STRATEGY: Improving Secondary Mathematics and Science with Integrated Programming Experiences

Submitted in response to NSF solicitation 09-506:
ITEST: Innovative Technology Experiences for Students and Teachers

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IN COORDINATION WITH

Poudre School District, Fort Collins, CO

Aurora School District, Aurora, CO

Greeley/Evans School District, Weld County, CO

Mapleton School District, Denver County

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The Innovative Technology Experiences for Students and Teachers (ITEST) program is intended to enhance participation in the U.S. STEM and ICT-intensive workforce, through the design, implementation, scale-up and testing of strategies for students and/or teachers. All research and development activities within DRL aim at generating knowledge, informing practitioners, and **transforming practice in STEM education**.

"Strategies" projects are guided by the following questions:

- What strategies will best support student development for productive participation in the STEM, especially ICT-intensive, workforce of the future?
- What are the knowledge, skills, and dispositions that students need in order to participate productively in the changing workforce in STEM, and how can we prepare teachers to help students acquire such knowledge, skills and dispositions

"Strategies" projects should make a case for the potential of the strategy on the basis of research about workforce development, teaching and learning, or STEM workplace demands; or make a case on the basis of evidence from experience and professional judgment, or other relevant theory or arguments that support the strategy.

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Full Project Description is online at: http://www.biographixmedia.com/ITEST/2009proposal.pdf

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....---== **Project Summary** ==---....

The driving goal underlying this ITEST Strategies project is to provide secondary school students an engaging introduction to computer science, a cornerstone of ICT (Information and Communication Technology), by developing computer algorithm and programming modules that are integrated into their secondary mathematics and science curricula. Students will learn the basics of CS, a foundation of the STEM and ICT workforce, and with the Python language and its extensions for science and engineering, they will gain experience with Matlab-style tools supporting advanced scientific computation.

The project's vision is for high-school students in mathematics and science classes to **learn** the basics of algorithms and programming with examples, exercises, labs, and projects that **engage** and **apply** the concepts they learn in class, as they **create** simulations, **explore** limits, or **solve** problems through algorithms implemented in software. The activities defined within this project are: (a) to develop and test a curriculum-integrated set of programming modules for secondary mathematics and science classes; (b) to teach the teachers the programming language and algorithmic skills they need to lead students successfully through the modules; (c) to support teachers as they use the materials with their students; and (d) to independently evaluate the effect on ICT & STEM instruction, student engagement and attitudes, and career directions.

The target is high-school mathematics and physics classes: teachers will have training developed for them in programming and simulations, and will be supported as they develop and integrate programming modules into their lessons. If each teacher used this strategy with only one class, the 21 teachers supported by this project could impact approximately 500 students annually, on an ongoing basis.

....---== **Intellectual Merit** ==---....

The innovation herein is to merge aspects of computer science into the mathematics and science classroom, as opposed to a traditional approach of separating algorithms and programming by placing them in Computer Science electives. The modules and teacher training provide an important avenue toward broadly infusing scientific programming into high-school STEM instruction. Simulations can provide key visualizations of system dynamics and can allow analysis of complex systems; these simulations possess added power to engage learners, as they were developed by the students themselves. These visually rewarding projects will enrich students' subject experience, provide students with engaging applications of ICT as a means to stimulate interest in both ICT and STEM fields, and better prepare them with tools of the contemporary STEM workforce.

The PI and his organization have a ten-year track record of successfully completing NSF-funded work in interactive visualizations for education, and the PI has a strong background in mathematics and science simulations. Collaboration with the University of Northern Colorado provides graduate-accredited teacher training and ongoing work with summer students, and working with ISTeC at Colorado State University provides avenues for exploring university programs and industrial careers in ICT and STEM.

....---== **Broader Impacts** ==---....

The proposed strategy adds a new component to traditional STEM pedagogy – a computational bridge between theory and experimentation. This strategy adds a programming component where students create simulations of phenomena under study and develop an understanding of numerical simulations as key tools in the contemporary practice of science. Additionally, the professional development created to support this strategy spreads the knowledge and skills of programming and scientific computing broadly across mathematics and science teachers, rather than focusing the technology on the CS teacher.

The developed instructional materials will be freely available through the ITEST Resource Center and the BioGraphix web site. The project experience and classroom case studies will be disseminated through interdisciplinary conferences and workshops, science and education journals, and practitioner forums. The project will involve a diverse mix of secondary schools, thereby encouraging the inclusion of teachers and students from traditionally underrepresented groups.

(1) Project Overview

The strategy embodied within this project is to provide secondary school students with a stimulating introduction to computer science, a cornerstone of ICT (Information and Communication Technology), by integrating computer algorithm and programming modules into mathematics and science classes. The vision is for high-school students to **learn** the basics of algorithms and programming with examples, exercises, labs, and projects, that **engage** and **apply** concepts they are learning in class, as they **create** simulations, **explore** limits, or **solve** problems through computer programming. The generic term *teaching module* is used in this proposal to indicate a curricular unit for the classroom that may range from simple teacher-led examples and exercises, to in-class laboratory sessions, to more involved take-home assignments, or to yet more complex capstone projects.

To achieve this goal, we propose (a) to develop and test curriculum-integrated teaching modules; (b) to teach mathematics and science teachers the algorithmic and programming language skills and simulation concepts needed to guide students successfully through the modules; (c) to support the teachers as they implement the strategy in their classroom; and (d) to assess changes in student attitudes toward ICT and engagement in STEM. The intention is *not* to teach students the full breadth of an introductory computer science class, but to incrementally teach enough so they can complete assignments that complement and extend their studies. In the long term, modules could be developed across all STEM classes, but to provide a sharper focus within the three years of this project, the project scope is to develop modules for mathematics and physics; working at several levels of mathematics (geometry, algebra, calculus) assures that all students would be exposed to the programming language modules, since all students are required to complete several years of mathematics as a graduation requirement.

Students will work with Python, a platform-independent, freely-available, open-source language currently popular in the ICT workplace for a diverse range of uses, from web databases to mobile-phone applications to scientific computing *(e.g., Scheible & Tuulos [2007])*. Python can be run interactively, which makes it easy to learn, and the language and libraries possess an expressive power that allows users to create interesting, useful programs quickly. Through this intervention, we can begin to prepare the next generation of STEM professionals for a computationally intensive workplace and encourage more students to consider STEM-related pursuits for further study and careers.

The viability of this strategy was explored in a high school physics class in the Fall semesters of 2007 and 2008. The goals were to gain experience in bringing this strategy into the classroom instruction, develop a baseline model for its practical implementation, and gather feedback from the student experience. Dr. Polhemus, a Poudre High School physics teacher, and Dr. Crawford designed a sequence of programming lab sessions addressing constant-velocity motion, elastic and inelastic collisions, motion with a constant force, and multi-body orbits. Students worked with Python and the Vpython extensions of Chabay and Sherwood [2007b]. The 100-minute lab sessions were divided about equally into CS instruction, guided programming as a group, and independent activity where student pairs worked on extensions beyond what was done as a group. Dr. Crawford taught the labs, while Dr. Polhemus observed and assisted. Students completed a follow-up survey early the next semester that captured basic feedback on this effort; in replying to an open-ended question, 14 of 14 students said that the programming modules were valuable and should be continued. Example materials and student projects from this class and from previously mentored students are online at: http://www.biographixmedia.com/ITEST

The benefits of this pedagogical strategy are multi-faceted. From an ICT perspective, students learn the core concepts of programming languages and algorithmic thought. From a Workforce Skills perspective, the capability to use tools such as Python represents a key skill for STEM practitioners in coming years, much as using tools such as calculators and spreadsheets are today. From a Career Exposure perspective, the ability to easily develop interactive programs and simulations with visual appeal in Python will open many students' eyes to a new field. From a STEM Instruction perspective, students are introduced to the development and use of algorithmic computations and simulations in science and mathematics, key tools of contemporary science, linking physical experimentation and theoretical models.

To develop this strategy so that it works for a diversity of students, the guiding themes for project activities are:

1. Define, test, and revise the modules: Modules need to be defined within the subject areas that are amenable to straightforward programming, and then placed in a sequence so that the programming language constructs can be developed in a pedagogically appropriate progression. Support materials needed for classroom use will be developed, trialed, and revised with critical inputs received from the teachers and students.
2. Embed the modules in their curricular context: The modules must support the pedagogical sequencing of the subject matter and address requirements of any guiding national, state, or content standards (such as Advanced Placement or International Baccalaureate curricula).
3. Professional development for the teachers: The teachers need a foundation of algorithmic and programming language concepts and skills, a review of concepts associated with the modules, and an understanding of basic principles of discrete-time modeling and stochastic simulations. A three-credit, graduate level course will be designed and delivered in a summer workshop format.
4. Support teachers in their classroom implementations: Teachers need support as they use the modules in their classes. A computer science subject expert will work individually with each teacher to help use the modules with the students in and to troubleshoot issues that may arise. The teachers will document their implementation experiences.
5. Reach a wide student demographic during development: By working across the secondary-school mathematics sequence, we can pilot our work on as diverse a population as the school itself. The districts identified for this project to date include a broad socio-economic and geographic (urban, rural, suburban) spectrum.
6. Measure student attitudes, interest, and engagement: Through independent assessments, quantify the impact of this strategy on STEM and ICT pursuits.

Anticipated outcomes:

- Teachers will develop confidence and skill with algorithms, programming, and simulations.
- Teachers will become skilled in using computational labs, exercises, and projects in their classes.
- Students will be introduced to the core of programming concepts and skills.
- Students and teachers will be exposed to ICT career paths.
- Project workbooks and documentation will support validated examples, exercises, labs, projects for class assignments, and larger ideas for independent study or special projects.
- Materials and approach will enhance the discovery-learning component of STEM curricula.
- Students will develop deeper understandings through defining and programming the algorithms underlying the phenomena they study abstractly in class.
- An external evaluation will assess and document project successes in realizing these outcomes.

In reviewing this proposal with local high-school teachers, one teacher wrote: "*We need teachers who are willing to dive deeper into the promise of technology and start offering students a powerful, useful way to visualize and explore the world, and this grant to assist teachers in learning how to teach students to be able to create and explore simulations and phenomena is a great step in this direction.*"

(2) Project Goals & Objectives

The general goal of this **ITEST Strategy** project is to provide students a stimulating introduction to computer science and ICT by integrating algorithms and programming modules into their STEM courses, and to assess the impact of this strategy. Specific objectives support attaining this overarching goal:

ICT objective: Engage students in programming experiences as a way to stimulate student interest in the field and to build a foundation of programming fundamentals.

- Interactive projects and graphical simulations provide a rich learning environment: the program's results are immediately visible, making debugging easier and the final results more tangible and rewarding. As one student noted, *"The instantaneous visual response to changes in textual programming dramatically increased my interest in programming and, more specifically, modeling."*
- Students work with the core of current programming constructs: control constructs, objects, event handling, and Java-like operator syntax and semantics.
- Students understand simulations as an important class of scientific tools and applications.
- Many students have a preconceived notion that programming and computer science are too difficult and unrewarding; several students noted it was not as hard as they expected.
- Boyer [2006] surveyed several physics classes that implemented programming projects: 45% of the students in one class and 57% in another indicated that their interest in programming had "increased" or "significantly increased" after the experience.

Workforce Objective: Teach students how to use a tool and language that are important within STEM and ICT workplaces and explore related career opportunities.

- Students learn the basics of Python, a tool increasingly used for scientific computation and modeling, and more generally also for software prototyping and rapid development.
- Python is actively used for rapid application development in firms as diverse as Google, Hewett Packard, Industrial Light & Magic, Verizon, and game developers. Students and teachers will attend ISTeC's Annual IS&T High-school Day, where various IS&T (Info Science and Technology) programs within the university, and industrial partners discuss IS&T careers.

Educational Objective: Support and improve the state of mathematics and science instruction by actively engaging students in computational simulations and problem solving.

- Encourage students to explore and develop concepts presented in class; students will learn and retain more through active processing activities than by simply reading or listening attentively.
- Support inquiry-based learning strategies in mathematics and science teaching.
- Simulations can provide key visualizations of system dynamics, and allow analysis of systems beyond one's ability to solve analytically. As a student noted, *"I think I have an overall better understanding of the physics concepts … I was never able to see everything moving."*
- Improve the quality of science laboratory activities, which the National Research Council [2006] concluded were of generally poor quality for most students.

This project is well aligned with the ITEST program goals and objectives. Through the specified activities, we will develop, implement, and evaluate strategies that: (a) encourage high-school students' interest in, and foundation for, ICT and STEM pursuits and careers; and (b) provide teachers with knowledge and resources to provide classroom experiences that opens student ICT/STEM pathways.

(3) Project Design Principles

Chabay and Sherwood [2007a] observe, *"In the past, the physical sciences and engineering could be characterized as involving theory and experiment and the interplay between the two. Now however these disciplines involve theory, experiment, and computation, and the interplay among all three."* They note that computational modeling makes feasible the analysis of situations beyond the analytic abilities of introductory students, and that simple first-order algorithms with sufficiently small step sizes can be run sufficiently fast on today's student computers. Simulations are becoming key tools in the teaching of science and mathematics: bridging physical experimentation and symbolic equations, they provide key visualizations of the dynamics of scientific principles.

Many useful simulations have already been developed for classrooms, in texts and on the web. And in the mathematics teaching, tools such as Geometers Sketchpad and GeoGebra support student creation of visualizations. Our rationale in challenging students to develop simulations from scratch has several additional aspects beyond using simulations as discovery learning tools. One key aspect aligns with the ITEST initiative: **teaching programming** and **enticing students** with their control of the machine. Another aspect is that the projects **provide in-depth engagement** with a concept by realizing it in a working, dynamic artifact. From a learning perspective, students creating their own work helps build enduring conceptual understanding. Students assume ownership of what they create and often recall elements and insights gained from these experiences in their future pursuits. A further noteworthy aspect is the **emphasis on reproducibility** of experimental results, the rationale behind science investigations that are often replicated. In computer science research, simulations are routinely re-programmed so that investigators can both understand what is inside the "black box" and independently verify the integrity of simulations that we depend upon.

Using programming languages, understanding advanced computations, and creating simulations are **crucial STEM workforce skills**. In discussing a mathematical software package from the University of Washington, William Stein [2007] notes: "*Commercial programs don't always reveal how the calculations are performed. This means that other mathematicians can't scrutinize the code to see how a computer-based calculation arrived at a result. Not being able to check the code of a computer-based calculation is like not publishing proofs for a mathematical theorem … It's ludicrous.*"

Fangohr [2004] divides solving a programming problem into two phases: (a) finding an algorithmic route to the solution, then (b) implementing that algorithm in a programming language. The first phase is important for actively exploring and understanding the concept at hand; the second phase is more focused within the realm of computing. Fangohr compares the languages C, Matlab, and Python as possible implementation languages. In focusing his pedagogy on the first phase and trying to streamline the second, he selects Python since it has functionality well matched to the problem solutions. In addition, Python is a credible and emerging language within STEM and ICT workplaces; this language will help build essential knowledge, skills, and dispositions for participation in that workforce.

Graphical, highly visual programming projects entice students and encourage them forward in computer studies. As Astrachan and Rodger [1998] note, *"animations and interactive graphics generate student interest and enthusiasm which usually translates into better comprehension and mastery of the material in our courses. In addition, the visual component of the animations offers another dimension that assists in debugging, a task with which students have great difficulty and one we struggle to teach."*

A Prototypical Example:

> *First, a caveat: This section is presented to provide, by example, some depth into what it means to develop a sequence of modules embedded in a curriculum. The proposed project is broader in scope than this one example as it will be addressing several areas of mathematics as well as physics classes at different levels.*

```
ball.x = ball.x + n
if ball.x > 400 :
    n = -n
if ball.x < 0 :
    n = -n
```

One quick lesson: By iterating over these few lines of code at the right, a student can simulate a billiard ball moving horizontally and bouncing between bumpers on a 400-pixel-wide table. By merely extending to **y** what's been done with **x**, the ball will now move in two dimensions and bounce off bumpers as they (ideally) would. Observation of the actions generated by this one simple piece of code can lead to conceptually deep investigations and discussions of vector motion and angles of reflection, depending on a teacher's instructional goals. And so, with a minimal amount of programming overhead, a student creates a visually reinforcing simulation that can lead to deeper exploration of the subject. Other examples in action and the simplicity of their code are online at: http://www.biographixmedia.com/ITEST .

What follows in this sub-section is a model of how projects may be integrated into a sequence of physics lab sessions. The programming lab sessions are a double-length class period (typical for science labs) and students either produce a simple program or modify an existing program in that time. Over the course of the term, some of the programs will become quite sophisticated through repeated additions and refinements. The projects described below show a sample progression towards a sophisticated program for simulating wave motion in a solid.

1. One dimensional motion: The primary goal of this initial lab is to introduce the programming environment and produce some visible result. The goal is to make balls that move in one dimension, bouncing off of the walls of a box. The students vary the speed of the ball, the size of the box and the time step. Questions guide the explorations, e.g., *"Count the number of times the ball crosses the box in 30 seconds. How many crossings will it make in ten seconds if the speed is tripled? (Predict and test.)"*

2. Two dimensional motion: The previous program is modified for two dimensions. Students set up initial conditions to arrange the balls in some shape moving with a constant velocity and see how the shape is modified by collisions with the walls, and they explore the vector components of velocity.

3. Motion with a constant force: Students modify their previous program by adding a constant force that will change the velocity of the objects between each time step. With a downward force (gravity), students complete some projectile experiments, e.g., *"Launch balls with the same speed but at different angles. Which angle produces the greatest range?"* Students use screenshots to support their conclusions.

4. Basic orbits: Students add code to make the force position-dependent, using Newton's universal law of gravitation. Scaled Earth and Sun data should produce a nearly circular orbit. Students modify the data to explore orbital shapes, and investigate the relationship between a circular orbit's radius and period.

5. Multi-body orbits: Students modify their orbit program to make the forces dependent on the relative positions of objects, first for two objects and then for three. This is the first problem they implement that they cannot study analytically. Students should create a system with a Sun and two planets, a Sun, Earth and Moon system, a planet orbiting a binary star and a system with three objects of similar mass.

6. Wave motion: In this lesson, the gravitational force is replaced by a spring force. Students should first experiment with two and then three objects connected by springs. This stretchy string of objects will put on quite a show bouncing about in their box. A stretchy string of ten objects will allow them to observe both transverse and longitudinal waves in the string.

This sequence of six labs would fit well into the mechanics unit of any introductory physics class. The appropriate location of each lab is shown for the AP curriculum [College Board 2005], the International Baccalaureate [2001] program, and for the AP physics text by Wilson and Buffa [2003]:

Labs	A.P. Topics	I.B. Topics	Wilson and Buffa
1. One dimensional motion	I.A.1	Topic 2.1	I.2
2. Two dimensional motion	I.A.2	Topic 2.2	I.3
3. Motion with a constant force	I.B	Option A.1	I.4
4. Basic orbits	I.F.4	Option A.2	I.7.5
5. Multi-body orbits	I.F.5	Option A.3	I.7.6
6. Wave motion	IV.A	Topic 4	III

These all directly address Colorado State Science Standard 2.9 *(Physical Science, Newton's Three Laws of Motion: explain the relationship between the forces acting on an object, the object's mass, and changes in its motion)*, and the associated National Science Education Content Standard B *(Physical science, motion and forces)*. The orbit labs also address Colorado State Science Standard 4.14 *(Earth and*

Space Science, Gravity governs the motions observed in the solar system and beyond Earth and other objects in space) and the associated National Education Content Standard D *(Earth and Space Science, Origin and evolution of the Earth system and Origin and evolution of the universe)*. [All referenced in Colorado Department of Education, 2007].

In their initial collaboration, Drs. Polhemus and Crawford implemented labs along the above outline, which, qualitatively, had a positive effect on student interest and engagement. Key aspects of the funding for this proposed project is to develop and try out similar sequences of modules at several levels of secondary school mathematics, and provide a rigorous evaluation of the modules in practice. Since all students within a district are required to take several years of mathematics, they would all be exposed to the basics of algorithmic thinking and programming languages sometime during secondary schooling.

(4) Project Description & Timeline

This project brings together participants from several disciplines to effectively develop the module sequences, train the teachers, support their classroom implementations, and measure the impact on the students. At the core though is a professional development initiative for teachers to transform aspects of their classroom pedagogy.

<u>What it looks like, from a secondary-school teacher participant's perspective</u>:

A cohort of teachers takes a nine-day summer workshop, with the overall goal of preparing the teachers to implement the computational modules with their students in the following academic year. The workshop covers: design of algorithms, programming and debugging with Python, subject matter background, principles and practice of dynamic and stochastic simulations, and the integration of simulation projects into their mathematics and science classes. Teachers will use the computational modules with their students during the following school year. They will be supported by Computer Science teachers who will mentor the teachers, assist in their classrooms, observe the projects in practice, and troubleshoot the hardware and software. This interaction between teachers will benefit both. The high-school teachers often teach in isolation, and having a professional in the classroom will be a valuable experience and resource for them. For the CS faculty, it provides them an early connection with potential future students. UNC will offer three units of graduate-level credit after completing both the workshop and the implementation of the projects in their classes.

Teachers will also be supported through an online community, including email lists, bulletin boards, discussion groups, or other collaboration tools. Teacher participants will be selected so that represented schools have at least two teachers from each, and the paired teachers will be able to provide each other mutual assistance throughout the academic year.

The teachers will be invited back to UNC the following summer for two days. This will provide an opportunity for the teachers to share their reflections, provide collective feedback to the project team, convey experiential advice to the next cohort of teachers, and expand their professional network.

PROJECT PARTICIPANTS – *who does what:*

<u>Two Cohorts of Secondary Mathematics and Science Teachers</u>: The first teacher cohort (<u>TC1</u>) will work with the initial module development. Six teachers are anticipated for this cohort. During project year 1, these teachers will identify places where modules would support/improve their pedagogy and work with the CS teachers and instructional designers to create a sequence of modules and integrate them into their classes. They will be the participants in the first summer's teacher workshop, and will provide formative feedback for the workshop's overall design. They will work with the modules and help define and create the necessary support materials for their classes, and use the modules with their students in the following academic year. It is not necessary that they have programming experience; they are needed for their classroom experience within their discipline.

The second teacher cohort (<u>TC2</u>) will follow the <u>participant's perspective</u> sketched out above. These teachers will be pilot testing the overall project strategy and its class modules. They will participate in a summer teacher workshop, use the modules with their students in the following academic year, and report on their implementation experiences. Fifteen teachers are anticipated for this second cohort. As with the TC1s, these teachers will be selected for their classroom experience, from among those who make a difference with their peers. With the help of the project advisory board, we will select a group balanced with respect to gender, ethnicity, years teaching experience, and geographical location (urban, rural, suburban). Lori Reinsvold (UNC) has contacts with many of the high-school science and mathematics coordinators across the state, and Kate Canine (PSD) is a regional coordinator for the Colorado Council of Teachers of Mathematics; they will both be able to identify and recruit participants within the region.

To date, four school districts from the metro Denver and northern Colorado region have expressed interest and support for this work. These districts represent a diverse demographic (detailed in the later section, "Collaborative Relationships"). From just two of these districts, nine teachers, from seventh grade mathematics and science through high school calculus and physics, have already volunteered to participate.

The CS Team (CST): The PI, with Elizabeth Boese from Colorado State University, and Victoria Eisele from Front Range Community College, compose this team. Ms. Boese and Ms. Eisele both have extensive experience with teaching introductory Computer Science. Together with the PI and the instructional designers, they will: (1) help identify a sequence of places in the curriculum for examples, exercises, or projects; (2) organize the CS pedagogy needed to sequence those modules; (3) team-teach (as necessary) in the secondary school mathematics or science class; and (4) support the teachers as they use the modules with their students.

Their commitment, over the course of one-semester, would be to: organize/teach/support 8-9 lab-length classes in local HS classes (over a period of 18 weeks, this is basically one class every other week). Doing this for four classes is roughly a half-day, twice weekly commitment on site at the high school; this is equivalent in commitment to teaching a one-semester college class.

The Instructional Design & Development Team (IDDT): They will guide instructional approach of the project overall and of the pairs of secondary and CS teachers as the modules are developed across a course. Dr. Paul Kennedy, leading the direction for mathematics, brings years of experience and a deep understanding of overall curriculum design, having co-authored a dozen secondary school mathematics texts for the publisher Holt. Using an action research consultative model, Dave Young will help teachers identify the segments of their curriculum most in need of improvement and target those areas for which the "student-centered programming" strategy would appear to hold the most promise as an effective intervention. Dr. Polhemus will guide the overall strategy for physics.

Evaluation Team (ET): Evaluation researchers from Colorado State University (CSU) and the University of Northern Colorado (UNC) will provide external and independent formative and summative assessments of the project, the teacher workshop, the curriculum modules, and the strategy's effect on student attitudes and engagement. The lead evaluator will be Dr. Albright from the R&D Center and School of Education at CSU. He has served as the evaluator for many federally funded projects and he has special expertise in the assessment of innovative teaching practices in STEM classes. As lead evaluator, Dr. Albright will direct all evaluation activities, and will be responsible for the teacher participant and project leadership team components of the evaluation. Andrea Weinberg, an advanced PhD student at CSU in research methods, will be responsible for the evaluation research related to student engagement and she will assist Dr. Albright and the UNC team members with the student follow-up study. From UNC, Lori Reinsvold and one graduate research assistant (GRA) will assume primary responsibility for the preparation, administration, analysis, and reporting of the computer science student attitude survey.

Advisory Board: The advisory board will review the project annually, assist in the selection of teacher participants, and help facilitate the project's collaborations and directions across its three years. Dr.

Carole Basile, co-PI of the NSF-funded Rocky Mountain Middle School Math and Science Partnership project, brings a wealth of connections into our regional school districts. Dr. Wendy Adams, as Director of Research for the Science Education Initiative and co-director of the Physics Education Technology Project at the University of Colorado, Boulder, brings expertise in the design, creation, and evaluation of simulations in the science classroom. Dr. Karen Kaminski, in addition to her strong background in instructional design and development, is on the Education Advisory Committee of the Information Science & Technology Center (ISTeC) at Colorado State University. The project will look to Dr. Kaminski as a liaison to the ISTeC industrial advisors, who would in turn work with students and teachers to identify opportunities for career exploration and mentoring and for interactions with STEM professionals active in the field. Dr. Terry Scott, a professor of Computer Science at UNC, will coordinate the teaching of the summer workshops for credit through UNC. Representatives from the school districts participating in the project will be invited to participate as advisors, as well.

The MAST Institute at UNC: UNC's Mathematics and Science Teaching (MAST) Institute routinely coordinates and provides graduate-level education courses and professional development opportunities for high-school STEM teachers. The MAST institute will provide logistic support and facilities, and the instruction will be developed and delivered by the CS Team. UNC will award graduate credit for the participants. Additionally, UNC's Frontiers of Science Institute (FSI) will provide opportunities for using the modules with summer students and for the teachers to work with a pool of students on the modules.

PROJECT TIMELINE – *when and where – assuming a September 2009 start, through August 2012*.

Sept 2009 to May 2010	Commit 6 teachers for TC1 TC1 / CST / IDDT identify curricular places for modules and prototypes them CS team guest teaches modules in the TC1 classrooms AY1 schools: solicit donations, configure equipment
Summer 2010	1st Workshop at UNC for TC1s; modules used with FSI summer students. Embed final set of modules into curriculum (TC1 / CST / IDDT)
9/10 to 5/11: Academic Year 1 (AY1) **Prototype Phase**	TC1s use programming modules in their classrooms CS team assists / monitors / mentors on site *(1 day every other week per TC1)* Collaboration & support through blogs, website, collective debriefing Pilot assessment of teachers and students *(strong formative component)* Commit 15 second cohort teachers (TC2s) for summer 2011 workshop and AY2 AY2 schools: configure equipment; solicit donations.
Summer 2011	Feedback session: TC1s and their AY1 class experience 2nd Workshop at UNC for TC2s - TC1s mentor TC2s; modules used with FSI students. TC2s & TC1s revise support materials for classroom use Write-up of preliminary status and results for conferences and presentations
9/11 to 5/12: Academic Year 2 (AY2) **Pilot Testing**	TC2s and TC1s (21 in total) use modules and support materials in classes CS team assists / monitors / mentors on site *(1 day every other week per TC1 & TC2)* Collaboration & support through blogs, website, collective debriefing Full scale assessment across ~500 students and 21 teachers *(formative & summative)*
Summer 2012	All 21 teachers (TC2s & TC1s), CST, and IDDT participate in a 2-day follow-up session, for collective feedback, future directions & needs

	Follow-up with AY1 students Analyze student and teacher data; document results Summarize results; submit to academic journals and practitioner forums.

(5) Collaborative Relationships

Poudre School District (PSD), Fort Collins, CO, Greeley/Evans School District, Greeley, CO, Aurora School District, Aurora, CO, and Mapleton School District, Mapleton, CO

Initial pilot versions of the programming modules will be defined, implemented, and sequenced in collaboration with mathematics and physics teachers from these districts. These districts were chosen because they are near enough for us to provide close interaction and support for the teachers, and we have established working relationships with them. From two of these four districts, nine teachers have volunteered for this project; from this group we can commit the first cohort of six teachers immediately on approval of this project proposal.

Poudre School District is a small city district in northern Colorado. This is the home district for CSU and many of the project collaborators with whom there are strong working relationships. *(Letter of Support attached).* Mapleton, a high-need district in the urban corridor of the Denver metro area, has received supplementary funding through a Rocky Mountain MSP (coordinated through our advisor Carole Basile) to enhance teacher leadership through a Master Teacher Program. From this group, six teachers have asked to participate in this project. Greeley/Evans is a high-need district with an under-served, rural population of Colorado. *(Letter of Support attached).* Aurora Public Schools (metro Denver) have begun a Galaxy Initiative, which is to provide a focus for STEM instruction and STEM career preparation. They are partnering closely with Raytheon to provide students insights into their high-tech careers. *(Letter of Support attached).*

University of Northern Colorado, Greeley, CO

Through a sub-award to the University of Northern Colorado (UNC), we can bring our program to high-school teachers and provide a base of students with whom the teachers can initially work. UNC will award graduate credit to the participants. UNC's Frontiers of Science Institute (FSI) will provide opportunities for using the modules with summer students and for the teachers to observe a pool of students working with the modules. UNC's Frontiers of Science Institute (FSI) is a 50-year-old residential program dedicated to boosting the scientific aspirations and achievement levels of Colorado's high-school juniors and seniors. One strand (out of four) of their summer studies will be devoted to learning programming with Python in a STEM context. This programming class will be taught by the project CS faculty team, providing a chance to work through the modules with a student audience before the academic year.

Equipment Support

Since ITEST funding does not support equipment purchases, we are looking to other avenues of support in this regard. The Metro Denver WIRED Initiative (Workforce Innovation in Regional Economic Development), a partnership among industry, workforce, education, and economic development in the nine-county Metro Denver region, is about to release an RFP that will support spending on equipment but not personnel, which is an ideal complement to this ITEST proposal. A key goal of WIRED is strengthening the talent pipeline at all levels to produce a workforce skilled in STEM for our region's fastest growing, high-wage, industries – aerospace, bioscience, energy, and IT software. In addition, once an approval of the project proposal is given, IBM and HP will be approached, both supporters of our educational community since they have a local presence, and so will Apple, which is once again starting to provide equipment in support of secondary STEM. Should none of those options work out, BioGraphix (the PI's affiliation) will commit to providing one laptop per teacher participant, at a minimum, and as resources permit, develop mobile laptop teaching environments for participating schools.

(6) Key Personnel Qualifications

Stewart Crawford, PI, PhD (Computer Science), brings expertise in dynamic and stochastic simulations, computer science, and CS classroom teaching. He will work with the TC1 teachers to define programming modules, pilot the modules with FSI summer students, organize and teach the summer teacher workshops, prepare support materials for classroom, and assist high-school teachers in their classroom activities (3 academic year months, 3 months summer)

Leonard Albright, PhD (Education at CSU), has served as an external evaluator for NSF-funded projects over the past eight years, and teaches a graduate-level program evaluation course at Colorado State University. He is presently the lead evaluator on two NSF projects concerned with the integration of innovation into science and mathematics curricula and impacts on teachers and students. He will lead the external formative and summative evaluations for this project. (Consultant)

Paul Kennedy, PhD (Mathematics Education at CSU), has co-authored a dozen textbooks for Algebra and Geometry. He has a broad view of the secondary school mathematics curricula and is connected to publishers. He is also active in professional development summer programs for teachers. He will consult on the instructional design of the mathematics modules and the summer teacher workshop. (Consultant)

Elizabeth Boese teaches introductory CS classes at CSU. She has published an introductory textbook on programming with an emphasis on enticing students with highly visual exercises. She will assist the high-school teachers in their classroom activities, and participate in the design and delivery of the summer teacher workshop. (6 academic year weeks, 2 weeks summer)

Victoria Eisele teaches CS classes at Front Range Community College. She has developed manipulatives to help understand the basic concepts of programming. She will assist the high-school teachers in their classroom activities, and participate in the design and delivery of the summer teacher workshop. (6 academic year weeks, 2 weeks summer)

Gavin Polhemus, PhD (Physics), teaches AP and International Baccalaureate Physics at Poudre High-school. He is interested in improving mathematics and science instruction, and will test the proposed labs in his physics classes and coordinate similar activities with his peers in the mathematics program. (1 months in each of the first two years)

David Young has designed and delivered classroom, online, and mixed-mode instruction and training at the University of Colorado-Denver for K-12 teachers and has studied integration of technology into their teaching. David will bring his instructional design expertise to creation of the module sequences. He also has experience in supporting online Communities of Practice, which he will organize for the secondary school teachers.

Lori Reinsvold, (UNC - Director of the Technology Literacy Center in the MAST Institute), has over 20 years experience in professional development for K-12 teachers, and in their use and integration of technology into their classes. Currently completing her doctorate in educational psychology, she will provide administrative support for recruiting teachers, technical assistance to staff, teachers, and students during the project, and assist in the project's summative evaluation. (1 month per year)

Lori Ball, PI for the UNC sub-award (UNC-FSI Program Administrator, Director LPSEF), has supervised summer training activities for teachers, and high-school students in the Frontiers of Science Institute. She coordinates the annual Longs Peak Science and Engineering Fair with 140 students and 16 schools. Lori runs the logistics for the teacher workshops and working with the FSI students. (2 months per year)

(7) Anticipated Results

One key outcome of this project will be classroom resources and a programming technology grounded in practice, embedded in the progression of a curriculum, consistent with applicable local, state, and national educational standards, and supported through evidence-based results. In the near-term, teachers will be able to use Python in their classes after their summer workshop, and students will be able to solve computational problems with Python after having it in class. By the end of this three-year project: class resources will be ready for general use (examples, case studies, administrative guide); a supporting web site will be generally available (with class resources, a teacher blog, example work, and project contacts); and teacher professional development workshop materials will be ready (including a workbook and reference material).

Both students and teachers will be involved in measuring the effect of our overall project strategy. Another key outcome will be research findings about the implementation and impact of this programming technology and the associated educational resources on student attitudes, interests, and ongoing involvement in ICT or STEM studies. Details about the data collected and assessing progress toward our goals follow in the Evaluation section.

In the long-term, we would be interested in the college majors selected by our students (2-4 years later), their initial career choice (6+ year later), and how prepared they felt compared to their peers in using computational tools. While these choices and perceptions are beyond the time-span of this project, we will collect and archive participant contact information so that, should the opportunity be available in the future, we can contact and follow-up with the students and teachers involved in this project.

(8) Evaluation

In structuring the evaluation plan, some key issues need to be addressed:

- How effective are the materials to be used in the mathematics and physics classes?
- How well did the summer workshop prepare the teachers for their classroom use of the simulation projects?
- How well did the academic year proceed, when trying to do this with students in classes?
- To what extent are student attitudes toward computer science improved as a result of this instruction?
- Does student engagement in STEM courses increase while participating in IT simulations?
- To what extent are students pursuing additional study and careers in STEM areas?
- To what extent are teachers adopting these IT simulations for ongoing instructional use?
- What are sustainable outcomes of this project?

The conceptual framework for the evaluation of this project is driven by these issues, and is organized using important evaluation perspectives, best explicated in the standards for program evaluation promulgated by the Joint Committee on Standards for Educational Evaluation [Sanders 1994; Sanders & Sullins, 2006]. These standards relate to the utility, feasibility, propriety, and accuracy of the educational intervention being evaluated, and of the processes used in the evaluation efforts. The specific design of the evaluation is delineated in Table 1. Collectively these formative and summative evaluation questions will address the major project goals of the project, including those related to successful integration of programmed simulations and models into STEM curricula and the impacts on student academic growth and career interests.

Table 1: Evaluation Design

Evaluation Question(s)	Evaluation Function	Type of Instrumentation	Data Collection Activity	Timeline
1. How well do the programming simulations align with math and	Formative; Addresses	Teacher Online Feedback Form	Teachers will be given simulation activities and coding	During and after summer training

Evaluation Question(s)	Evaluation Function	Type of Instrumentation	Data Collection Activity	Timeline
science standards and support their current curricula?	Accuracy evaluation standard		sheets that ask for their ratings.	workshops
2. How feasible for classroom use do teachers believe the simulations to be? How well did the workshops communicate the content and pedagogy associated with the project materials?	Formative; Addresses Feasibility evaluation standard	Teacher Online Feedback Form Field notes taken during classroom observations.	Collect evaluative judgments from teacher workshop participants.	During and after teachers workshop, and after they have used the simulations in their classes.
3. What concerns do teachers express about implementing the computer simulations in their classrooms? How do these concerns vary by teacher characteristics {e.g. grade level, academic discipline, course(s) taught}?	Formative; Addresses Propriety evaluation standard	Teacher Online Feedback Form Follow-up focus group interviews.	Teachers complete a module feedback form. After using the class materials, evaluative feedback will also be directly solicited.	During and after each Teachers Workshop.
4. How do teachers assess the simulation activities? How do students respond to these activities?	Formative & Summative; Addresses Utility evaluation standards		On-site & focus group Interviews with teachers & selected students following their use.	During and after each Teachers Workshop meeting.
5. How does student interest in computer science change as a result of exposure to simulation activities? To what extent are students pursuing additional IT coursework?	Formative & Summative; Addresses Utility evaluation standards	Student attitudes toward computer science survey Teacher and student interviews - telephone and/or direct on-site interviews	Pre-post test comparison group design Open-ended dialog with each teacher following their class use of the materials. Review of student achievement records with teachers.	Before & after Academic Years 1 and 2, when students used the sequence of modules.
6. To what extent does exposure to simulation activities increase student engagement in math and science?	Formative & Summative; Addresses Utility, Feasibility & Propriety	Adapted version of the Student Classroom Engagement Questionnaire Use of the Student	Pretest-posttest design Teacher reporting of students' engagement prior to, and during module	2-4 weeks prior to module instruction & post module instruction

Evaluation Question(s)	Evaluation Function	Type of Instrumentation	Data Collection Activity	Timeline
	evaluation standards	Engagement Checklist (SEC) Use of Student Collective Engagement(SEC) instrument	instruction Evaluator observation & recording of student engagement in classrooms	2-4 weeks prior to, and post module instruction During classroom observations
7. What appears to be the longer term lasting effects of this project?	Formative & Summative; Addresses Utility, Feasibility, & Propriety standards	Focus group sessions with teachers.	Project review session, keying on accomplishments, areas that needed improvement, and enduring processes and outcomes that occurred.	During last quarter of the second and third project years.

As indicated in Table 1, multiple data collection methods will be used to obtain teacher, student, and project staff critique of project activities and outcomes. For the participating prototype and pilot teachers, we will employ four strategies (i.e. workshop assessments, module assessment forms during workshop and pilot-testing, post-workshop focus group sessions, and direct classroom observations), all of which will provide important information about the feasibility of the simulation modules, the effectiveness of the workshop training program, and the quality of the pilot-test implementation practices.

Three data collection strategies will be used with students. These are:

(i) Student attitudes toward computer science. First, in order to determine the effects of the project on student attitudes, we will adapt the student attitudes toward computer science instrument that has been developed by Moskal, et al., (2007) and is presently being tested with high school students through an NSF grant (Award # 0511940). We will use this instrument on a pre-post test basis with participating students and use a comparison group design to determine student attitudinal changes.

(ii) Student classroom engagement. Since student motivation is at the heart of teaching and learning (Appleton, et al., 2008), the use of engagement as a student outcome measure will be examined as our second student data collection strategy. Student engagement reflects active student involvement, which is an observable pathway to examine motivational processes (e.g., Furrer & Skinner, 2003), including "intrinsically motivated behavior, self determined extrinsic motivation, work orientation, and mastery motivation" (Reeve, et al., 2004, p147). Engagement has been shown to have influential and positive relationships to student feelings of teacher support (Osterman, 1998), affective connections with school (Furrer & Skinner, 2003), school persistence (Finn & Rock, 1997), academic achievement (eg. Finn, 1993; Skinner, et al., 1998; Voelkl 1995), and school completion (Connell, et al., 1994).

We will use three methods to assess student engagement. First, students in our study will complete the Student Classroom Engagement Questionnaire (SCEQ), which is an adapted version of Fredericks et al.'s (2003) student engagement instrument. Psychometric properties for each of the constructs (behavioral, emotional, and cognitive engagement) were verified (α = .72-.82). Minor adaptations were made to focus on specific classroom engagement rather than the more general school engagement. This questionnaire will be completed on two occasions: once 2-4 weeks prior to module use, and once immediately following completion of the module. After the prototype phase, the SCEQ will be revised as needed for the final pilot testing phase. Second, teachers will complete a Student Engagement Checklist (SEC) twice:

once 2-4 weeks prior to the use of the module, and again immediately following module completion. For each student the teacher will indicate their responses to four statements using a 1 to 5 Likert scale. The items, based on the SCEQ, were constructed to provide a concise measure of teacher perceptions of student behavior, emotional, and cognitive engagement. When the checklist is completed prior to the module, teachers will be instructed to consider each student based on their experiences with students during the entire school year. Then, teachers will be asked to take into account the student's engagement during the module implementation period only. Our third method for assessing student engagement will be through classroom observations. The evaluator will use a Student Collective Engagement observation instrument (SCE) assembled by Reeve et al. (2002) based on five earlier studies. The SCE consists of five Likert-type items intended to provide a measure of overall classroom involvement and personal responsibility for learning. Data on each of these five items will be collected 5 minutes after the class has begun and again after each subsequent 10 minute period. At these observation points, the evaluator will take into account 1) the proportion of students exhibiting each behavior and 2) the intensity of the behavior. These items will be combined into one overall engagement score, as was done in prior studies. In addition, unstructured field notes of classroom dynamics and general observations will be maintained. The quantitative and qualitative observations combined will help yield a comprehensive view of the classroom context and student engagement. Observations will occur at all sites during the prototype phase and at least half of the pilot test sites.

(iii) Student participation in STEM. Our third student data collection strategy will be a follow-up of students who participated in the project during project year 1. Here we want to check, through academic records review and student interviews, the impact of the project on further pursuit of STEM coursework and career direction.

Our third stakeholder data collection activity will be centered on teachers and core project leaders. In addition to the ongoing participation in teacher workshops and project events, we will conduct two focus group sessions with teachers & core project staff members to identify project strengths, weaknesses, and elements that have enduring qualities. Both are intended to be project reflection sessions. The first session, more formative in design, will be conducted mid-point during the 2nd project year and will look critically at project progress to date. The second will occur near the end of the project and will place a stronger emphasis on project outcomes, sustainability components, and future directions.

In summary, the external evaluation of this project will focus primarily on the quality, integrity, timeliness, and utility of the modules, module user workshops, teacher guides, project materials in instructional settings, and impacts on student attitudes, motivation and career direction.

(9) Dissemination and Sustainability

There will be many common issues that the participating teachers will face. They are a community of practice (CoP), and to maximize the power that participating teachers can derive from this CoP, tools such as Tapped In (http://tappedin.org/tappedin) will be utilized to facilitate the activities of this community.

The online CoP will benefit the project in several dimensions:

- It will be a repository for the module materials and plans, both in-progress and completed.
- It will allow teachers to regularly share experiences and reflect on those experiences as they develop teaching modules and integrate them into their instruction.
- It will promote teacher-to-teacher interaction for problem-solving as instructional or programming obstacles are encountered, or during the development of teaching modules.
- It will provide a way to monitor progress of the geographically diverse teacher cohorts in real-time and intervene (either online or in-person) as necessary.
- It will establish a mode of operation that will allow the project to scale and sustain over time.

Project reports and the instructional materials will be freely available through the BioGraphix web site, the ITEST Resource Center, and the Computer Science Teachers Association web repository.

Additionally, a workbook / textbook for the teacher training will be prepared for publication. Dissemination of the project ideas and results will be made through interdisciplinary conferences and workshops. A three-tiered results dissemination process, using three different communications products, will be employed to inform interested stakeholders of the findings of this project:

- Practice briefs: A short one-page summary of findings for each module targeted to specific stakeholders (e.g., teachers or administrators), for easy viewing and access.
- Activity summaries: These provide more detail on the modules for those who seek a thorough description of the project, the module, and associated teacher-tested comments on how to foster student learning with the module. Each summary will be submitted for publication.
- A technical report: The third communications vehicle will be a full technical report of the project, including detail about the modules and the outcomes of project evaluation.

Results will be distributed regionally through the Colorado Science Education Network and the Colorado Council of Teachers of Mathematics. In addition, presentations on the project will be offered to national STEM conferences including the National Science Teachers Association (NSTA) and National Council of Teachers of Mathematics (NCTM). Funds are budgeted to send participants to national conferences, two of the participating teachers and a CS team teacher, to present and support this project in tandem.

This work will be sustained in several ways after the three years of this proposal:

- UNC will incorporate the teacher workshop as a graduate course offering in their MA in Natural Science degree, adding a needed computer application course to their STEM offerings and bringing the strategy to new teachers every year.
- A workbook / textbook will make this course a possibility within other institutions.
- The existing 21 lead and pilot teachers will have a firm grasp of this strategy by the end of this project, and with demonstrated success, they will be motivated to continue with their students.
- The FSI program at UNC will have incorporated a “Programming for STEM” strand as an integral part of their program, that will reach promising high-school students every summer.
- With the comprehensive evaluation plan of this project, we hope to demonstrate the success of our strategy in a local setting, thus laying a foundation for potential future funding, through NSF or state education agencies, to expand our integrated CS & STEM program.

(10) Results from Prior NSF Support

The PI, Dr. Crawford, successfully completed previous work funded under an SBIR Phase I grant, Interactive Anatomy for Grade 7-12 Students and Teachers (NSF Award Number: 0340214, $97,620 for the period 1/1/04 – 6/30/04). The PI was Tom McCracken, and Dr. Crawford was the project manager and developer. The teaming with Dr Albright as lead evaluator worked well in that Phase I grant, and provides a foundation for our continuing collaborations.

The Phase I research was successful in meeting its SBIR-defined goal: proving the feasibility of an educational strategy that can lead high-school students to interact with the full, detailed Visible Human data set. We developed a series of demonstration modules and then evaluated these modules with a group of teachers at a workshop organized at the University of Arkansas Medical Sciences (UAMS) Center.

The Findings section of the Phase I evaluation report [Albright 2004] details the reviewing teachers’ responses. Overall, the teacher workshop was highly valued by the participants. On a 5-point Likert scale, 8 of 9 gave it the highest rating, while the other participant gave it the next-to-highest rating. They noted that the content effectively addressed their state and national standards in this area. The software was considered user-friendly and provided a wealth of rich instructional information upon which to draw from and to attract student interest. They also remarked positively about the quality of instructional materials provided, and the effective teaching and listening style of the instructor, Dr. Crawford.

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UNIVERSITY *of*
NORTHERN COLORADO

MAST Institute
Mathematics and Science Teaching Institute

February 13, 2009

Stewart Crawford
Director of Technology for BioGraphix, LLC

Dr. Crawford:

The Mathematics and Science Teaching (MAST) Institute at the University of Northern Colorado (UNC) is pleased to support and collaborate on Dr. Crawford's proposed project, *Improving Secondary Mathematics and Science with Integrated Programming Experiences*. Over the past twenty-years the MAST Institute has developed STEM opportunities for science and mathematics K-12 teachers. We have strong partnerships with K-12 schools in Colorado, so we have the ability to recruit science and math teachers who work with diverse student populations. We currently coordinate a MA in Natural Science, K-12 Teaching Emphasis degree for many science teachers throughout our region. Dr. Crawford's computer programming class that he will develop and deliver on our campus will be incorporated as a graduate course offering in our MA in Natural Science degree. This work will add a needed computer application course to our STEM offerings and ensure the sustainability of the project's work.

I fully support Lori Ball's (Program Administrator for the Frontiers of Science (FSI)) work with this project. She will ensure that teachers and students who attend the summer programs on our campus have the appropriate facilities to successfully participate. She will work to insure the STEM Programming session that is developed for FSI students is supported by UNC facilities. She also will organize and coordinate FSI's summer program so this computer course can be included in future FSI program offerings.

I also support Lori Reinsvold's work to recruit teachers through a statewide science education leadership group, Colorado Science Education Network. She also has contacts with many of the science and math high school coordinators in schools across the state. As Director of the Technology Literacy Center within MAST, Lori has the ability to provide technical support to the project's summer activities on UNC's campus. Because of Lori's research experiences, she is very capable of insuring that all Human Subjects and IRB proposals for the evaluation work of this project are reviewed and accepted. She will work with the project evaluation team to collect and analyze data and present the project findings at regional and national STEM education conferences.

I fully support this proposal, *Improving Secondary Mathematics and Science with Integrated Programming Experiences*, and commit the MAST Institute staff and UNC facilities as described in the proposal. If I can provide additional information, please email me (steven.anderson@unco.edu).

Sincerely,

Dr. Steven Anderson, PhD
Director of the MAST Institute
University of Northern Colorado

POUDRE SCHOOL DISTRICT

February 12, 2009

Stewart Crawford, Ph.D.
Director of Technology for BioGraphix, LLC
PO Box 721, Fort Collins, CO 80522

Dear Dr. Crawford,

Poudre School District eagerly supports your NSF ITEST proposal, ***Improving Secondary Mathematics and Science with Integrated Programming Experiences.***

The computer programming and simulation labs you taught with Dr. Polhemus during the last two Fall semesters in his Physics labs were well received by his students. Thank you for taking the time to work with our students to make that happen. The general idea of integrating programming work into our existing math and science classes has the potential to both further the students' interest in their classes and expose them to computer programming, as well.

Our district curriculum coordinators, Kate Canine in Math and Lisa Pitot in Science, reviewed your work plan and heartily support your proposal. In addition, Poudre School District as a whole is committed to improving and expanding STEM education.

Kate and Lisa will work with you to identify lead teachers who can help both develop the concepts within the constraints of our guiding standards and bring it into the classroom. Already, Gavin Polhemus is looking forward to continuing your work with Physics classes, and Scott Durkin is eager to work with you in Middle School Math classes. As a regional coordinator for the Colorado Council of Teachers of Mathematics, Kate will be able to help disseminate the results of this work and to identify and help recruit other participant teachers and schools within the Northern Colorado region.

As part of the initiative to improve student achievement, I am excited about the potential that your proposal has to integrate computer programming in our Math and Science classes.

Sincerely,

Chuck DeWayne
Director of Curriculum, Instruction and Assessment
Poudre School District

Aurora Public Schools

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February 17, 2009

Dear Dr. Crawford,

As the Deputy Superintendent of the Aurora Public Schools (APS), I would like to express the district's support in partnering with the Colorado State University's proposed project "Improving Secondary Mathematics and Science with Integrated Programming Experiences". We anticipate that we would have approximately six teachers involved with this project.

The Aurora Public School District is focused on providing our diverse population of over 32,000 students with learning environments that produce successful academic achievements in support of their post-secondary and career choices. To enable both our thriving and struggling students with these opportunities, APS is proactive in establishing educational environments that meet the variety of needs of our students.

The pathway initiatives that have been implemented within our district are examples of these innovative and focused academic efforts. The *Galaxy Initiative,* a P-20 pathway to support and guide Aurora Public School students to STEM related professions through rigorous academic programs, associated field experiences, and exposure to career opportunities, will serve as the primary platform for the implementation of integrating programming experiences. We will implement these STEM academies in grades six through nine in five of our secondary schools in August.

In addition, the district has established a *Galaxy Initiative* partnership with Raytheon that includes Raytheon providing their content expertise in curriculum, mentoring students, expanding after school programs, and assisting with in-school projects and relevant instruction.

Within the initiative, we are looking for ways to provide professional development opportunities for teachers, which include:

- Instructional coaching embedded in their classrooms
- Training in implementing enriched Science and Math curriculum
- Classes provided by outside groups to enhance teachers' knowledge in STEM related areas

Our administration recognizes that the research proposed in this project will not only improve the mathematics and science instruction of our teachers in our culturally and economically diverse district, but will also provide us with information on how to support our teachers as they implement formative programming practices.

Regards,

Tony Van Gytenbeek
Deputy Superintendent

Greeley - Evans
Weld County School District 6

Division of Academic Achievement
Greeley Evans School District
1025 9th Avenue
Greeley, Colorado 80631

February 17, 2009

Stewart Crawford, Ph.D.
Director of Technology, BioGraphix, LLC
PO Box 721
Fort Collins, CO 80522

Dear Dr. Crawford:

Weld County School District 6 is pleased to be a partner with BioGraphix and the Math and Science Teaching (MAST) Institute from the University of Northern Colorado (UNC) in this Information Technology Experiences for Students and Teachers (ITEST) grant for the “Connecting Computer Programming across STEM" grant project. District 6 is a district of 19,000 students located on the plains of Northern Colorado in Greeley and Evans, Colorado. District 6 been designated by the Colorado Department of Education as a “high need district” based on demographics and low student achievement results.

As we strive to improve student learning in the district, we are always looking for ways to make student learning more rigorous and relevant. One example of our current work is the establishment of a STEM program at one of our high schools in which general education and Career and Technical Education programs are working together to provide a rigorous and relevant curriculum. This work takes the rigor from the academic areas of math and science and marries it with the relevance found in Career and Technical Education programs. Through this grant project, our teachers will have the opportunity to learn how to integrate programming projects into STEM curricula. They will also learn how to help students understand the career opportunities that exist in the area of information technology.

As a project partner, District 6 will recruit participants for each of the teacher cohorts so our teachers will gain new skills and knowledge in how to use programming to help students understand math and science concepts. Teachers involved in the project will also be better equipped to help students understand how development of information technology skills can lead to rewarding career opportunities. It is our hope that, in addition to gaining new skills and knowledge, teachers participating in the project will develop leadership skills that will benefit our district and our students. Without our involvement in this project, neither of these would be possible for our district.

Sincerely,

Dana S. Selzer

Dr. Dana S. Selzer
Assistant Superintendent for Academic Achievement