Design of a Premier Evaluated Pre-College Program

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Abstract

The Wireless Integrated MicroSystems (WIMS) Engineering Research Center (ERC) has hosted about 20 to 30 Detroit Area Pre-College Engineering Program (DAPCEP) seventh and eighth grade students in each WIMS SuperStar Challenge pre-college Saturday Program session starting in Spring 2002 through 2009, at The University of Michigan – Ann Arbor (UM). Additionally, as a highly evaluated premier partner, DAPCEP selected WIMS to conduct both Spring and Fall sessions during 2008 for their National Science Foundation (NSF) funded Innovative Technology Experiences for Students and Teachers (ITEST) program.

During each of five Saturday sessions totaling approximately 20 instructional hours overall, the WIMS SuperStar Challenge program curriculum contained (1) instruction for science, mathematics, and engineering motivated with (2) hands-on experiments that incorporated concepts for construction, system operation, programming, physical science, microfabrication, wireless communication, sensing, actuation, control, and microsystems. The first two Saturday sessions were devoted to flexible adaptable construction of electrically-powered LEGO robots to introduce microsystems, wireless communication, sensors, programming, and control algorithms. The third session was devoted to biomedical micro-probes electrode arrays with dual application as sensors for health-care monitoring and as actuators for delivering health-care treatments. The fourth session was on computer concepts, starting with the binary number system and logic, leading to digital functions and electronic gates, and medium-scale functions such as half adder or decoder as a sub-component of a microprobe microsystem design. The fifth/last Saturday session includes a nanocamp that provides an opportunity for each student to do a fabrication process to write a pattern on a wafer that he/she takes home as a memento.

This paper provides information regarding the WIMS SuperStar Challenge Saturday program, its program design considerations and decisions, including the educational content, program structure, participant demographics, and provides reasons the programs has been highly evaluated over several years. This paper addresses motivation of middle-school students to enthusiastically develop academic growth and acquire technical knowledge, facilitated by graduate and undergraduate student mentors.

DAPCEP – The Organization

Students in the Saturday program are participants in the Detroit Area Pre-College Engineering Program (DAPCEP). To better serve the students, it is important to know the DAPCEP mission, goals and objectives that are repeated here as found at the DAPCEP web-site [2]:

> **Mission:** DAPCEP's mission is to increase the number of historically under-represented minorities (African-American, Hispanic-American, and Native-American) who are motivated and prepared academically to pursue careers in science, mathematics, engineering, and technology-related fields.
>
> **Goals and Objectives:** DAPCEP's ultimate goal is to give underrepresented students the interest and preparation needed to succeed in a University-level science or engineering curriculum.

DAPCEP achieves results by offering intensive computer, technology, science, math, and engineering training from experienced professionals and instructors in their respective fields. Students receive hands-on opportunities in work environments in addition to classroom-based curriculum activities.

Saturday Programs: DAPCEP collaborates with colleges, universities, and corporations to provide innovative and interactive classes to children in grades K-12. Classes focus on quantitative subjects such as mathematics, computer science, engineering, physics, and chemistry. Equally important qualitative skills are taught including communication skills, networking, teamwork, resume writing, professional etiquette, and time and resource management.

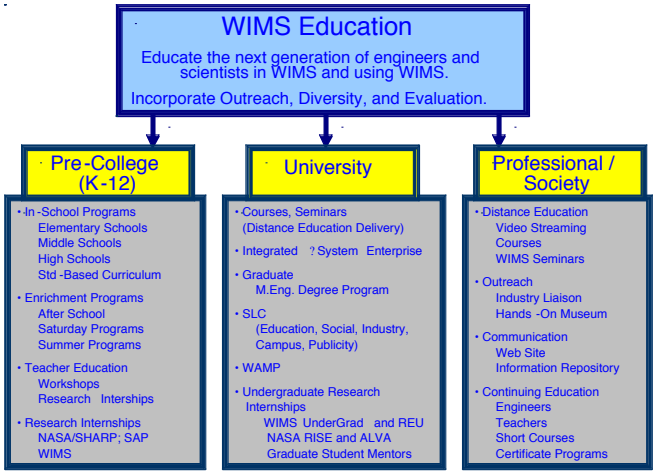
Regarding DAPCEP's mission, goals, objectives, programs, and organizational structure, a very important feature that attracted WIMS to work with DAPCEP is its very strong parent organization, with highly committed and active parents. As WIMS was considering design of this pre-college program, the strong DAPCEP parent organization factor was a great influence on the design. Moreover, DAPCEP and its strong parent organization are integral to WIMS Saturday programs, the very highly regarded WIMS summer programs, and WIMS outreach initiatives such as regional tournaments, and Tech/Design Day exhibits at the core universities.

WIMS – The Organization and Pre-College Education Programs

WIMS is a National Science Foundation Engineering Research Center, with detailed description at web-site [7]. WIMS is structured with nine thrust areas, one area being Education Programs.

Education Programs Thrust Structure: The goals of the WIMS Education Programs Thrust are to educate the next generations of engineers and scientists about WIMS and with WIMS, and to rapidly transfer results from the research domain to the classroom domain. Proactive diversity and outreach initiatives, as well as evaluation, are to be integrated within each program. As depicted in Figure 1, the Education Programs Thrust provides comprehensive opportunities with three sub-components: pre-college programs for K-12 students, university programs for undergraduate and graduate students, and professionals/society programs for practicing professionals and society.

Figure 1 – Comprehensive Scope for WIMS Education Programs.



Pre-College Education Structure and Programs: The goal of the WIMS pre-college effort is to increase the number of students that select science, engineering, and math as their major in college, as well as to improve their academic ability and preparation to enter those majors [1][5]. The strategy is to provide programs for in-school, teacher education, and enrichment (after-school, weekend/Saturday, and the summer). WIMS pre-college education programs are characterized by two key factors:

1. Emphasis is on WIMS core concepts (microsystems, microfabrication, wireless communication, sensors/actuators, microcontrollers), along with societal impacts.

2.Educational programs have academic content that is a subset of core concepts.

WIMS SuperStar Challenge Saturday Program – with Schedule Template

While developing a program for DAPCEP students, several questions arose:

- What level of student should be targeted – elementary, middle, high school, or mixture?
- How to find students?
- What administrative support would be needed?
- What academic and technical content should be in the program?
- Who should be the teachers, instructors, and assistants?
- What are the expenses?
- What/Who are the sources for funding?

Answers for some of the questions were rather easy. The Multicultural Engineering Programs Office (MEPO) at The University of Michigan (UM) had a long standing relationship (perhaps 15 years) with DAPCEP to provide programs for 7th-8th grade middle-school students. MEPO provided administrative support for lunches and round-trip transportation between Detroit and Ann Arbor (a distance of about 45 miles). DAPCEP had an Open House for students to apply for Spring and Summer programs. The Electrical Engineering and Computer Science (EECS) Department at The University of Michigan had been part of the DAPCEP/MEPO/UM programs for perhaps 8 to 10 years at that time. The author of this paper had been a DAPCEP Board member for about 5 years during the 1990s, and thus was familiar with the DAPCEP mission, goals, organizational structure and leadership, commitment to programs, and its strong parent organization. Also, the author had been the faculty advisor for the EECS DAPCEP program for perhaps 4 years at that time (now about 12 years as faculty advisor after the Spring 2009 program). Thus, working with MEPO for the DAPCEP programs was an answer for the first three questions, as well as an answer for the last question regarding source for funding.

Expenses for the DAPCEP program have risen from about $4,000 in 2002 to about $5,000 in 2009. One expense consists of paying for lunch and refreshments for the students. WIMS provides morning refreshments for the students just after their arrival (box drink, breakfast bar, fruits). After one year WIMS opted to provide lunches at its own expense to improve quality of the lunch items (better quality pizza was the initial concern). Also, WIMS provided variation different than pizza as the lunch every Saturday, sometimes having sub sandwiches. Vegetarian options were always available, being respectful of student and family values. Families of students with special diets are invited to provide their own lunch and refreshments. Another expense was note-taking packets (pads of paper, pencils, pens, folders) and copies of documents (presentations, reference documents, etc). Also, copying handouts was an expense. The WIMS Program Coordinator and mentors receive a small token stipend.

Consistent with the DAPCEP mission and goals, the WIMS SuperStar Challenge program was designed with several goals and strategies:

- provide weekly learning experiences in engineering, with special focus on WIMS technical educational content and applications;
- prepare and improve participants technical, analytical, and problem-solving skills;
- enhance student personal growth;
- present University of Michigan students as successful role models; and
- provide information on career opportunities in engineering.

Over the long term of many years of such pre-college programs, another goal is to

- increase the number of well prepared students that select engineering, science, and math as their future university major leading to professional careers in those disciplines.

For academic content, DAPCEP students are introduced to WIMS technical topics of engineering, science (physics, chemistry, biology), mathematics, transducers (sensors, actuators), microfabrication, wireless communication,

microsystems, and society beneficial applications. For fun entertaining education it was decided to adopt and use LEGO Mindstorm Robotic Invention System (RIS) units [4], because many of the desired WIMS academic content could be prototyped with RIS units. Academic content contained (non-LEGO) important WIMS topics of digital microelectronics, microfabrication, microprobes, MEMS, and applications.

Regarding teachers, the WIMS Center has internationally renowned faculty, post-doctoral fellows, outstanding graduate students, and technical staff members. Over the years, faculty members and advanced PhD students have made presentations on society beneficial application topics that include environmental monitoring, microelectromechanical systems (MEMS), brain research, microprobes for sensing and stimulation treatments for ailments such as Parkinson's and epilepsy, infrared imaging, and microsystems. Also regarding teachers, graduate and undergraduate students serve as teachers and program assistants, often referred to as Mentors, in the WIMS SuperStar Challenge program. Moreover, part of the designed intent of this program was to benefit the graduate and undergraduate student program assistants.

A typical program schedule and overview of curriculum topics are the following:

Saturday 1

- Introduction to Program
- Pre-Test
- Introduction to WIMS, its Research, and Society Beneficial Engineering Applications
- Ice-Breaker for DAPCEP Students, Mentors, and Program Staff to Introduce Themselves
- LEGO Tutorial
- Robot Construction and Programming

Saturday 2

- Wireless Communications (Infrared)
- Microsystems
- Student Decision and Design of Robot to Carry-Out functions of
    - Pressure Sensing
    - Light Sensing
    - Human Body Part Movement
- Student Construct and Program his/her Designed Robot
- Reliable Construction
- Revise/Modify Design as needed

Saturday 3

- Application of Microsystems to Benefit Humans (Overview by WIMS Director)
- Biomedical Microsystems Applications to Benefit Humans (Overview by WIMS Director)
- Microprobe (Micro-Electrode Array) Simulated with Different Color LEDs
    - Microprobes for electrical sensing, position sensing, actuation, micropumps, hearing
    - Smart Microsystems with Microprobes
- Sessions in Earlier Years: Cochlear Implant for the Hearing Impaired
    - Overview of Human Hearing; Sound Waves and Energy

Saturday 4

- Digital Computer and Microcontroller Concepts
- Binary Number System and Binary Logic
- Electronic Logic Gates: NOT, NAND, NOR
- Design of Small Functional Systems: Half-Adder, Full-Adder, 2-to-4 Decoder
- Construct and Test Small-Functional System

Interface Small-Functional System with Robot and Micro-electrode array to form Microsystem

Saturday 5

Nano-Camp

Introduction to Lithography
Chemical Etch Process
Writing Pattern on Wafer

Parallel Activities

Size and Scale
Nano Products
Memory-Shaped Alloys
Magic Sand
Tour of Lurie Nanofabrication Facility (LNF) – Facility viewed from outside the lab

Post-Test

Entry and usage of the Lurie Nanofabrication Facility (LNF) is a highlight experience. The University of Michigan LNF is one of thirteen university facilities that form the nationwide NSF National Nanotechnology Infrastructure Network (NNIN). The nanocamp session is an opportunity for students to enter and use the LNF chemical room to write a pattern on a wafer and do a chemical etch process. Often the pattern written on the wafer is the student's name, or a cartoon character, name of a family member, or good friend (BFF). The patterned wafer is taken home by each student. The chemical room can accommodate about 6 to 8 students, thus, parallel activities are arranged to educate students about other nanotechnology concepts and products during the times other students are in the chemical room.

The curriculum topics are coordinated because each week a student group designs [3], constructs, and tests a portion of the ultimate goal (a microsystem with microprobe simulated by varying color LEDs, electronic digital small-functional system, and programmed LEGO robot.

Another program design factor was recognition of the students and take-home memorabilia. At the end of each five Saturday sessions program, students get items to take home to show parents, family, and friends. One take-home item is the wafer that each student wrote a pattern. Second/third take-home items are both WIMS SuperStar Challenge and DAPCEP certificates.

Student Selection: Students are selected during a DAPCEP Open House, except for the 2008 ITEST program. During the DAPCEP Open House, students and parents drop-off their applications at the WIMS exhibit table. Within an hour after the Open-House ends, students are selected and notified early the next week. Typical selection criteria include the student having an interest in science and mathematics, course grades of B or better in science and mathematics classes, and overall grade-point-average at least 3.0 (B average), though some students with lower grade-point-average have been selected. Occasionally, parents and children of younger students stop by to observe the WIMS exhibit and inquire about programs that might be suitable in future years for the younger student.

For the 2008 ITEST program, sixty students were pre-selected by DAPCEP to participate for two years in a sequence of Fall, Summer, Spring rotating programs. The sixty students are divided into two groups of 30 students each. During the Spring, each group of 30 students participate in two separate programs, then all sixty students are in a single summer residential program on a university campus, and the two groups of students rotate to opposite programs during the Fall. Table 1 indicates the schedule for the two groups for the 2008 calendar year. Thus, WIMS had a group of 30 students for Spring 2008, and a different group of 30 students for Fall 2008. Figure 2 has WIMS Fall 2008 photo. For calendar year 2009, a similar schedule is being done with the same 60 students in two groups of 30 students, but with a completely different non-repeat selection of three programs (program 4, program 5, and program 6).

Table 1 – Schedule for DAPCEP ITEST Students for Calendar Year 2008

	Group A (30 Students)	Group B (30 Students)
Spring 2008 – Commuter/Bused	WIMS Ë → Program 1	Program 2
Summer 2008 – Residential	Program 3	Program 3
Fall 2008 – Commuter/Bused	Program 2	WIMS Ë → Program 1

Figure 2. DAPCEP students for Fall 2008 Session, with two Mentors and Faculty Advisor.

Variations of the Program Design: Schedule variations have occurred over the years, with some schedule items left to the WIMS Program Coordinator. One Spring had a field-trip to the Center of Science and Industry Museum; another Spring had a field-trip to the Ford Museum. During earlier Springs (2005 to 2007), students constructed and took home an array of seven-segment light emitting diodes (LEDs) to write his/her name or write arithmetic expressions (add to divide). In the most recent Spring 2009 program, Saturday 5 included a closing program with parents and families invited. During both Spring and Fall 2008, there was no closing program.

Mentors and Program Assistants – with DAPCEP Evaluation

Graduate and undergraduate students serve as mentors and help the middle-school students enthusiastically develop academic growth and technical knowledge. Specifically, the WIMS graduate and undergraduate students help the middle-school students understand and relate the instructions and experiments for the specific hands-on experiments for the day. The mentors help the students understand the instructional presentations by the WIMS faculty. Thus, DAPCEP students receive personal attention to focus activities, learning, and progress for each individual, with special emphasis to build upon each student's background knowledge and questions. Each mentor has responsibility to advance motivation and inquisitive attitudes. Many mentors are volunteers of the WIMS Student Leadership Council (SLC), with specific leadership from graduate students members and the chairperson of the SLC Education Committee. Mentoring is one of the most important design features of WIMS pre-college programs and has immense benefits. Mentoring is the topic of another paper by this author [6].

A DAPCEP Program Coordinator visited and reviewed each program twice during each ITEST session. After her visit to WIMS, and during the next DAPCEP ITEST meeting with program faculty, the DAPCEP Program Coordinator praised and used the WIMS mentor structure as a suggested template to other DAPCEP ITEST university program providers. Several times, she stated that having one WIMS Mentor assigned to each group of two DAPCEP students provided the personal attention that facilitated student learning. Also, she reported that DAPCEP students made positive comments to her on the low ratio of 1 mentor to 2 DAPCEP students.

Summary and Conclusions

WIMS SuperStar Challenge is an outreach program designed to help middle-school students develop and improve their technical knowledge, and to have enthusiasm for academic study and future careers in technical fields of science, engineering, and mathematics. This paper presents program design considerations, ranging from recruiting

and selecting targeted students, academic and technical content, instructors/teachers, expenses of the program, and sources to fund the program. The program was designed to present WIMS technical concepts and applications to serve the DAPCEP mission, including its goals for Saturday programs. This paper provides some real world examples of the operation of this program for nine programs over eight years. Mentors serve a crucial role to achieve the WIMS and DAPCEP goals by providing personal attention to the DAPCEP students; DAPCEP students and administrators have evaluated highly the benefit of mentors and the low mentor:student ratio.

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List of Acronyms

DAPCEP	Detroit Area Pre-College Engineering Programs
EECS	Electrical Engineering and Computer Science Department (at UM)
ERC	Engineering Research Center
LED	Light Emitting Diode
LNF	Lurie Nanofabrication Facility (at UM)
MEMS	Microelectromechanical Systems
MEPO	Multicultural Engineering Programs Office (at UM)
NSF	National Science Foundation
SLC	Student Leadership Council
UM	The University of Michigan – Ann Arbor, Michigan
WIMS	Wireless Integrated MicroSystems