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ROBOCAMP – USING ROBOTICS TO TEACH MATH, SCIENCE, AND ENGINEERING PRINCIPLES*

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ABSTRACT

RoboCamp provides an innovative experience in the area of robotics for educators. This fun, hands-on experience strengthens the teachers' knowledge and skills in science, mathematics, engineering, and telecommunications and prepares them to effectively transfer the experience to students in the classroom.

RoboCamp is supported with a grant from the Tennessee State Department of Education and is a collaborative effort involving the Oak Ridge National Laboratory (ORNL), area school systems, industry supporting robotics, and the Universities of Tennessee and Memphis.

RoboCamp is held on-site at the ORNL and gives the teachers first-hand look at research in action. The teachers work side-by-side with scientists and engineers on robotics-related topics. These topics include the following:

- history and future of robotics;
- science, mathematics, and engineering as they relate to robotics;
- national standards and state and local curriculum frameworks;
- classroom implementation of robotics education utilizing national standards;
- current thinking on pedagogy and assessment; and
- fun, innovative ways to answer the age-old question, "But how do we use it in real life!?!"

RoboCamp participants tour a variety of sites that use robots. These tours include production plants, research facilities, and build several kinds of robots based on different operating public schools involved in robotics education. Participants also principles, use computers and the Internet for robotics-related research, and work on a design problem using robotic solutions. Finally, participants work in teams to develop plans to transfer the experience to their schools.

Approximately twenty teachers are selected for participation in *RoboCamp*. Participants apply, and are selected, as members of a school team. A team is comprised of 3-5 members and may include teachers of the same grade or educators teaching different grades but within a school; teams are encouraged to include administrators and guidance counselors. Participants are paid a stipend and expenses. Teams are solicited statewide.

INTRODUCTION

The purpose of *RoboCamp* is to provide an experience for educators in the area of robotics, which will strengthen their knowledge and skills in science, mathematics, and engineering. The *RoboCamp* program prepares them to share the experience WITH students in the classroom.

PROGRAM DESIGN

The *RoboCamp* program is designed around five major program goals.

Program Goals

The goals of the program are to:

(1) expand knowledge about robotics to educators;
(2) strengthen related content knowledge in science, mathematics, engineering, and telecommunication;
(3) provide hands-on experiences with robotics that can be transferred to the classroom;

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(4) integrate robotics education into curriculum frameworks (state and local school systems) and national standards; and
(5) expose educators to the modern workplace and career opportunities.

Collaborative Team Effort

RoboCamp is a collaborative effort involving a wide range of partners. The Office of University and Science Education of Oak Ridge National Laboratory (ORNL), area school systems, ORNL's Robotics and Process Systems Division, business and industry supporting robotics, and the University of Tennessee are all involved in implementation of the *RoboCamp* program.

Teacher Training Teacher Model

The day-to-day operation of *RoboCamp* is under the direction of a lead teacher, utilizing the "*teacher training teacher*" model. Program staff using the criteria shown in Table 1 identifies the lead teacher.

Table 1: Criteria for selecting a Lead Teacher for the "Teacher Training Teacher" Model

· Past participant in a *RoboCamp*
· Familiar with the resources of ORNL and the local area
· Extensive teaching experience including leading teachers
· Strong academic background
· Evidence of outstanding teaching ability
· Active professionally
· Knowledgeable about curriculum frameworks and national standards

The lead teacher works with the design team, comprised of area teachers and staff from the University of Tennessee and ORNL, to develop and implement *RoboCamp.*

RoboCamp builds on the experience gained with each previous *RoboCamp*. Lessons learned are included in each subsequent program.

PROGRAM COMPONENTS

There are two components to *RoboCamp*:
(1) a 1-1/2 day orientation in the spring, and
(2) a two-week summer institute held in the summer.

Orientation Design

The primary purpose of the orientation is to introduce participants to the program, to one another and program staff, and to gather input from participants regarding structure and design of the summer institute.

Specifically, participants will:
(a) be introduced to key concepts about robotics,
(b) carry out hands-on activities related to robotics,
(c) provide input regarding structure and design of the summer institute,
(d) practice team-building skills, and
(e) gain enthusiasm about the summer activity.

The participants are given assignments to complete and materials to gather prior to the summer institute. In addition, participants meet the lead teacher for *RoboCamp* as well as other program staff.

Summer Institute Design

The summer institute is designed to support the five overall program goals and builds on the needs and interests expressed by participants during the orientation. Traditionally, there are discussions and seminars in the following areas: history and future of robotics; content knowledge on the science, mathematics, and engineering of robotics; telecommunications as a tool supporting education; best practice in teaching and learning; state and local curriculum frameworks and national standards; classroom implementation of robotics education utilizing national standards and curriculum frameworks; current thinking on assessment; and careers of the future.

KEY PROGRAM ELEMENTS

RoboCamp involves a variety of key program elements that fully immerse participants in the world of robotics.

Robotic Industry Tours

Tours are an integral component of *RoboCamp*. The tours visit a cross section of sites, which utilize robotics in a variety of ways. The lead teacher visits sites before the actual program tour and Points to Note are developed. Points to Note provide background information on the organization to be visited as well as assist the participating educators to focus on certain aspects of each tour.

The industry tours include production plants, research facilities, and public schools involved in robotics education. For example, Saturn and Kamatsu are production plants that use robots on a regular basis. Vanderbilt and UT-Knoxville have research capabilities in robotics, and public schools in Bradley County and Oak Ridge have school-based programs which use robots.

While the topic of careers is explicitly discussed, perhaps more useful for career education is the variety of employees seen by participants at the numerous tours and research facilities. In addition, participants establish contacts at area businesses, industries, research facilities, and innovative schools which will strengthen their capabilities as classroom teachers.

Telecommunication Resources

Another important element of *RoboCamp* is telecommunications. Participants learn to communicate electronically with one another, the lead teacher, and staff from ORNL. They also learn to use the Internet to access information about robotics, the national standards, resources for teachers, and current thinking in education.

Robot Kit Assembly

Participant teams are actively involved in the construction of robots using commonly available, relatively inexpensive kits. Each team builds several kinds of robots of various levels of complexity with teams constructing robots different from one another.

Fig. 1: Participants assemble an educational robot as part of the *RoboCamp* hands-on learning experience. Each robot features a different control technology.

Fig. 2: *RoboCamp* participants display their assembled robots. As part of the institute, they also develop an advertising campaign to show the features and benefits of their models.

The robots each operate on different principles (activated by barrier, sound or light; programmable and/or computer operated, etc.) and are of differing levels of difficulty. After the robots are constructed, each team presents information on their robots: operating principles; helpful hints for robot construction and conducting a process-oriented, hands-on approach in the classroom; recommendations for student use; and integration with curriculum frameworks and national standards. (See Figs. 1 and 2)

Interaction with Robotics Engineers

Participants also experience the research and development of robotics. Several days are spent in the Robotics and Process Systems Division (RPSD) at the Oak Ridge National Laboratory where participants are introduced to a wide variety of robotics researches, including the topic of telerobotics.

Telerobots are remotely controlled robotic devices that synergistically combine robot and human capabilities, as shown in Fig. 3. Participants learn about key features of telerobots, are introduced to systems employed today, and come to understand the proper application of these advanced systems. While at RPSD, participants have the opportunity to operate remote manipulators and see systems being developed for environmental remediation and military applications.

Finally, participants are able to interact with scientists and engineers at RPSD to learn more about educational qualifications

commonalties: there must be clearly stated goals and objectives; there must be documented links between the transfer plan, local curriculum frameworks, and the national standards; assessment and use of telecommunications must be part of the transfer plan; and all team members must be included. Each team presents their transfer plan to their peers and program staff for review.

Teamwork and Leadership Development

Teamwork and leadership developments are important elements of *RoboCamp.* Educators work in several different teams to facilitate this. They work in their school-based teams to build robots and develop transfer plans. In addition, there are a number of teams with responsibility to support the actual institute itself: logistics, materials and supplies, daily assessment, recreation, and final ceremony.

The leadership development approach encourages the active involvement of participants in the success of the institute, provides experience in serving as leaders and followers, and in fact, results in a smoothly organized program.

As part of the teamwork development, teams are given a robotics design challenge to solve a complex problem by using robotics and automation. The challenge is met with knowledge and skills learned through *RoboCamp* participation, and can be transferred to the classroom. A real-life robotics challenge pertaining to automating an analytical chemistry laboratory is shown in Fig. 4.

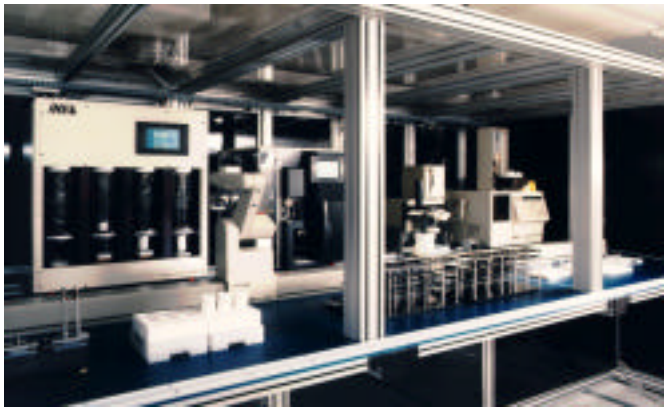

Figure 4: *RoboCamp* participant teams work together to solve a problem through the use of robotics, similar to this real-life automated analytical chemistry laboratory which uses a robotic arm to transfer samples from station to station.

Teacher Development Program Templates

Templates for the design and assessment of teacher development programs are used to ensure the best of research and practice is used in program development.

PROGRAM BACKGROUND

RoboCamp is held at the Oak Ridge National Laboratory, which is a Department of Energy (DOE) multi-program laboratory, employing approximately 5000 individuals of whom about 1700 are scientists and engineers. The mission of the Laboratory is to conduct basic and applied research in order to advance the nation's energy resources, environmental quality, and scientific knowledge and to contribute to educational foundations and national economic competitiveness. The Laboratory is located on a 2,900-acre site outside of Oak Ridge, Tennessee, about 20 miles from Knoxville. It is managed for DOE by Lockheed Martin Corporation.

Throughout its 50-year history, Oak Ridge National Laboratory (ORNL)'s major Research and Development thrusts in energy, environment, and basic and applied science have been closely coupled with support for mathematics, science, and engineering education. In fact, education was mentioned as a primary mission of the Oak Ridge National Laboratory in the first Laboratory mission statement of 1947.

Strengthening Mathematics and Science Education

Today, with a new and enlarged role as a designated U.S. Department of Energy (DOE) Science Education Center, ORNL offers an even wider array of research-participation, education, and training opportunities for students, teachers, and faculty members at all academic levels, from the early elementary years through graduate and postgraduate study and advanced training and professional development.

The goal of this comprehensive effort, conducted through ORNL's Office of University and Science Education (OUSE), is to further develop and strengthen mathematics and science education as a primary mission of the Laboratory, helping to fulfill the objectives of the DOE Science Education Enhancement Act of 1990. DOE-sponsored educational outreach and research-participation programs at ORNL are designed:

(1) to improve the quality of science and mathematics teaching and learning,

(2) to increase the size and diversity of the educational pipeline in these fields, and

(3) to ensure the nation's future availability of people with required scientific and technical skills.

Inquiry-Based, "Hands-On" Learning

The focus is on inquiry-based, "hands-on" learning and research experiences for both students and their teachers. A major effort involves new educational, training, and research partnerships--including those with other federal agencies, e.g., the Appalachian Regional Commission and National Science Foundation; with schools, colleges, and universities; with educational consortia and museums both regionally and nationally; and with the private sector.

Through its Science Education Center, ORNL provides opportunities for more than 20,000 students and faculty annually, beginning at the earliest states in the education pipeline.

PARTICIPANT RECRUITMENT AND SELECTION

The target audience for *RoboCamp* is area educators. Applicants apply as members of a school-based team consisting of 3-5 educators. Teams are encouraged to include administrators, guidance counselors, teachers who have never participated in a higher education Title 11 project, and new teachers as members of the team.

Recruitment Strategies

While recruitment occurs on a state-wide basis, special efforts are made to recruit participants from several areas: East Tennessee, Chattanooga, Memphis, and Nashville. As *RoboCamp* will be based in East Tennessee, Oak Ridge, it is logical, and economical to recruit strongly in that area.

To ensure participation of minority teachers and teachers of minority students, it is necessary to recruit in areas where those populations are found including the metropolitan areas of Chattanooga, Memphis, and Nashville.

The State Department provides mailing lists of minority teachers as well as private schools that are used as part of the recruitment process. In addition, ORNL has an extensive database of potential program applicants, which include diverse participants from all backgrounds.

Information about *RoboCamp* is disseminated through targeted mailouts and announcements placed in materials targeting educators--Tennessee Science Teachers Association, school newsletters, Tennessee Middle School Association, etc.

Application Review Process

A selection team that consists of teachers, program management staff, and the lead teacher reviews applications. The selection team independently rates applications using the criteria shown in Table 2.

Table 2: Selection Criteria for *RoboCamp* Participants

- Philosophy of education
- Professional development activities
- References
- Essay describing why applicant wants to participate in *RoboCamp*
- Explanation of how *RoboCamp* activities will be transferred to the classroom
- Related experiences

Teams combine individual applicant scores and team scores are rank-ordered from high to low. Priority is given to teams that include administrators and/or counselors, experienced teachers who have never participated in a higher education Title ll project, new and minority teachers, and educators at schools with high minority populations.

Graduate Credit

Graduate credit is available through the University of Tennessee on an optional basis, following standard guidelines for ORNL education programs.

Assessment and Follow-up Strategies

Evaluation and assessment are integral to the development and implementation of *RoboCamp,* beginning with program design. Working with the National Center for Improving Science Education (NCISE), a consulting firm in evaluation, a number of templates has been developed for use in program design. These templates identify elements of best practice to facilitate program planning, implementation, and assessment and are used to design effective programs for students and teachers. The template for teacher development programs is used to design, implement, and assess *RoboCamp.*

Daily Activity Assessment

Formative evaluation is used to assess daily activities in terms of interest, perceived usefulness and allow for course correction while summative evaluation looks at final outcomes. Participants assess each segment of the program on a daily basis, giving that information to the daily assessment team for review and recommendations.

Overall Final Assessment

At the completion of the institute, participants review the overall program in terms of perceived usefulness and organization. In addition, knowledge-based pre-and posttests are given to participants to monitor the information gained during *RoboCamp.*

Follow-up and Dissemination Activities

During the academic year, the lead teacher and program staff of ORNL monitors the implementation of transfer plans. This is done in a number of ways:

(1) site visits,
(2) communication by fax, telephone, or email; and
(3) group meeting in conjunction with the Tennessee Science Teachers Association (TSTA).

Program participants are encouraged to provide in-service activities for their schools and/or school systems. Participants are also required to attend the annual TSTA meeting as part of their follow-up activities. While at TSTA, the group meets and shares experiences on implementing robotics education as well as makes formal presentations at the conference.

Cooperative Endeavors

RoboCamp is designed to meet the needs of educators and their school systems and to link with state curriculum frameworks and support the national standards. This is done in a number of ways. One of the major functions of the spring orientation session is to gather input from participants on how *RoboCamp* can best meet their needs. This information is then used to develop the summer institute. The *teacher training teacher* model is another mechanism to ensure that the needs of educators and school

systems are met. The lead teacher is an integral part of the program development and implementation process as well as a member of the participant selection team.

Transfer plans require alignment with both the state curriculum frameworks and the national standards. To assist educators in this, copies of the frameworks and the standards are available and model transfer plans are on display. In addition, a representative from the State Department of Education leads a discussion on state frameworks and the standards and their integration into the classroom.

Program Outcomes

The stated purpose of *RoboCamp* is to provide an experience for teachers in the area of robotics, which will strengthen their knowledge, and skills in science, mathematics, engineering, and telecommunications. *RoboCamp* helps to prepare them to effectively transfer the experience to students in the classroom. By giving them hands-on experience, introducing them to potential classroom activities, and building the teamwork within the educational network, this can be done effectively and with enthusiasm for math, science, and engineering.

PARTICIPANT BENEFITS AND EXPERIENCES

As a result of *RoboCamp*, educators are more knowledgeable about an area of high interest, robotics. They have a better understanding of the science, mathematics, engineering, and technology on which robotics is based and the many careers related to robotics.

The participants have experienced the research community where sophisticated science is an everyday occurrence and developed an appreciation for the scientific process and the people that carry out that process. They have been able to see real-life robotics in action, like the dual-arm manipulator shown in Fig. 5. They have had experience integrating robotics education with curriculum frameworks and national standards and they have enhanced skills using technology to communicate and locate information.

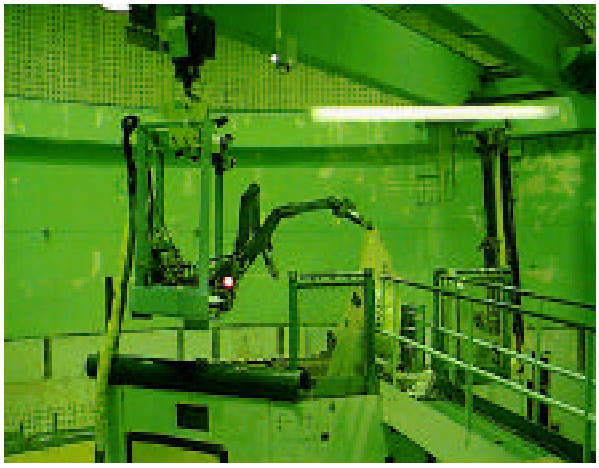

Fig. 5: A dual-arm manipulator system at ORNL is an example of the types of leading-edge robotics technologies that are part of the *RoboCamp* experience for educators.

Student Benefits

Ultimately, the final beneficiary of *RoboCamp* will be students--students better prepared for the future -- students who see the application of math, science, and engineering as a topic of great interest. And, who ultimately benefit from an educational team who is energized, experienced, and armed with the state-of-the-art technologies. The students are able to work with hands-on activities that bring complex concepts into simple, fun experiences. See Figs. 6 and 7.

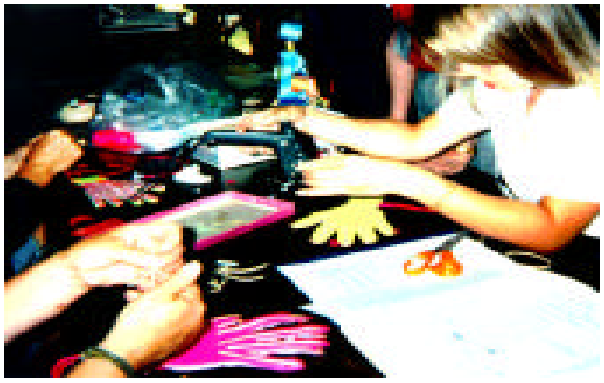

Fig. 6: *RoboCamp* participants assemble a working robotic hand using easily obtained materials such as styrofoam, rubber bands, drinking straws, and string.

Fig. 7: Two teachers demonstrate the kinematics of their working robotic hand.

SUMMARY

RoboCamp provides a fun, hands-on, learning opportunity for educators. The *RoboCamp* experience helps to strengthen their knowledge and skills in science, mathematics, engineering, and telecommunications and prepare them to effectively transfer the experience to the classroom.

To date three *RoboCamp* sessions have been held. Eisenhower Funds have funded these sessions. RoboCamp has provided for far-reaching impact through a variety of follow up activities including presentations at professional meetings. And the most important follow up – implementation in the classroom.

The two components to *RoboCamp* are a spring orientation in the spring, and the summer institute. The primary purpose of the orientation is to introduce participants to the program and to one another. The summer institute is a blend of activities to support program goals.

RoboCamp consists of discussions and seminars on the following topics: history and future of robotics; science, mathematics, and engineering as they relate to robotics; national standards and state and local curriculum frameworks; classroom implementation of robotics education utilizing national standards and curriculum frameworks; and current thinking on pedagogy and assessment.

There are tours to a variety of sites, which involve robots. These tours include production plants, research facilities, and public schools involved in robotics education. The tours give the teachers a true feel for the "real-world" and also allow for contacts to be made outside the classroom.

Participants build various robots based on different operating principles, and learn about resources available to the classroom for hands-on robotics activities. Finally, participants work in teams to develop plans to transfer the lessons learned to their schools, which is where the true benefits of their *RoboCamp* experience really pays off.

RoboCamp is a successful example of a collaborative effort to teach math, science, and engineering principles in a fun and innovative way.

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And finally, special thank you's to the teacher participants who have so enthusiastically taken the information gained through *RoboCamp* back to their students.

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