Incorporating Industrial Co-op Experience in High School Classroom Outreach

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Abstract – This paper describes high school STEM lessons created by three undergraduate mentors. The mentors participated in a classroom outreach program called Computer Science Investigations (CSI: Cincinnati) as part of the Mentoring for Connections to Computing effort funded by the National Science Foundation’s Broadening Participation in Computing program. The CSI program performs pre-college outreach with a team of undergraduates in computing-related majors who deliver an original lesson with hands-on activities and interact with high school students in their classroom. The mentors leverage their industrial and academic experiences to create the lessons and act as role models for college and professional success. The evaluation of the CSI activities includes pre- and post-surveys of the high school students’ interest in computing as well as reflections from the mentors’ journals.

Index Terms – K-12 outreach, STEM education, undergraduates as mentors, cooperative education

INTRODUCTION

The Computer Science Investigations (CSI: Cincinnati) project brings undergraduates in computing-related fields into urban STEM classrooms to interact with and teach high school students. CSI: Cincinnati is funded under the National Science Foundation’s Broadening Participation in Computing program and its goals include: (1) introducing underrepresented populations of high school students to computing topics, field of study, and the profession in a fun but challenging way, and (2) training computing undergraduates to mentor youth and teach computing topics.

The team of 8 undergraduate mentors and the PI visited 3 different classrooms at two different Cincinnati Public School district high schools. The team developed and taught 9 lessons that related computing topics to everyday life and showcased career opportunities. The lessons were aligned with Ohio Department of Education Academic Content Standards for math, science, and technology [1]. Each week, one student conducted the lesson while the rest of the team members sat with small groups of students to interact informally and assist with the lesson activities. Materials developed for activities are available in an online repository, including lesson plans, supply lists, activity descriptions, and other supporting documents [2].

In this paper, we present lessons developed by students in Computer Science, Computer Engineering, and Electrical Engineering majors in the areas of land mobile radios, medical imaging, and VLSI chip design, based on the students’ professional experiences. The students acquired the necessary background for their lessons while participating in our co-operative education (co-op) program.

Co-op has historic roots at the University of Cincinnati (UC), dating back to its inception 1906. In the College of Engineering at UC, all 9 undergraduate degree programs are 5-year programs with mandatory co-op. Students are required to complete 4 co-op terms but many complete 6-8 terms. Co-op terms alternate with academic terms during the students’ middle 3 years.

The undergraduate students serve as role models who convey their significant responsibilities and achievements as a result of their college educations and field experience. They are able to relate factors that contributed to their success as well as their enthusiasm for their majors and future careers to the high school students.

THE HIGH SCHOOL ENVIRONMENT

The undergraduate mentors taught their lessons in an urban high school with an effective designation from the state department of education. The school met 6 out of 12 indicators determined by the state during the 2007-2008 academic year. There are 713 students enrolled in the school with a high percentage minority students (78%), economically disadvantaged students (56%), and students with disabilities (25%). Additionally, only 88% of the classes are taught by properly certified a teacher, creating an opportunity for project participants to have a positive impact on the STEM classes in which they are teaching computing-based lessons. The students participating in the lessons described here were two 11th grade Algebra II classes with approximately 40 students total, of which 29 completed the demographics based pre-survey. Both classes were approximately 66% female and 60% minority. Almost all students stated that they expected to continue their education after completing high school and all students had access to computers at home or outside school. These students reported using computers more at home or outside school compared to within their school. Ninety percent used computers frequently or once or twice a week at home and this percentage dropped to 75% or 62% for school computer usage among the two classes. Of the choices given, the most
popular computer activities were browsing the internet and completing school assignments.

**MEDICAL IMAGING**

Brian Myers, a Computer Science senior, worked as a software engineer for six co-op terms at Philips Medical Systems in Cleveland, OH. In his third and fourth co-op terms, he investigated whether Graphical Processing Units (GPUs) would be efficient for performing mathematical computations required to turn x-ray data from a CAT scan machine into an image on a computer. In his final term, he worked with a team of programmers to develop a testing utility to simulate a CAT scan machine so that the team could test algorithms without requiring connection to a scanner. This background led him to develop a lesson and several activities around the theme of medical imaging. The classroom activities developed and led by Brian are described below.

**Summary of the Lesson Objectives:** Students compare the behavior of x-rays to the behavior of light. Then they learn how algebra can be used to create a cross section of an object given x-ray data from different angles. Finally, they learn how to build a 3D model from a series of slices.

**Materials:** A presentation using a computer and projector is used to introduce the topic and activities. Two handouts (called Case Files in our Computer Science Investigations program) guide the activities and provide opportunities for the students to record their observations and reflections. Other materials used during the activities include:

- white sheet and flashlight
- objects that reflect/refract/absorb light differently: flat dish, glass bowl, ball
- objects that make a circular shadow but are not all spheres: bell, flat dish, ball
- styrofoam 3D brain model slices in three different thicknesses

**Activities:** In the presentation, the students see a photograph of Brian at Philips Medical Systems with a CAT scan machine (Figure 1.) They learn that Computed Tomography is the technique used to create 3D images from 2D images created using x-rays. Then they explore what they can learn about an object from looking at its shadow:

1. Have two student volunteers hold up a sheet in front of the class. From behind it, shine a flashlight on it; then shine the projector on it. Students are prompted to make observations about the quality of the light sources for detecting shapes behind it (such as a hand.)
2. Demonstrate a variety of objects with different light absorption, refraction, and reflection properties.
3. Demonstrate a variety of objects with the same 2D shape but different 3D shapes.
4. Students individually record their observations on the Case File: Light and Shadow handout.

Next, the presentation is resumed; it discusses how x-ray detectors are used to construct 2D images (Figure 2), and that each kind of tissue in the body has a specific CT number. Images of organs and bones are shown (Figure 3).

5. Each student receives the Case File: Building 3D Models handout. Students color in the 2D brain image based on the given CT numbers.
6. Students work in groups of three or four with one brain slice kit per group. Groups assemble their slices into 3D brain models and compare with other groups.
7. Each student records his or her observations and reflections on the Case File worksheet.

**Case File Excerpts: Light and Shadows** asks for observations and conclusions, then relates them to a real-world example:

> When doctors observe CT images, they need extremely accurate details. They may be looking for small light or dark spots that are millimeters in size or less. Sometimes, there are small errors in the images created by x-rays which can lead to a bad diagnosis. These errors are called image artifacts.

> Given the extreme need for accurate detail and given your knowledge of shadows created by light striking different objects, what are some artifacts that might appear in images that could cause the wrong diagnosis of a patient?

Building 3D Models explores how a 3D model of an organ is made once the radiodensity of each square is found. The students are asked to speculate based on their observations:

> Can you think of potential problems with using thin slices? (Hint: It takes more x-rays to create thinner slices. Each slice requires memory space in a computer’s hard drive.)

> Can you think of potential problems with using thick slices? (Hint: Often times, doctors look for details in the images that may only be millimeters or less in size.)

**Connections to Computing:** This lesson introduces (1) computerized automation of collecting and processing x-ray images, (2) an algorithm for computing x-ray detection, and (3) software engineering as a profession and its contributions to health care imaging.

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**Figure 1. Brian Myers at Philips Medical Systems**

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Figure 2. X-ray detection: divide the 3D object’s image into tiny boxes and find the radiodensity of each one; uses algebra to solve systems of equations

Figure 3. 3D images: thousands of x-rays going through thousands of squares from dozens of different angles can construct detailed pictures [3]

**COMPUTER CHIP DESIGN**

Robin Forry, an Electrical Engineering senior, worked at two different companies in three different roles during her 6 co-op quarters. At Intel, she worked as an Automation Engineer developing a vision system to automate the inspection of units on an assembly line and she worked as an Electrical Design Engineer for cellular and handheld devices. Her final two co-ops were as a Manufacturing Engineer at Toyota where she helped set up a manufacturing process for a new car model. She leveraged her experience designing chips for cell phones in the creation of her lesson.

**Summary of the Lesson Objectives:** Students create a layout for a special purpose computer that uses mathematical functions to compute a target value given two inputs. Then they learn about how miniaturization of transistors led to explosive growth of computing but necessitated developing software to help humans design the increasingly complex hardware. The second activity has the students creating a floorplan (layout) of components of a Pentium processor while trying to minimize the area of the chip.

**Materials:** The Case File: Computer Chip Design worksheet, and accompanying presentation, along with a computer, projector, and digital camera are utilized; in addition, Robin created a foam puzzle of cut out components from an Intel Pentium processor floorplan.

**Activities:** The presentation illustrates the electronics inside of a cell phone and Robin’s experiences at Intel. The students’ familiarity with algebra is used to introduce the notion of hardware components computing a function.

1. Students use mathematical functions (and functional composition) to create a representation of a specialized computer processor. Figure 4 shows the slide and Figure 5 shows an excerpt from the Case File.

2. The presentation is resumed with illustrations of old and current computer technologies, along with how capabilities and price have changed. For example, the IBM RAMAC 305 hard drive could store 5MB and cost $160,000, while the contemporary Sony Microvault USB drive holds 2GB and costs about $80. The need for software to design hardware leads to a discussion of how computer algorithms help designers optimize floorplans. The goal of floorplanning is to place all the components of a final circuit design into the smallest possible area.

3. Students work in groups of 3 or 4 to assemble a foam puzzle of the components of a Pentium chip (Figure 6) while trying to fit it into its original rectangle on the worksheet.

**Case File Excerpts:** In the first activity, the students use functional composition to create a design of a specialized computer. The worksheet is shown in Figure 5.

In the second activity, students try to fit all of the Pentium chip components inside a rectangle on the worksheet. They are instructed to try to make the occupied space as small as possible, and they have the following constraints:

- Each piece must touch at least one other component.
- Pieces may be sideways.

A student with a completed puzzle appears in Figure 7.

**Connections to Computing:** This lesson introduces (1) using computer software to design computer hardware, (2) the relationship between mathematical functions and hardware components, (3) historical trends in computer storage devices in terms of capacity and price, and (4) electrical and computer engineering careers in manufacturing and design of familiar commercial products.
Your Job:
Design a Specialized Computer Chip

• takes values of x and y, computes z
• compose building blocks that compute functions to obtain your assigned value

Figure 4. Composing functions to simulate design of a specialized computer chip and relating it to hardware components

Figure 5. Case File: Computer Chip Design (excerpt)

LAND MOBILE RADIOS

Michael Wolf, a Computer Engineering senior, co-oped a total of 7 quarters for two different land mobile radio companies. At Tyco Electronics in Lynchburg, VA, he designed land mobile radio communication systems and microwave backbones to interconnect sites. At W S Electronics in Xenia, OH, he installed and programmed land mobile radio systems and designed and made cables for interconnecting hardware. A photograph of Michael testing communications hardware appears in Figure 8.

Summary of the Lesson Objectives: Students learn about half-duplex (walkie-talkie, land mobile radio) and full-duplex (cell phone) communication and experiment with small walkie-talkies in class. They learn about conventional and trunked communication with a grocery store checkout line metaphor. They apply a queuing model to simulate processing in conventional and trunked systems and compute wait time and total processing time for all events in a system.

Materials: The lesson uses the Case File: Land Mobile Radio Communication worksheet, a presentation with a computer and projector, and walkie-talkies.

Figure 6. 1993 Intel Pentium Chip (attached to a colorful foam sheet and cut out with a craft knife) [4]

Figure 7. A student with a completed puzzle
Figure 8. Testing communications capability

Figure 9. Conventional and trunked queue problems

Activities: The presentation introduces different types of radio communication and illustrates emergency response personnel using land mobile radios.

1. In the first activity, students use walkie-talkies in pairs and experiment with trying to communicate one at a time (half-duplex) and both at the same time (full-duplex) which is not supported by walkie-talkies. Students record their observations on the worksheet.

2. The presentation introduces communication channels and shows how conventional use of dedicated channels is like waiting in a specific line at a grocery store checkout; trunked communication is like one waiting line and the next available checkout station is used.

3. The students are introduced to the concept of a queue and they use this to model a system of requests under both conventional and trunked communication styles on the Case File worksheet.

Case File Excerpts: The conventional and trunked queue examples used by students to compute longest waiting time and total time for processing all requests are illustrated in Figure 9.

Connections to Computing: This lesson introduced (1) different types of radio communication, (2) conventional and trunked communication, (3) using queues to model communication channels, and (4) computer engineering careers related to radio communications.

Evaluation

Evaluation of the CSI lessons consisted of pre- and post-surveys from participating high school students and reflective journals written by the undergraduate mentors. Post-survey results indicated that this grant activity was successful in positively exposing high school students from underrepresented populations to computing topics. Fifteen students (48.4%) stated that their involvement in the CSI activities increased their interest in computing topics. Additionally, 83.9% of the students (n=26) were somewhat or very interested in learning more about computing topics.

There were 5 lessons taught to two different classes reported in the following results. When asked to voluntarily identify the lesson each high student learned the most from and why, 9 (out of 31) students identified the Land Mobile Radio lesson, 4 (out of 21 responses) stated the Computer Chip Design lesson and 3 (out of 21 responses) chose the Medical Imaging lesson. An analysis of the open ended responses stating why these lessons helped them learn indicated that the hands-on activities were very helpful. For the Land Mobile Radio lesson, students appreciated using actual walkie talkies and learning how computing concepts (frequencies and queuing) impact the time needed to send and receive messages. For the Chip Design lesson, the puzzle “allowed for a hands on approach” and the students learned how the parts of a cell phone “chip fit together to make it work.” For Medical Imaging, students appreciated that “someone who is currently working with it is sharing their experience.” The real-life connections to computing and the undergraduate mentors sharing their cooperative work experiences were novel and appreciated by the high school students.

The undergraduate students serving as mentors completed biweekly on-line journals and exit surveys. All three mentors felt that the high school students were impacted by their lessons. Representative quotes are:

I felt I made an impact on the students when sharing about my college experiences.

I think that overall our first two sessions were successful. I think that several of the students were really enthusiastic about what we were doing.


I found that many students answered as I was hoping that they would in the papers from my lesson. I even found that some of the students came up with great ideas that I hadn’t even thought of for the questions.

I felt like the kids opened up to me a little and trusted me. And I felt like that made it easier for me to talk to them and help them out.

For future lessons, the mentors recommended encouraging more interaction with the high school students so they can “talk to students about their future goals and plans so we can better relate to them.” Additionally, they wanted to provide context for their lessons. Journal entries included:

why this lesson is important to high schoolers .. If we don’t make it important to them, then it’s just going to be another piece of trivial classroom knowledge to forget five minutes after learning it.

I had been trying to figure out what activities would be best suited to the lesson plan I want to use and would actually keep the students interested in the lesson.

These recommendations by the participating mentors underscore the unique opportunities co-operative work experiences give our undergraduate students when mentoring younger students to increase interest and knowledge of computing careers.

RELATED WORK
A related effort at the University of Cincinnati, NSF Project STEP [5], places engineering graduate fellows into high school STEM classrooms for intensive interaction with students and teachers. Lessons developed by students, faculty, and teachers are discussed in the literature [6-10].

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REFERENCES


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