TECH-EXPLORER: ENGAGING STUDENTS IN
STEM EDUCATION AND TECHNICIAN CAREERS

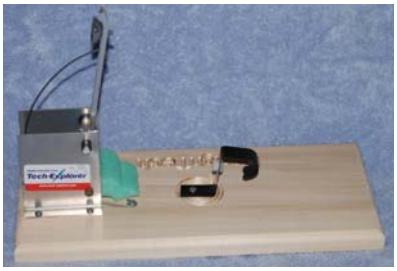
1. Rationale

Product design and high-tech manufacturing is a core component of the nation's economy; however, it faces stiff competition from overseas. To remain competitive, U.S. manufacturers must have highly skilled workers with advanced engineering and technical skills. Unfortunately, those workers are in short supply due to a lack of secondary school and college students engaging in science, technology, engineering, and mathematics (STEM) education and career pathways.

Lamenting the shortage of skilled technicians, in 2006 the Sierra College Mechatronics and

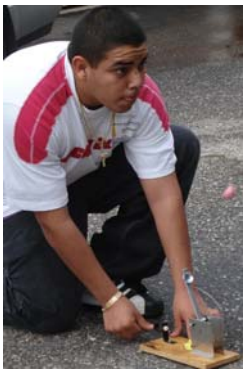
Center for Applied Competitive Technologies (CACT) industry advisory committees recommended that Sierra College collaborate with high schools to engage students in STEM to prepare them for careers as technicians, designers, engineers, and scientists.

Based on this recommendation, in 2007 a team of Sierra College instructors and Career Technical Education (CTE) staff developed the *Tech-Explorer* catapult fabrication event during which students experience the thrill of making something. This California Community College grant-funded project exposes students to experiences similar to what manufacturing technicians encounter on the job. They use mills, lathes, drills, and hand tools in a mobile lab called "shop in a box" to make and assemble parts into a catapult in three hours. Upon completion, participants compete with their catapults to test distance and accuracy. Students are given a safety talk prior to a catapult construction event, a pre and post interest survey, and STEM career pathways information.



Tech-Explorer project goals are to engage students and their teachers in applying academic principles through project-based learning; tie to State Content Standards; demonstrate that STEM education and careers are for women as well as men; and interest students in Sierra College's

Mechatronics, Engineering, Engineering Support Technology, and Energy Technician certificate, degree, and transfer programs. The instructional concepts employed in Tech-Explorer are hands-on, project-based learning; team problem solving; and equipment & methods used in industry. To hold a catapult building event, the project requires a mobile shop of power and hand tools modified for safety, raw materials, back up parts, portable tables, and a team of trainers to teach students how to use the equipment. Project documentation includes a demonstration DVD as well as technical drawings, a catapult building workbook, and an instructional DVD.



Over two+ years the catapult project was tested at 23 middle and high schools in nine school districts with 840 students in CTE, mathematics, history, English, and business classes. This first phase of the Tech-Explorer project delivered hands-on and contextual learning. To measure the project's effect on students, we reviewed pre and post student interest surveys and interviewed teachers and administrators regarding their impressions. From the interviews we learned that the project sparks interest and whets students' and teachers' appetites for more project-based learning. Additionally, our evaluation generated this essential question: **would teaching mathematics just in time for students to apply while building a catapult enhance their experience, provide them a way to gauge their aptitude, and increase their interest in STEM education and careers?**

To investigate the hypothesis, and identify project-based educational strategies proven to be effective, we conducted a literature review. In a recent National Council for Advanced Manufacturing report, they observed that: "If American students and workers are to compete successfully in the 21st century workforce, they must have access to a learning system that provides them with the knowledge and skills built on world-class academic and workforce standards."[1] One of the report's recommendations is "to include applied learning in the curricula for all students in grades PreK – 12, leveraging business/education partnerships to ensure workplace-relevant learning activities."[2]

We also reviewed data from: the Association for Career and Technical Education's *Promising Programs;* a document from the National Center for Engineering and Technology Education titled

Selected NSF Projects of Interest to K-12 Engineering and Technology Education (November 6, 2007) Daniel L. Householder; a presentation to the National Science Teacher's Association 2009 National Conference (March 21, 2009) titled *Problem-Based Learning: A Practical Approach for STEM Education*, Nicholas Massa and Judith Donnelly; and the California Center for College and Career (ConnectEd) publications, to name a few. ConnectEd best characterized the theme emerging from the literature review: "…students change their attitudes about school when they are solving exciting problems and working on projects that link their academic and technical courses to an authentic, career-related theme."[3] After reviewing best practices in engaging students in STEM education and careers, and consulting with industry advisors, we determined blending academic concepts with CTE is the right course of action.

This proposal's foundation is that knowledge and know-how are prerequisites for success in education and technical careers. Our goal is for students to transfer knowledge from academic content to technical applications and vice versa through a career-themed project. This approach enriches these courses by incorporating context and application via classroom instruction and laboratory experience. Through the next phase of the Tech-Explorer project, students will be introduced to a blend of academic and technical instruction, combined with the catapult build, to provide them with a means by which to gauge their interest and aptitude in STEM education and attract them to technical careers.

Over the two year proposed project we will: 1) create two instructional modules to teach catapult-related mathematics concepts in

CTE, Mathematics, and/or Physics classes before and after building a catapult; 2) connect the modules to State Content standards – both academic and CTE; 3) deliver the catapult project and modules in six events; 4) develop and administer pre and post assessments to determine learning and retention; 5) continue the pre and post student interest surveys to compare the 840 students we have already worked with to the new cohort; and 6) evaluate overall project success. We will continue presenting STEM career pathway information with an emphasis on attracting girls to STEM education and careers.

Intellectual merit

The Tech-Explorer catapult creators and implementation team have invested hundreds of hours in developing and testing the catapult laboratory experience named Tech-Explorer, *Projects that Move Minds*. Tech-Explorer curriculum was generated out of two Sierra College Computer Integrated Electronics professors' 25+ years of experience teaching applied academics. The core of this proposal is to add just in time mathematics concepts to the catapult build experience. We will create and teach two modules, such as a basic equation of motion, in CTE, Mathematics, and Physics classes before and after building a catapult. We will test the ConnectEd premise to see if working on the catapult project, linking academic and technical courses to a career-themed hands-on experience, will engage interest and ultimately increase the number of students pursuing STEM education and careers. The catapult build will be a vehicle to integrate mathematics into technical education and vice versa while exposing students to what goes on in a manufacturing and repair environment. The project's intellectual merit is in advancing knowledge and understanding regarding the effectiveness of pairing mathematics modules with career-themed hands-on projects.

Broader impacts

This project will have a broader impact in three ways. We will: 1) take a step toward addressing employers' needs for future technicians; 2) advance understanding of integrating academic and CTE concepts by partnering with six secondary school partners to implement the proposal; and 3) disseminate products and outcomes to other institutions for adoption and implementation. Information regarding how

this project advanced knowledge and understanding of project-based learning as a means to engage students in STEM education and careers is an expected outcome. All project outcomes, curricula, and career pathway recruitment materials will be widely disseminated to secondary and post secondary educators via a searchable Internet database for download and implementation resulting in an impact extending well beyond the Sierra College district.

Integrating diversity

The Tech-Explorer project emphasizes attracting girls and women to STEM careers. Using a gender-balanced training team of women and men, students see that being skilled at using tools and fabricating parts is not gender-based. Moreover, we have made a special effort to bring the catapult project to a variety of secondary schools and socio-economic levels: urban, suburban, rural, alternative, court ordered, as well as Sierra College Mechatronics classes.

2. Goals and Activities

The project addresses ATE program improvement areas of innovative laboratory methods, rigorous STEM content into technical programs, and education pathways to Sierra College's Certificate, A.S. degree, and transfer programs in Mechatronics, Engineering, Engineering Support Technology and Energy Technology. Major goals for the project include: 1) Connect career-themed laboratory experiences and rigorous STEM content; 2) Increase student understanding through student-centered learning; 3) Increase student interest in pursuing STEM education and careers; 4) Evaluate and assess the project to enhance the infrastructure for educational research; and 5) Have a broad impact.

Goal 1: Connect career-themed laboratory experiences and rigorous STEM content

- Activity 1: Research best practices regarding project based learning to teach mathematics.
- Activity 2: Develop curriculum to make abstract lessons relevant.

This project will research integration of authentic career-themed lab experiences, academic and CTE content, and pedagogy resources so that new curriculum modules will build upon a body of knowledge

focused on attracting and preparing students for engineering technician-related education and career pathways. The Manufacturing Education Resource Center that houses a searchable database of peer reviewed materials, and the Materials Education Resource Center that includes a curriculum database on properties of metals and general materials properties integrated with lessons in mathematics, will be the first point of contact. A cadre of instructors from the project's six participating schools will be interviewed regarding the components and mechanics of integrating technical and mathematics curriculum. Their recommendations will provide a framework for developing and testing new curriculum.

Two curriculum modules will be developed and aligned with California Mathematics Content Standards, and include: 1) an introduction of the concept or theory and an anticipatory (pre-build) exercise; 2) an application of mathematics concepts and formulas in a lab setting, using the Tech-Explorer catapult; 3) an evaluation of the applied mathematics in context to the performance of the catapult project. For instance, Algebra 2 or Pre-Calculus students can learn how to calculate a parabolic equation ($y=a\,(x-h)2+k$) using their Tech-Explorer catapult by determining the vertex of the parabola as well as an additional point (e.g. the endpoint) of the trajectory. Applications of mathematics concepts tested in the classroom will be linked to engineering technician applications in business and industry through a discussion of engineering, manufacturing, and product design related careers.

Goal 2: Increase student understanding through student-centered learning

- Activity 1: Deliver the catapult project and applied instructional mathematics modules to 150 students at six events.
- Activity 2: Develop pre and post assessments to determine learning and retention and to identify areas that will need re-teaching and /or further review and reinforcement.

Based on the work of Dr. Robert Karplus (Atkin & Karplus, 1962)[4] and using tools and resources from the NSF-funded POGIL Project (Process Oriented Guided Inquiry Learning), we reviewed three approaches to student centered learning: problem-based learning, process-oriented guided inquiry

learning, and peer-led team learning in an effort to have this proposed Tech-Explorer phase continue to move beyond traditional content-driven curriculum. "Studies of how people learn show that active-learning environments involving problem-solving discussions with peers are more effective than traditional lectures. There is no doubt that good lectures are efficient ways to illuminate course content and that they work quite well for some students, but even the best lectures remain generally in the realm of 'passive learning,' and it is arguable that some students survive despite this approach, rather than because of it."[5]

To accomplish Activity 1, and provide an active-learning environment, the instructional modules delivered to student cohorts will be hands-on and project-based; incorporate team problem solving; and employ equipment & methods used in industry. Modules will provide students with an authentic, career-themed experience, integrated with applied mathematics. Cohorts will include a mixture of academic (mathematics) and career and technical education (e.g. woodshop) classes. Five events will engage students in grades 9-12, and one event will engage students in grades 7-8.

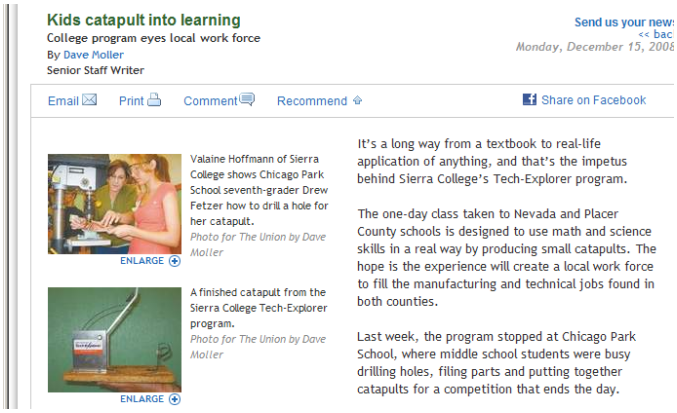
Students will self-assess their knowledge and application of mathematics concepts by completing pre- and post-unit tests, and by demonstrating mastery of desired skills and knowledge through the laboratory exercise. Modules will include rubrics for self-evaluation and grading.

Goal 3: Increase student interest in pursuing STEM education and careers

- Activity 1: Develop and deliver recruitment materials on Sierra College Mechatronics, Engineering Support Technology, Engineering, and Energy Technology technician degree and certificate programs for students, parents, and counselors at partnering high schools and middle schools.
- Activity 2: Present STEM career pathway information with an emphasis on attracting girls to STEM education and careers.

Using the existing Sierra College marketing and outreach infrastructure, students will be recruited to Certificate, A.S. degree, and transfer programs via two channels: 1) The project's outreach coordinator

will conduct pre- and post-classroom events, including a presentation on Sierra College STEM-related CTE programs, as part of the Tech-Explorer laboratory experience; and 2) Sierra College Career Education Liaisons (CELs), funded through Perkins IV legislation, are assigned to all high schools in the Sierra College District to promote career and technical education programs. Information specific to Sierra College STEM-related technical programs will be presented to grade 9-12 students at partner schools on a regular basis, and serve as leveraged resources for this project.



Kids catapult into learning

College program eyes local work force

By Dave Moller

Senior Staff Writer

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Monday, December 15, 2008

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Valaine Hoffmann of Sierra College shows Chicago Park School seventh-grader Drew Fetzer how to drill a hole for her catapult.

Photo for The Union by Dave Moller

ENLARGE

A finished catapult from the Sierra College Tech-Explorer program.

Photo for The Union by Dave Moller

ENLARGE

It's a long way from a textbook to real-life application of anything, and that's the impetus behind Sierra College's Tech-Explorer program.

The one-day class taken to Nevada and Placer County schools is designed to use math and science skills in a real way by producing small catapults. The hope is the experience will create a local work force to fill the manufacturing and technical jobs found in both counties.

Last week, the program stopped at Chicago Park School, where middle school students were busy drilling holes, filing parts and putting together catapults for a competition that ends the day.

Marketing materials and communication products (e.g. press releases, career pathway products, and presentation materials) will incorporate images of women and girls in STEM-related occupations or activities; and provide examples of STEM career pathways with women role models and success stories. The NSF-funded STEM Equity Pipeline project resources (such as the Five Step Program Improvement Process)[6] will be referenced and applied as appropriate.

Goal 4: Evaluate and assess the project to enhance the infrastructure for education research

This project is focused on developing two instructional modules to teach mathematics concepts related to the construction and use of a catapult. We feel we can effectively evaluate in these three areas:

- Activity 1: Analyze student surveys regarding interest in STEM education and technician careers.
- Activity 2: Evaluate student learning based on Tech-Explorer lab experience tied to instructional modules.
- Activity 3: Assess overall project success.

We will collaborate with the California Partnership for Achieving Student Success (Cal-PASS) to conduct the evaluation. Cal-PASS is an initiative that collects, analyzes, and shares student data in order to track performance and improve success from elementary school through university. The organization assists educators to understand student performance, improve instruction, and increase student success. Cal-PASS has California data from 6,800 elementary schools, high schools, community colleges, and

universities, including the middle and secondary schools with which we are working. We will work with Cal-PASS to develop an evaluation plan and protocol.

Documentation that will be collected for evaluation and analysis will include: 1) lessons learned; 2) mathematics assessment test results to determine understanding and application of concepts presented before and after the catapult build; 3) student course taking patterns, success, and persistence; 4) student interest surveys and 5) qualitative interviews with faculty regarding the effectiveness of pairing instructional modules with the catapult. The documentation and analysis combination will provide a measurement regarding overall project success as it relates to the essential question: does teaching mathematics concepts just in time for students to apply while building their catapult enhance their experience and provide them a way to gauge their interest and aptitude in STEM education and careers?

Goal 5: Have a broad impact

- Activity 1: Address employers' future need for technicians.
- Activity 2: Collaborate with regional secondary schools to create and implement two mathematics instructional modules to advance discovery and understanding.
- Activity 3: Disseminate project documents and outcomes for use at other institutions.

The Tech-Explorer catapult project was created at the request of two Sierra College industry advisory committees (CACT and Mechatronics) regarding their current and future need for technicians. CACT advisory committee member Nick Bruno, CEO, Harris and Bruno, described advisors' thinking when he stated: "As an employer in manufacturing, it is absolutely critical that Sierra College reach down to middle and high school students and gets them excited about manufacturing because there are certainly a lot of opportunities." The addition of two mathematics modules to the catapult build will advance the Tech-Explorer project one more step toward accomplishing Activity 1.

As noted earlier, the catapult build was held 23 times over the previous two years. The events were so successful that the demand for catapult builds exceeded our capacity to deliver them. One

outcome of the project is that it became a catalyst for teachers to collaborate across disciplines and with Sierra College to improve student learning. Due to the credibility of the catapult project, we have formed partnerships with Colfax, Oakmont, Placer, Chicago Park, Lincoln, and Nevada Union schools to create and implement this next Tech-Explorer phase.

To accomplish Activity 3, instructional modules, evaluation results, and other resource materials will be developed and posted online via a project website. Modules will also be submitted for peer review and posting to the NSF-funded MERC Online site, managed by the National Center for Manufacturing Education. Information and access to project resources will be shared with the eleven other Centers for Applied Competitive Technologies (CACTs) throughout the state, which have received training and instructional materials for the Tech-Explorer catapult project.

As we have stated throughout this proposal, the addition of mathematics curriculum is the logical next step to further the goal of recruiting and preparing students for STEM education and technician careers. The long-term project goal is to better understand how to interface abstract and technical curriculum for optimal student learning and engagement.

3. Deliverables/Expected Outcomes

Project deliverables will include: 1) two instructional modules to teach mathematics concepts needed for construction and use of the catapult; 2) assessment instruments for two instructional modules and assessment results; 3) 150 students experiencing Tech-Explorer over six events; 4) student interest survey results to compare to previous data; 5) quantitative and qualitative evaluation results regarding the effect of the catapult build tied to instructional modules; and 6) dissemination of project documents through the project website and presentations.

4. Project Timeline

Date	Activity
Year 1: Spring Semester 2010	Finalize research on best practices.

Date	Activity
	Develop 2 instructional modules and materials. Develop pre and post assessments to determine learning and retention. Collaborate with CalPASS to begin the evaluation activities.
Year 1: Summer 2010	Refine instructional modules and materials for implementation fall semester 2010.
Year 1: Fall Semester 2010	Pilot instructional module and assessments at 3 catapult builds. Collect student interest surveys for review. Collect qualitative data on all activities.
Year 2: Spring Semester 2011	Evaluate the fall semester catapult builds and revise activities and refine curriculum for late spring semester catapult builds. Post preliminary results to the project website. Pilot refined instructional modules at 3 catapult builds. Collect student interest surveys for review. Collect qualitative data on all activities.
Year 2: Summer 2011	Perform final evaluation activities. Post curriculum and results on the project website for dissemination. Present project outcomes at appropriate conferences.

5. Management Plan, Principle Investigators, and other Senior Personnel

Sierra Community College District is an accredited two-year public California community college with approximately 20,000 students. Sierra College has a history of successfully managing grants, is well versed in managing special projects with short timelines, and has the ability to accomplish the goals and outcomes of the proposed project. For example, the college's grant-funded Center for Applied Competitive Technologies delivers training and technology transfer services to small and medium sized manufacturers. The college also administers federal Career and Technical Education Act (CTEA) funding to support improvement in 20 technical education programs.

Through an organizational management structure and line of accountability, this project will report to, and is directly responsible to, the Assistant Superintendent/Vice President of Educational Programs and Services, and then the Superintendent/President of Sierra Community College. This project has the full support of the executive leadership of the college.

Principal Investigators

The background, experience, and other qualifications of the Sierra College Principal Investigators are more than sufficient to carry out their designated roles. The role of Principal Investigator (PI) will be held by Sandra Scott, Director, Grant Development and Career Technical Education. Mike Sequeira, Dean, Sciences and Mathematics will be co-Principal Investigator. It is envisioned that Mike Sequeira will commit 10% of his time to this project and provide mathematics and physics curriculum review and oversight as an in-kind resource. Sandra Scott will commit 10% of her time and will be responsible for the overall direction, guidance, and timely completion of each activity called for in the proposal and work plan, as well as for the overall success of the project. The Principal Investigators will meet on a routine basis with the Assistant Superintendent/Vice President of Educational Programs and Services and the college's Finance Director to update all concerned with project direction and activity/timeline accomplishments.

The cross-disciplinary project team has collaborated for over two years to develop and execute the Tech-Explorer catapult project. Representing Sierra College, the teams includes the PI and co-PI, Mechatronics professors, and the CACT director. Classroom teachers, administrators, and counselors represent the secondary school team from Chicago Park, Colfax, Lincoln, Nevada Union, Oakmont, and Placer schools. CACT and Mechatronics program industry advisors will provide technical assistance regarding workforce skills.

Sandra Scott

University of Minnesota	History	BA, 1971
University of Minnesota	Textiles	BS, 1983
University of Minnesota	Design, Housing, Apparel	MA, 1987

Sandra oversees the college's Grant Development and Career Technical Education department. Her duties include educational administrator for the college's federally funded CTEA program, working with 20 technical education programs; overseeing the Center for Applied Competitive Technologies (CACT); and developing grant projects for Sierra College. Sandra will act as the project administrator working closely with all other personnel to ensure project success.

Mike Sequeira

Shasta College	Chemistry	A.S., 1967
California State University, Chico	Chemistry/Physics	B.S., 1969
University of California, Davis	Chemistry/Physics,	M.S. 1971
University of California, Davis	Secondary Teaching Credential	1971

Mike is the Dean of the Sciences and Mathematics Division at Sierra College. Prior to his becoming Dean, Mike was a physics professor at the college starting in 1976. He was also a high school chemistry and physics teacher between 1971 and 1976. Mike is a member of the American Association of Physics Teachers and was an active member of the Sierra College Curriculum Committee. Mike is a seasoned educator and classroom instructor with physics and chemistry curriculum development expertise.

Senior Personnel

Michael Halbern

California State University, Long Beach	Industrial Education	BA, 1976
California State University, Long Beach	Industrial Education	MA, 1980

Michael is a Professor of Mechatronics and Computer Integrated Electronics at Sierra College where he has taught for 26 years. His primary focus has been on student project design and development, linear circuits, and curriculum development. He has also designed electronics projects for use in local high schools. In 1997 he was President of the California Council of Electronics Instructors. Michael will be involved in the project is as the senior project designer and co-creator of the catapult project.

Steven Hunter

California State University, San Jose	Industrial Arts	BA, 1972

Steven is a Professor Emeritus of Computer Integrated Electronics at Sierra College where he taught for 28 years. He initiated curriculum for an embedded systems/robotics and electro optic/fiber

optic certificate and degree program. He began his teaching career working for Litton Industries and instructing part-time at the College of San Mateo. After joining Sierra College, in addition to his regular teaching duties, he developed Sierra College industry training programs. Steven also helped establish the student internship program that places students with business and industry. He will be involved in the project as the senior technical project coordinator for the mobile laboratory and curriculum advisor.

Carol Pepper-Kittredge

University of California, Davis	Environmental Planning & Management	BS, 1979
University of San Francisco	Human Resources & Organization Development	MHROD, 1995

Carol is the Director of the Sierra College Center for Applied Competitive Technologies, and has over 25 years of economic and community development experience. Prior to joining Sierra College, she managed, evaluated, conducted research, and provided training for a variety of community colleges and educational institutions as an independent consultant. She served as Senior Project Associate for the Center for Civic Partnerships, a center of the Public Health Institute. Carol will be involved in the day to day implementation of the project as Project Coordinator.

Marianne Cartan

University of California, Davis	Spanish	BA, 1977
California State University, Sacramento	Counseling	MS, 1986

Marianne's professional experience includes regional occupational program administration for the Placer County Office of Education in student services and curriculum oversight for career technical education. She has also served as the Assistant Principal, Nevada Union High School, Head Counselor at Nevada Union High School, and English as a Second Language instructor at the University of California, Davis. Marianne is currently pursuing her doctorate in Organizational Leadership. She will provide secondary education practices and curriculum leadership for the project.

6. Sustainability

The project described in this proposal is geared toward engaging students in project-based learning tied to an authentic career theme. Tech-Explorer was our

response to the CACT and Mechatronics advisory committees' appeal to increase the number of students engaged in STEM education and technician careers to meet their future workforce needs. As demonstrated in the proposal's narrative, considerable time, effort, and resources have been invested in creating and piloting the catapult project's first phase. The partnerships and activities functioning before this grant proposal will be the foundation on which we launch the next phase.

Additionally, by sharing curricula and project outcomes with community colleges and secondary schools, the project can be replicated; this is already happening. For example, on October 1, 2009, Tech-Explorer team members were invited to present the catapult build project at the annual conference of the National Coalition for Advanced Competitive Technologies in Chicago. The presentation was well received, and project materials were distributed to workshop participants for replication. As Tech-Explorer evolves, this project will become a model for project-based learning nationwide.

Conclusion

Sierra College is invested in the Tech-Explorer catapult project and is committed to work with the NSF community to build on the project's success. With $150,000 of NSF funding, Sierra College will create and integrate two math curriculum modules into the proven catapult project-based learning experience in both academic and Career Technical Education classes in middle and high school. The evaluation will illuminate the project's impact on learning outcomes and student interest in pursuing STEM education and careers. The resulting insight will guide educators on how best to entice students to study subjects that will prepare them to fill highly-paid, in-demand technical employment openings. Furthermore, we expect that implementing this next phase will result in more comments such as Chicago Park School Principal Dan Zeisler's, "You and your team are simply wonderful. Watching the kids today help each other finish up and then support each other in their playful competition was a joy to watch."