UC DAVIS CENTER FOR INTEGRATED COMPUTING AND STEM EDUCATION (C–STEM)

Research and Outreach

Transforming computing and STEM education through integrated learning.

UC DAVIS
C–STEM CENTER

c-stem.ucdavis.edu

ABOUT C–STEM

The UC Davis C-STEM Center aims to transform computing, science, technology, engineering, and mathematics (C-STEM) education in both formal and informal in K-14 programs through integrated learning, guided by two key objectives:

- Close the achievement gap by broadening participation of students traditionally underrepresented in computing and STEM related careers and post-secondary study.

- Develop students' 21st century problem-solving skills to tackle real world concerns through integrated computing and STEM education.

Through cutting edge research with funding from the National Science Foundation, the C-STEM Center, in collaboration with our industry partners, has developed innovative educational computing and robotics technologies for K-14 hands-on learning. By working with K-14 educators, the C-STEM Center integrates computer programming and robotics into teaching STEM subjects by creating project-based computing and robotics activities, integrated curriculum, and hands-on personalized and collaborative learning strategies aligned with Common Core State Standards and CTE Standards. This integration helps students make meaningful connections between regular STEM topics and their relevance to real-life applications as well as help develop students' critical thinking and problem-solving skills. The Center focuses on Algebra topics, the gatekeeper for STEM disciplines, to help close the achievement gap, engage traditionally unrepresented groups and at-risk students in learning STEM subjects while preparing all students to be career and college ready.

The C-STEM Center and our partners organize annual curriculum- based RoboPlay Competitions and Math Programming Competitions in various regions to further engage students in project-based team activities and to showcase their accomplishments and creativity in not only math and engineering, but also in writing, art, music and film production. For successful implementation of the C-STEM curriculum in classrooms and afterschool programs, the C-STEM Center provides unique professional development through the C-STEM Summer Institute and Fall and Winter Academies as well as on-site training for STEM educators who have no prior computer programming or robotics experience. Working together, we can transform K-14 education and inspire students to pursue computing and STEM related careers and post-secondary study.

Harry H. Cheng

C-STEM Center Director and Professor

Exploring Mathematics with Computing and Robotics

This course is designed to help 4th to 6th grades explore mathematical concepts in the Common Core State Standards- Mathematics through practical applications with hands-on and fun computing and robotics activities. Students write C/C++ computer programs to control a single robot and multiple robots. Through both personalized and collaborative group computing and robotics activities, students learn and reinforce the algebraic thinking with arithmetic operations in whole and decimal numbers, fractions, measurement, variables, data conversion, lines, angles, ratios, and proportions. The hands-on computing and experiments help students make meaningful connections between abstract math concepts and their relevance to real-life applications, as well as help develop students' critical thinking and problem-solving skills. (The full curriculum will be available for adoption in Fall, 2014)

* Teaching resources contain optional robotics activities.

"The material provided students with real-world skills proving math to be both applicable and enjoyable. … it helps make abstract ideas concrete and allow students to apply mathematical concepts to the real world."
- Francesca DeFazio, Middle School Teacher

C–STEM MIDDLE SCHOOL CURRICULUM

MATH 7 WITH COMPUTING

This course, based on the Common Core Math 7 standards, uses computing to develop and expand students' understanding of Math 7 topics. Students analyze real life situations, identify given information, formulate mathematical steps to find a solution, and analyze the results for accuracy, all within the context of computer programming. The logical process of computer programming allows students to organize their approach to problem solving and efficiently analyze and correct their work. Topics covered include evaluating expressions, one variable equations and inequalities, rates, proportions, percents, probability, similarity, plotting points and linear equations, and identifying slopes and intercepts. Optional group computing activities allow students to collaborate on critical thinking activities based on algebraic topics while developing their ability to effectively communicate, listen, share responsibility and respectfully address the suggestions of others. Optional robotics extension activities allow students to reenact physically derived mathematical problems through robotics technologies to visualize situations, associate graphs with physical phenomenon, predict and identify key features of the graphs with the specific physical situations, and solve physical problems through algebraic means.

* Teaching resources contain optional robotics activities.

MATH 8 WITH COMPUTING

This course, based on the Common Core Math 8 standards, uses computing to develop and expand students' understanding of Math 8 topics. Students analyze real life situations, identify given information, formulate mathematical steps to find a solution, and analyze the results for accuracy, all within the context of computer programming. The logical process of computer programming allows students to organize their approach to problem solving and efficiently analyze and correct their work. Topics covered include evaluating expressions, one variable equations and inequalities, rates, proportions, probability, scientific notation, statistics, plotting points, linear equations in slope-intercept form, systems of linear equations, radical expressions and equations, similarity, and geometric transformations, including translations and reflections. Optional group computing activities allow students to collaborate on critical thinking activities based on algebraic topics while developing their ability to effectively communicate, listen, share responsibility and respectfully address the suggestions of others. Optional robotics extension activities allow students to reenact physically derived mathematical problems through robotics technologies to visualize situations, associate graphs with physical phenomenon, predict and identify key features of the graphs with the specific physical situations, and solve physical problems through algebraic means.

* Teaching resources contain optional robotics activities.

COMPUTER PROGRAMMING WITH Ch

This course introduces students to the fundamentals of computer programming with an emphasis on applications of math concepts using the user friendly C/C++ interpreter Ch. Students start with basics of how a computer works and then explore programming in Ch to solve real life problems. Students write computer programs with graphical plotting and animation in an integrated development environment (IDE). Through computer programming based problem solving and engaging activities, such as generating random numbers for applications in math and gaming, students develop critical and computational thinking skills. Each section includes objectives, pre-requisites, applicable Common Core Language, Reading and CTE ICT standards, terminology, text with examples and applications, and exercises.

* Teaching resources contain optional robotics activities.

"What I like about Ch programming is learning how a computer works, how to manipulate the Linkbot using Ch, and learning from my mistakes while writing a program."

EXPLORING ROBOTICS AND FILM PRODUCTION

This course introduces students to the working principles of robotics with applications for film production using the modular robot Linkbot. Students will explore fun applications, such as robotic soccer and robotic drawing by controlling a single robot out of the box, and continue on to multiple robot applications aided by a graphical user interface, pose teaching, and computer programing using the C/C++ interpreter Ch. Students write robotics programs to perform various tasks with applications for the RoboPlay competition. With robots, students explore their creativity in writing, art, music, choreography, design, video editing and film production. This course emphasizes hands-on robotics activities to explore applications of robotics to gain effective communication and team work skills.

** This course can be implemented as a standalone robotics course or as a supplement to a **Physical Science** or **Engineering course**.*

AFTERSCHOOL PROGRAMS ON COMPUTING AND ROBOTICS

The C-STEM Computer Programming and Robotics curriculum can be used in an after school setting.

C-STEM COMPUTING AND ROBOTICS CAMPS

The condensed C-STEM Computer Programming and Robotics curriculum can be used for a one week self-sustained camp for elementary and middle school students, held on school campuses and colleges.

"Before this program, I didn't know anything about robotics. Now, I feel confident about programming. I would like to learn more."

C-STEM GIRLS IN ROBOTICS LEADERSHIP (GIRL) CAMPS

The self-sustained Girls in Robotics Leadership (GIRL) Camps, held on college campuses, are to motivate girls in middle school to learn science, technology, engineering, and math (STEM) concepts through a fun and exciting robotics-based curriculum. The girls learn leadership and communication skills and meet inspiring women leaders working with science and technology at college campuses. The girls are introduced to robotics, computer programming in C/C++, film production, and the creative process involved in making a full length film with robotics in the context of a global problem.

"I feel satisfaction whenever my program runs perfectly. Almost like a pat-on-the-back for success."

"If I hadn't have taken this program, I would never have been interested in computer science."

ALGEBRA 1 WITH COMPUTING

This course guides students through Common Core Algebra 1 topics while simultaneously teaching them basic computer programming skills. Students use programming to reinforce and extend their knowledge of algebra 1 concepts by analyzing real life situations, identifying given information, formulating steps that a computer program could calculate to find a solution and analyzing the results for accuracy and precision, going back and modifying their programming solution when necessary. Topics covered include evaluating expressions, one variable equations and inequalities, absolute value equations and inequalities, linear equations in standard form, slope-intercept form and point slope form, systems of linear equations and inequalities, evaluating, multiplying, factoring and plotting polynomial functions with an emphasis on quadratic equations, rational, radical and exponential functions, statistical analysis and probability, and arithmetic and geometric sequences. Optional group computing activities allow students to collaborate on critical thinking activities based on algebraic topics while developing their ability to effectively communicate, listen, share responsibility and respectfully address the suggestions of others. Optional robotics activities allow students to reenact physically derived mathematical problems through robotics technologies to visualize situations, associate linear and quadratic graphs with physical phenomenon, predict and identify key features of the graphs with the specific physical situations, and solve physical problems through algebraic means.

* Teaching resources contain optional robotics activities.

"I like it because it lets us do something different from the math and science textbooks."

INTEGRATED MATH 1 WITH COMPUTING

This course guides students through Common Core Integrated Math 1 topics while simultaneously teaching them basic computer programming skills. Students use programming to reinforce and extend their knowledge of mathematical concepts by analyzing real life situations, identifying given information, formulating steps that a computer program could calculate to find a solution and analyzing the results for accuracy, going back and modifying their programming solution when necessary. Topics covered include evaluating expressions, one variable equations and inequalities, absolute value equations and inequalities, linear equations in standard form, slope-intercept form and point slope form, systems of linear equations and inequalities, evaluating, multiplying, factoring and plotting polynomial functions with an emphasis on quadratic equations, radical and exponential functions, statistical analysis, probability, arithmetic and geometric sequences, similarity, and geometric transformations, including translations, rotations, reflections and dilations. Optional group computing activities allow students to collaborate on critical thinking activities based on algebraic topics while developing their ability to effectively communicate, listen, share responsibility and respectfully address the suggestions of others. Optional robotics activities allow students to reenact physically derived mathematical problems through robotics technologies to visualize situations, associate linear and quadratic graphs with physical phenomenon, predict and identify key features of the graphs with the specific physical situations, and solve physical problems through algebraic means.

* Teaching resources contain optional robotics activities.

COMPUTER PROGRAMMING FOR SOLVING APPLIED PROBLEMS (CALPADS 4619)

This course provides students with the fundamental knowledge of computer programming for solving applied problems. Students learn how a computer works and structured programming for software development. The topics include programming constructs, data types and declaration of variables, expressions and operators, selection statements, repetition, flowcharts for algorithm development, functions, arrays, and processing data files. Considerable attention is devoted to program design, task decomposition, testing, debugging, and software reuse. Students write computer programs with graphical plotting in an integrated development environment. Through problem-based projects, students develop critical thinking, problem solving, computational thinking, effective communication, and team work skills. The emphasis of the course is on algorithm development and computer programming for solving applied problems in science, technology, engineering and math, such as solving problems in Algebra and robotics.

* Teaching resources contain optional robotics activities.

"I like working with my classmates and I find programming really fun and exciting. We all have something in common."

ROBOTIC TECHNOLOGY (CALPADS 4647)

This course introduces students to the working principles and foundational knowledge of robotics. Students learn to control a single robot and multiple robots by graphical user interface, pose teaching, and object-oriented programs. Students write robotics programs to perform various tasks based on the sensory information of the robot. Through hands-on problem-based projects, students develop critical thinking, problem solving, effective communication, and team work skills. Robots are used as platforms to engage students in collaboratively learning science, technology, engineering, and math. This course emphasizes hands-on robotics activities with a concentration on algorithm development for solving problems in math and science.

This course can be implemented as a standalone robotics course or as a supplement to a **Physics or **Engineering** course.*

INTRODUCTION TO COMPUTER PROGRAMMING FOR ENGINEERING APPLICATIONS – A UC DAVIS ENGINEERING COURSE

This course introduces students to structured programming in C. Many algorithms for computer-aided problem solving are developed throughout the course to solve practical problems in engineering and science. The topics include number systems with internal representations of binary, octal, decimal, and hexadecimal numbers as well as binary two's complementary representation; limitations and numerical accuracy of different data types; 32-bit and 64-bit programming models; unary, binary, and ternary operators; selection statements for making decisions; iterative statements for repetitions; modular programming and code reuse; storage classes; arrays for data processing; pointers; dynamical memory allocation and deallocation; ASCII Code; characters and strings; structures and enumerations; top-down and bottom-up design of large-scale software project; file processing; and computational arrays for matrices and linear algebra for engineering applications.

COMPUTER-AIDED DESIGN AND 3D PRINTING CURRICULUM

This curriculum introduces computer-aided design with Autodesk Inventor to create accessories and parts for the Linkbot using a 3D printer. The curriculum can be used stand alone. It is also appropriate for use in conjunction with the C-STEM Robotic Technology, PLTW Introduction to Engineering Design, or PLTW Principle of Engineering course.
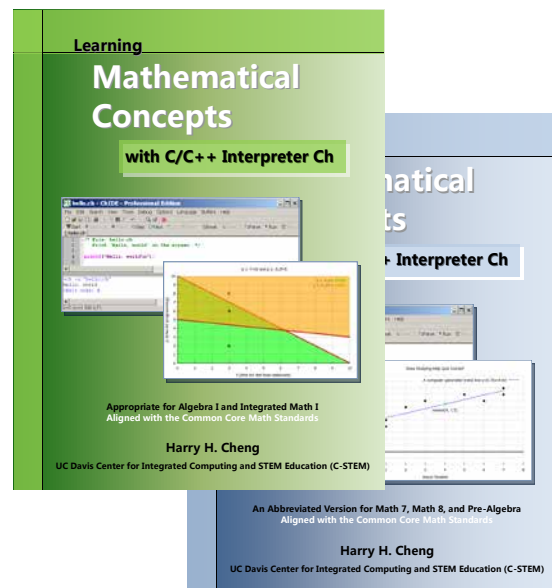
"It's incredibly simple yet challenging."

"I like how I learned something that could one day be a big part of my future career."

RESOURCES AVAILABLE FOR ALL C–STEM MATHEMATICS CURRICULUM

STUDENT TEXTBOOKS

- FOR SUPPLEMENT OR STANDALONE COURSES
- EACH SECTION INCLUDES:

  - Objective
  - Prerequisites
  - Common Core Math standards
  - CTE ICT Standards
  - Terminology
  - Exercises differentiated by levels of knowledge
  - Worked Examples and Applications

Learning
Mathematical Concepts
with C/C++ Interpreter Ch

Appropriate for Algebra I and Integrated Math I
Aligned with the Common Core Math Standards

Harry H. Cheng
UC Davis Center for Integrated Computing and STEM Education (C-STEM)

An Abbreviated Version for Math 7, Math 8, and Pre-Algebra
Aligned with the Common Core Math Standards

Harry H. Cheng
UC Davis Center for Integrated Computing and STEM Education (C-STEM)

TEACHER RESOURCES

- COURSE PLANNERS FOR EACH OF THE APPROPRIATE CLASSES
- EACH SECTION INCLUDES

  - Lesson Plan
  - Pre and Post Formative Assessments
  - Powerpoint Lesson
  - Video Lesson
  - Extra Practice Utility Programs
  - Optional Group Computing Activities
 - Optional Robotics Activities

- **Math 7 with Computing**
- **Math 8 with Computing**
- **Algebra 1 with Computing**
- **Integrated Math 1 with Computing**

- Curriculum Based Competitition
- Challenge revealed day of competititition
- 3 - 5 Middle School or High School students per team

C-STEM ROBOPLAY CHALLENGE COMPETITION

The RoboPlay Challenge Competition is designed for students to showcase their real-world problem solving skills in a competitive environment. This competition simulates an unexpected problem occurring at a remote location such as a space station or planetary habitat, where a robotic solution must be quickly developed and deployed, using only existing resources. The competition challenges students to creatively use modular robots and accessories to complete various tasks. The competition arena and specific challenge will be kept secret until the day of the competition. Using their math, programming, and problem solving skills, students try to most efficiently get the highest score for each task.
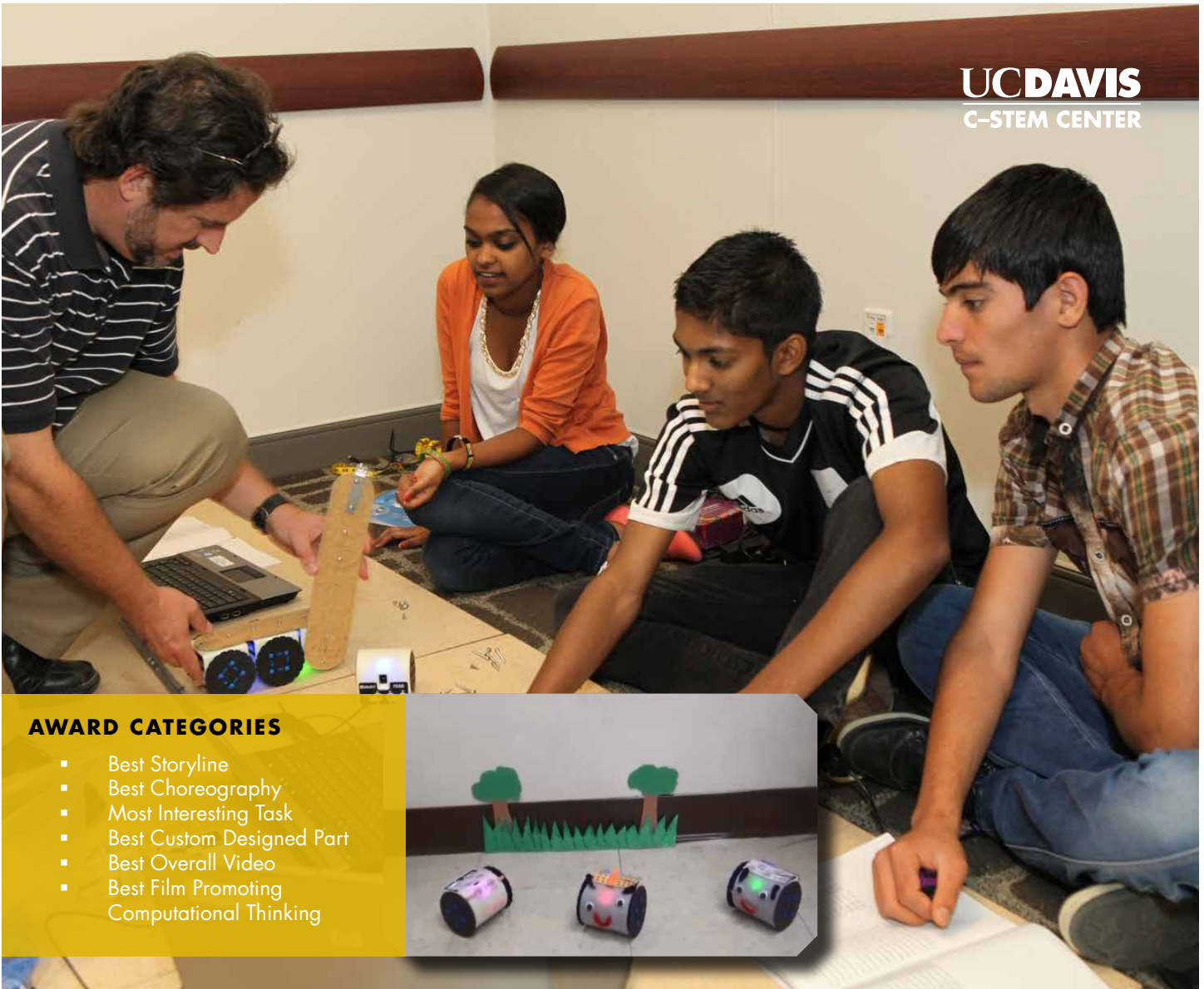
AWARD CATEGORIES

- Best Storyline
- Best Choreography
- Most Interesting Task
- Best Custom Designed Part
- Best Overall Video
- Best Film Promoting
  Computational Thinking

C-STEM ROBOPLAY
VIDEO COMPETITION

RoboPlay Video Competition is designed for K-12 students to learn robotics while having fun and exploring their creativity in writing, art, music, choreography, design, video editing and film production and at the same time seamlessly learning C-STEM subjects. The necessary robot coordination to match the movement of multiple modules to music requires not only teamwork in designing a well-organized visual performance, but also the math and programming skills to produce the desired actions. The competitions enable students with different interests to explore the basic concepts of C-STEM in conjunction with their artistic and music talents.
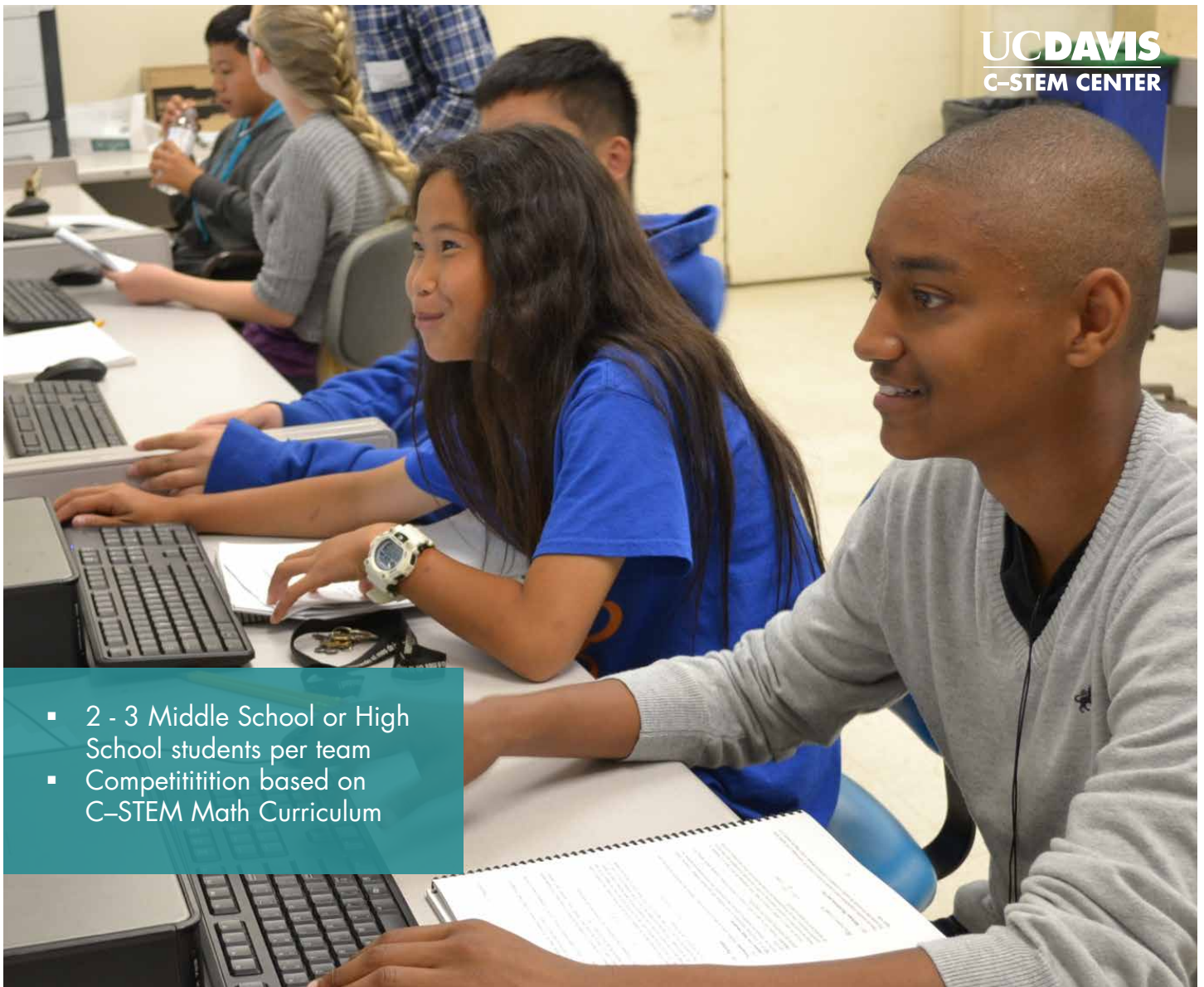
- 2 - 3 Middle School or High School students per team
- Competititition based on C–STEM Math Curriculum

C-STEM MATH PROGRAMMING COMPETITION

The C-STEM Math Programming Competition provides students with the opportunity to apply their fundamental computer programming skills for applications in mathematics. Being the gatekeeper to STEM careers, mathematics is necessary for all secondary school students. This competition challenges students to apply their programming and critical thinking skills to solve math problems.

- C–STEM Teacher of the Year
- C–STEM School of the Year

C-STEM ANNUAL CONFERENCE ON INTEGRATED COMPUTING AND STEM EDUCATION

The annual C–STEM conference provides a forum for K–14 STEM teachers, researchers, educators, policy makers and industrial partners to share their experiences, best practices, and ideas, and thereby influence the future direction of integrated computing and STEM education.

Outstanding STEM teachers are recognized with the C–STEM Teacher of the Year Award for their dedication and achievement on integrated computing and STEM education. The C–STEM also presents the C–STEM School of the Year Award to schools for achieving excellence in integrated learning with computing and STEM subjects and providing all students with computer programming experience in formal education.

INTEGRATED COMPUTING AND STEM EDUCATION
FOR BOTH FORMAL AND INFORMAL K–14 PROGRAMS

UC Davis Center for Integrated Computing and STEM Education
University of California, Davis
One Shields Avenue
Davis, CA 95616

Harry H. Cheng, Ph.D
C-STEM CENTER DIRECTOR
PROFESSOR, DEPARTMENT OF MECHANICAL
AND AEROSPACE ENGINEERING
hhcheng@ucdavis.edu
530-752-5020

Heidi Espindola, M.Ed.
C-STEM PROGRAM MANAGER
hespindola@ucdavis.edu
530-752-9082

UCDAVIS C-STEM Center **c-stem.ucdavis.edu**

UCDAVIS COLLEGE OF ENGINEERING

NSF

Sandia National Laboratories

Department of Education State of California

hp invent

Barobo
Research Grade Modular Robots

BOEING

Stratasys
FOR A 3D WORLD

SoftIntegration®

PATON
GROUP
EDUCATION THROUGH INNOVATION