inspires creative and critical thinking are among the classroom qualities to be groomed throughout the workshop and school year. Participants spend time experiencing hands-on mathematics influenced by everyday challenges in the fields of engineering and science. The modules that teachers design in cooperation with university content experts during the summer program are supported by classroom kits that can be taken back to the participants' schools for incorporation in the coming year's lessons. Experts at the university provide continued support and development of these modular activities through on-line forums and periodic school site visits. The activities are aligned with Wyoming standards for mathematics education and integrated for vertical growth through the K-6 and 7-12 programs. This initiative has helped to form a partnership between the university and Wyoming school districts [Adapted from 6].

It must be emphasized that these programs encompass a wide variety of subject matter experts, course material, and approaches. Space does not permit a full discussion of all of these valuable educational assets. Instead we will concentrate on one highly successful aspect of the program. Specifically, we will concentrate our efforts on how a low-cost, module-based, laboratory intensive instruction program was developed for common use in all of these programs. We have found this program to be flexible and easily adaptable to a wide variety of student cognitive levels from middle school age students to freshmen engineering students to K-12 faculty.

Methods

Objectives. A low-cost, module-based, laboratory intensive instruction program was developed for common use in a wide variety of engineering recruitment and enhancement programs. The overall objectives of the program were to:

- Expose participants to the engineering career field by showing them what an engineer does, the skills required, and the exciting projects engineers work on.
- Show that engineering is fun and exciting.
- Demonstrate that engineering is for both women and men.
- Emphasize hands-on, learn by doing exercises.
- Inform students of the excellent engineering educational opportunities at the university.
- Provide students engineering design, prototyping, and testing skills.

- Demonstrate how mathematics is routinely used in engineering design projects.
- Provide students the opportunity to experience the joy and frustration of working on team projects.
- Provide hands-on laboratory exercises using commonly available, low-cost parts to encourage students to independently continue their studies beyond the course.

Curriculum. The curriculum consists of a series of self-contained laboratory exercises that incrementally build upon one another. The exercises were adapted from laboratory exercises originally developed for use in a sophomore level, undergraduate electrical and computer engineering curriculum [7, 8, 9]. In developing the program an emphasis was placed on minimizing theoretical lectures while maximizing student investigation and discovery through hands-on laboratory exercises.

A typical schedule is provided in Table 1 while a summary of laboratory exercises is provided in Table 2. The schedule is divided into 12 separate 2 hour and 15 minute lessons. A 15 minute break is provided between the first and second half of each lesson. The schedule may be adapted to any schedule. The schedule provided has been used in its entirety for a three week student summer program which met during the afternoon. It has also been used in a five day intensive sequence where students met for three and one half hour sessions. It may also be easily truncated for shorter workshops.

As can be seen in the schedule an emphasis is placed on laboratory exercises. Laboratories were also completed using two person teams. Teams were initially chosen randomly but were changed as needed to balance team capability and personalities.

As a motivational (fun) method of reviewing course material, "Digital Jeopardy" was played periodically throughout the course. In Digital Jeopardy students were divided into teams of three. Questions were then posed by the instructor to review and reinforce course concepts. This technique proved very popular with the students as stiff competition was quite evident. The students maintained the same teams throughout the duration of the course. Top teams were awarded prizes for their efforts. Prizes were small bags of candy bars that students typically shared with their fellow class mates.

Table 3 provides a summary of parts used for the laboratory exercises. These parts are readily available from a number of electronic parts suppliers. It must be emphasized that the parts kits provide a low-cost method of designing and testing a number of digital circuits with no additional test equipment required. Prices are representative and are provided for single unit purchase. The kits may be purchased for approximately $25 each when parts are purchased in larger quantities.

Table 1. A typical schedule.

Lesson	Topic	Activities
1	Binary Number Systems	30 minutes: Introduction and Overview 30 minutes: Binary Number Systems 60 minutes: **Lab 1:** Familiarization Lab
2	Boolean Algebra Logic Gates	60 minutes: **Lab 1:** Familiarization Lab (continued) 60 minutes: Boolean Algebra/Logic Gates
3	Boolean Algebra Logic Gates (continued) Karnaugh Maps	60 minutes: **Lab 1A:** Mowing the Lawn 60 minutes: Karnaugh Maps
4	Karnaugh Maps	60 minutes: Karnaugh Maps (continued) 30 minutes: **Lab 2: Simplification of Boolean Functions (introduction)** 30 minutes: **Digital Jeopardy I**
5		60 minutes: **Lab 2: Simplification of Boolean Functions** 60 minutes: **Lab 3: Design of a Combinational Circuit – Voting Machine I – pre-laboratory design exercise**
6	Combinational MSI Components	60 minutes: **Lab 3: Design of a Combinational Circuit – Voting Machine I** 60 minutes: Introduction to MSI Components
7	Multiplexers Combinational circuit design with multiplexers	60 minutes: **Lab 4A:** Getting Acquainted with Multiplexers 60 minutes: **Lab 4:** Combinational Circuit Design with Multiplexers – Voting Machine II
8	Flip-flops Sequential Circuits	60 minutes: Flip-flops, sequential circuits 45 minutes: **Lab 5A:** 555 Time Base 15 minutes: **Jeopardy II**
9	Sequential Circuit Design	60 minutes: Orientation to university engineering opportunities - Computer and Electrical Engineering Curriculum at UW - Videotapes: UW, College of Engineering - Department tour: labs, solar panels, power lab, shop, mechanical machine shop 60 minutes: Sequential circuit design with flip-flops
10	Sequential Circuit Design	60 minutes: **Lab 5:** Design of a Sequential Circuit using D flip-flops 60 minutes: **Lab 6:** Counter Design using J-K flip-flops
11	Sequential MSI Components - counters - registers - shift registers - parallel to serial converters	60 minutes: Sequential MSI components 60 minutes: **Lab 7:** Binary Counter with Seven Segment Display – timed team competition, award for first three teams finishing with an operating circuit and also an award for the most neatly constructed circuit.
12	Digital Communications System	75 minutes: **Lab 8:** Digital Communication Systems 45 minutes: **Final Jeopardy**

Table 2. Summary of laboratory exercises.

Laboratory	Laboratory Description
1	**Familiarization Lab.** In this laboratory exercise students construct four switch circuits and four light emitting diode circuits. These circuits provide a method of providing digital input and digital output indication for a circuit under test. A circuit power supply is constructed from a 9 VDC battery and a 5 VDC voltage regulator.
1A	**Mowing the Lawn.** This laboratory exercise demonstrates how a familiar logical thought process may be converted into a digital logic circuit. The students use their switch and indicator circuits from laboratory 1 to thoroughly test the operation of their circuit.
2	**Simplification of Boolean Functions.** In the pre-laboratory exercise the students are purposely provided a very complex circuit equation. A schematic of the circuit is developed using AND and OR logic gates. The equation is then simplified using Karnaugh Map techniques. The students must prove that both the non-simplified and simplified version of the truth table provides identical circuit outputs. The students then construct and test the simplified circuit.
3	**Design of a Combinational Circuit – Voting Machine I.** In this laboratory exercise students design, build, and test a voting machine for a small corporation using combinational logic design techniques. This is the first laboratory that exercises all steps of the design process.
4A	**Getting Acquainted with Multiplexers.** In this laboratory students construct and test a circuit configuration for a 74151 8:1 multiplexer.
4	**Combinational Circuit Design with Multiplexers – Voting Machine II.** Students use the 74151 multiplexer test configuration developed in laboratory 4A to re-implement the voting machine of laboratory number three. This laboratory serves as a stepping stone to discuss current programmable logic design techniques.
5A	**555 Time Base.** Students construct a 1 Hz time base for use in the sequential circuit laboratory exercises to follow. The laboratory emphasizes the need for a time base in synchronous circuit design.
5	**Design of a Sequential Circuit using D flip-flops.** Students design, fabricate, and test a simple four state sequential circuit. Circuit operation is observed via LED indicators connected to key test points within the circuit.
6	**Counter Design using J-K flip-flops.** Students design, fabricate, and test a four state, two-bit binary up/down counter. This laboratory provides the students to practice their troubleshooting skills.
7	**Binary Counter with Seven Segment Display.** In this laboratory student build a binary counter with a seven segment display output. The laboratory emphasizes the use of a variety of MSI components and modular building and testing techniques. Student teams compete against one another for the first working prototype circuit and the neatest circuit. This emphasizes lessons such as the development cycle, first to market, and the importance of ease of circuit maintenance.
8	**Digital Communication Systems.** In this laboratory students construct a parallel-to serial converter which feeds a serial to parallel converter. This motivates the discussion of inter-computer communication concepts, serial communication concepts, and parallel versus serial communication.

Table 3. Laboratory Kit Contents

Quantity	Description	Jameco Part Number	Cost
2	Solderless breadboard, 3.3" x 2.1"	20600CE	10.50
1	5V, 1A voltage regulator (7805)	51262	0.32
1	9V battery clip	11279	0.22
1	9V battery	151095	0.99
1	4 position DIP switch	139002	0.70
2' each color	22 AWG colored hooked wire (blue, black, green, red, white, yellow) Purchased in 100' spools at 5.49/spool	36767, 36791, 36281, 36855, 36880, 36919	1.20
4	1.0 kohm resistor Purchased in 100 count bags for 0.99/bag	29663CE	0.04
4	330 ohm resistor Purchased in 100 count bags for 0.99/bag	30867CE	0.04
1	7400 quad two input NAND gate	48979CE	0.65
1	7402 quad two input NOR gate	49015CE	0.68
2	7404 hex inverters	49040CE	1.18
1	7408 quad two input AND gate	49146CE	0.93
1	7432 quad two input OR gate	50235CE	0.74
1	74151 8-input multiplexer	49525CE	0.65
1	74LS164 8-bit serial shift register	46851CE	0.43
1	74LS166 8-bit shift register with parallel load	46885CE	0.71
1	555 timer	27422CE	0.23
1	7 segment common cathode LED	17208CR	0.75
1	7474 dual D flip-flop	50551CE	0.59
1	7476 dual JK flip-flop	50593CE	2.95
4	Red Light Emitting Diodes	333366CE	0.68
1	11.0 kohm resistor Purchased in 100 count bags for 0.99/bag	30031CE	0.01
1	22.0 kohm resistor Purchased in 100 count bags for 0.99/bag	30453CE	0.01
1	47 μF, 10V electrolytic capacitor	135301CE	0.04
1	0.1 μF, 50V ceramic capacitor	151117CE	0.15
1	0.01 μF, 50V ceramic capacitor	15230CE	0.06
1	Wire cutter/stripper	78991CE	3.95
		Total per kit	**$29.40**

Figure 1 provides the layout of the solution for the first laboratory exercise. This figure is provided to emphasize the standalone nature of the kit. On the left hand side of the protoboard is a 5 VDC power supply provided by the 9 VDC battery and the 5 VDC regulator. An LED is also provided at the output of the regulator to serve as a power supply pilot light (on) indicator. The four single pole, single throw switches mounted in a common DIP package provide the capability to insert logic one and logic zero test signals into the circuit under test. The 7404 hex inverter is part of the four channel LED indicator circuit. The LEDs act as a four-channel logic probe to provide a visual indication of the circuit's logic output(s). This circuit is actually constructed on to breadboard snapped together. The center portion of the adjoining breadboards is left open. This is the area used in subsequent laboratory exercises to construct the circuits.

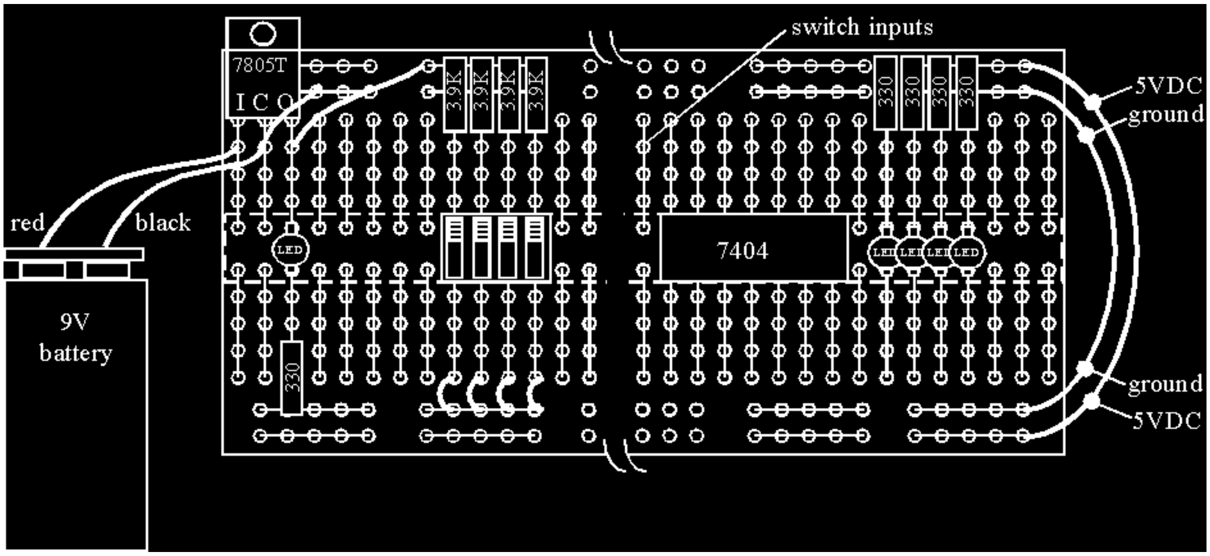

Figure 1. Laboratory protoboard layout.

Results

We have used this series of modular, laboratory exercises for five years in the HSI program, four years in the ESP program, four years in EE1010, two years in the Thinking and Doing Mathematics workshop, and one year in the CSEM Middle School Girls Camp. We have collected no data to quantify if this course resulted in a student's decision to pursue engineering at the university. This was not our specific intent. Our goal was to attract and expose students to careers in science and engineering.

- Overall student critiques are quite positive across the program. Here is a representative sample of student critiques:

  "I have learned that in all different jobs and careers people work in teams."

  "I can think and analyze stuff better."

  "I learned a great deal about computer electronics."

  "I know the basics of how circuits work and how circuits in computers work."

  "I had no clue about computers and now I feel more comfortable than before."

- Although the course heavily emphasized laboratory work, the student critiques indicated students wanted even more laboratory work.

- Interestingly, we have seen some students take HSI, then ESP, declare electrical or computer engineering, and then help teach both courses as student assistants.

- Two students attending ESP had previously attended HSI. They asked for permission to work a different, challenging laboratory project rather than the laboratory exercises they had previously completed in HSI. There assignment was to build a 24 hour clock using information provided in laboratory 7 as a guide. With no assistance from the instructor they were able to successfully complete the design task.

- Paul Crips, a middle school educator, attended Thinking and Doing Mathematics workshop and then adapted some of the coursework for his use in the classroom. Here is his candid assessment of the project:

  "We all know that classical physics is broken down into two basic concepts, mechanics, with its related study of motion, and charge, which deals with electricity and magnetism. Seventh graders often look upon these processes with fear because in many classroom settings they are simply exposed to physics through classroom lecture, occasional audiovisual presentation and teacher-led demonstrations.

  In order to spark an interest in electricity and charge with further exploration opportunities, students must be provided with every opportunity to develop labs that stress inquiry based science-teaching strategies. Inquiry based science is a main emphasis in national science standards which is the road map that all science teachers should follow.

  After students were shown various demonstrations on electricity using devices such as a Jacob's ladder, magnets, coils and motor demonstrations, they were given a chance to disassemble surplus personal computers and learn about the various parts through an investigation process that used volt/ohm meters and other test devices. The next logical step for students was to learn about truth tables and Boolean algebra. They spelled out their names using Boolean functions and then learned how binary counting systems are used to design circuits. One science content standard deals with the history and nature of science. Students learned how the binary numeral system started from an ancient Indian mathematician Pingala during the third century BC. Students also learned that Pingala discovered the concept of zero.

  After learning about the binary system it was on to constructing circuits using truth tables. Students started with the basic 555 microchip to make LED's blink and then built series and parallel circuits and tested them.

  A very important teaching paradigm is collaboration with other subject areas. With the No Child Left Behind Act, schools are required to show Annual Yearly Progress or AYP. Using science investigations, such as circuit design, students are able to write a science brief that covers the six traits of writing, which should show a relationship with mathematics. Students, through their writings, demonstrated a basic understanding of electricity and charge and were able to make the connection to electricity's application. Students were then given time to work on enrichment activities where they simply "fooled around" with basic circuits with guidance from various Internet sources and instruction manuals from the University of Wyoming.

Partnerships are important between public school systems and universities. The partnership that has been developing with this project will provide future students who are not intimidated by mathematics and science and can clearly see the benefit of taking academically challenging courses. One student, while working on a circuit design was overheard saying, "How hard can it be?" It is with this kind of enthusiasm that future engineers are born and take their rightful place in our ever-changing society."

Discussion and Summary

We think this program has been successful in exposing potential engineering students to the study of engineering and a potential career in engineering. We also believe it has been successful in retaining students who have declared electrical or computer engineering.

A few lessons have been learned that will help in the successful delivery of the program.

- Instructors for the course must be comfortable in working with a wide variety of students at different cognitive levels (middle school students through fellow educators).

- Instructors should be comfortable in working with young, energetic students. They must be flexible and be willing to take time out from the scheduled lesson plan to fill in student knowledge gaps on an as needed basis.

- It is important to keep the activities exciting and varied when teaching the program.

Conclusions

We highly recommend this approach to attracting and retaining students to the study of engineering. We will use this material in the coming year for all of the programs previously described.

All developed curriculum material is available for your use. Feel free to request the material by contacting Steve Barrett, e-mail: steveb@uwyo.edu

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References

1. High School Institute, **http://uwadmnweb.uwyo.edu/Provost/hsi/**
2. Engineering Science Program, **http://wwweng.uwyo.edu/highschool/esp/**
3. . Hamann, J., N. Peck, L. Hutchison, S. Steadman, and D. Coon, "The University of Wyoming Center for Excellence in Engineering Education: Recruiting, Retaining and Educating the Best in the West," Executive Summary for the William and Flora Hewlett Foundation, December, 2002.
4. White, D. and Doering, R., *Electrical Engineering Uncovered*, 2nd ed., Prentice Hall, 2001.
5. Fleddermann, C.B. and Bradshaw, M.D., *Introduction to Electrical and Computer Engineering*, Prentice Hall, 2003.
6. L. Hutchison, J. Hamann, S. Parker, "Thinking and Doing Mathematics," Wyoming Department of Education Title II Part B Program Description, December, 2004.
7. Dwellis, A., "EE 212: Digital Design," Colorado Technical University, Colorado Springs, CO
8. Barrett, S., "EE 281: Digital Design," The United States Air Force Academy, Colorado Springs, CO
9. Barrett, S., "EE/COSC 2390: Digital Design," University of Wyoming.