CCLI Phase 2: The Adaptation and Dissemination of a Programming Centric Computer Literacy Course at HSIs

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Project Summary

The United States trains an insufficient number of students capable of working in industries requiring computation-related skills. To address this, much attention has been paid to the challenge of attracting students to computing, in particular women. This has lead to the development of more widely accessible and highly motivational introductory-level curricula. Little research has been performed on attracting other under-served groups such as Hispanics to computing-related professions. Given this lack of attention, it is no surprise that disproportionately fewer Hispanics pursue education in these fields.

To address the shortage of students prepared to work in industries requiring computation-related skills, the University of Texas at El Paso (UTEP) and Texas A&M Corpus Christi (TAMUCC), in consultation with Georgia Tech and an external evaluator, propose to investigate the impact of the approach of Dr. Mark Guzdial's innovative course titled *Introduction to Media Computation.* This programming-centric computer literacy course attracts and retains the interest of women studying Liberal Arts. Our proposed three-year research effort will investigate how this course and its underlying techniques generalize to another under-served group: Hispanics enrolled at several Ph.D. and non-Ph.D. granting Hispanic Serving Institutions (HSIs). Our research will include students enrolled in pre-engineering/science, healthcare-related, and liberal arts programs.

In collaboration with experts in career planning, we will adapt Dr. Guzdial's course to further motivate the interest of students from a diverse range of disciplines towards computing and technology-related fields. In addition, we will collaborate with Dr. Guzdial to evaluate and to *extend* this curriculum We believe that this approach will meaningfuly increase computing literacy among non-cs majors. In addition, we hope to inspire this group to pursue further studies in computing and technical fields.

We will increase understanding of how curriculum design affects the attractiveness of technical careers, additional study in computing, and the ability to apply this knowledge in students' chosen fields. Longitudinal data will be collected so that attendance in these courses can be correlated with student success in engineering and other technology-related programs.

As founding members of an NSF-funded consortium of eight leading HSIs called the Computing Alliance for Hispanic-Serving Institutions, UTEP and TAMUCC are uniquely positioned to conduct this research. To propagate and institutionalize best practices, our dissemination plan includes deployment to and evaluation at four or more additional members of the Alliance.

Thus, the **intellectual merit** of this effort includes (1) substantially extend the presently sparse understanding of factors affecting Hispanics' career choices, (2) evaluation of the extent that the enhanced course increases non-engineering students' interest in computing-related courses at HSIs, and (3) determination of whether this course lowers the attrition rate of students and increases their success in HSI computing and engineering programs. The work will result in development of new course material and laboratory assignments that will be piloted in different settings and refined for dissemination.

The proposed work is designed to result in refinement, adoption, dissemination, and institutionalization of a successful model for providing meaningful computer literacy to students at HSIs enrolled in a wide variety of academic disciplines. It is anticipated that this work's **broader impact** will include an increase in the number of Hispanic students, who (1) graduate from college with meaningful computer literacy, (2) choose to continue study in technical areas, and (3) graduate with computing-related degrees. While the lens is placed on Hispanic students, the lessons learned from this research will benefit the education of students in general.

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Contents

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1 Overview

The key hypothesis behind our proposed effort is that a creatively engaging introductory course in media computation will substantially increase computer literacy, motivation to continue studies in technical areas, and success in studies related to computation and engineering for Hispanic students.

1.1 Motivation

The motivation for the proposed project is twofold: (1) to address the insufficient and declining number of students who achieve meaningful computer literacy; and (2) to increase the number of Hispanics who pursue studies in computation and other technical fields.

1.1.1 Shortage of IT Workers

The U.S. Department of Labor projects that computer software engineers should be one of the fastest growing occupations over the 2004-2014 period. (U.S. Bureau of Labor Statistics, 2006) U.S. Government "statistics indicate that under-represented student groups continue to experience high dropout rates, low graduation rates, low enrollment in graduate programs, and low participation in Computer Science and engineering. (Labrador and Perez, 2006) In 2002 there were approximately two million software workers in the U.S. Technology is projected to be the fastest growing industry, and each year there will be 15,000 more jobs created than students graduating with BS degrees from institutions in the U.S. (Bureau of Labor Statistics, 2002). It's clear that we are truly in an "Information Economy" where IT workers are a too-scarce commodity.

Part of the cause of this shortage are low success rates in computer science courses, caused both by high drop-out and failure rates that sometimes are as high as 30%-50% (Roumani, 2002; Guzdial, 2002)—and by the large numbers of students who don't even attempt computing-related coursework. Furthermore, a report by the American Association of University Women (AAUW, 2000) suggested that part of the problem, at least for women, is that computer science courses are, frankly, too boring. They argue that computer science courses are "overly technical" with little room for "tinkering." Women students are dissuaded from the field by the stereotype computer science as an asocial, uncreative activity (Margolis and Fisher, 2002). A recent multi-national study of first and second year computer science students suggests that even those who complete introductory courses successfully are not meeting our programming expectations (McCracken et al., 2001).

To a far greater extent than when they were first introduced, current introductory course content rarely reflects either the majority of challenges or the relevant activities of many computer science professionals. Furthermore, these courses rarely are designed to elicit innovation or creativity in their students. For example, it is common for first- and second-semester courses to emphasize the encoding of standard algorithms that solve common problems such as sorting. Meanwhile, few Information Technology (IT) professionals today construct their own sorting algorithms. More commonly, as Pfleeger notes in (Pfleeger et al., 2001), what IT professionals do today involves the application of computer-based solutions to non-computing problems (such as graphic manipulation), where the range of of creativity is limitless.

To address then insufficient number of students capable of working in industries that require computation-related skills, computer science educators have focused on more widely accessible and highly motivational introductory-level curricula that encourage students to creatively experiment, and some of these efforts have specifically addressed the challenge of attracting women to computing. As stated by Freeeman and Aspray (1999), "if the number of women in the IT workforce were increased to equal the number of men, even the tremendous shortages of IT workers noted in ITAA studies could be filled."(U.S. Department of Commerce, 1998)

1.1.2 Hispanics in Computing

In contrast to the research on women, little research has been performed on effective strategies for attracting traditionally under-served groups such as Hispanics to computing-related professions. Given this lack of attention, it is no surprise that disproportionately fewer Hispanics choose to pursue education in these fields. The latest population projections indicate that the greatest growth rate among all groups in the U.S. is projected for Hispanics (National Science Foundation, 2004; U.S. Census Bureau, 2005). At over 40 million, 14% of the total U.S. population, they are the largest minority group (U.S. Census Bureau, 2005); however, the number of Hispanics who choose computing areas as their field of study is not comparable to the rate of Hispanic population growth. NSF's Strategic Plan FY 2003-2008 (National Science Foundation, 2003) recognizes the importance of fully engaging people from under-served groups and institutions in order to maintain our nation's global leadership in computing. It is our belief that, by putting the lens on those from under-served groups, generalizable lessons can be learned.

Among causes for Hispanics dropping out of programs in general, the importance of academic performance to persistence cannot be underplayed. Grades have been found to be three times more influential on the decision to leave college for Hispanics than for whites (Nora, 2003; Swail et al., 2004; Cabrera and M., 2000). Related to academic performance is academic preparation which has also been found to strongly impact student's likelihood, including Hispanics, of persisting (Adelman et al., 2003; Shin, 2005). Additionally, isolation and alienation are among the best predictors of failure (Aspray and Bernat, 2000; Seymour and Hewitt, 1997; Rodriguez, 1993).

Sometimes, managing aspirations is more important than other factors. In addition, the following factors assist with persistence in school (Rodriguez, 1993; Rodriguez, 1994):

- the availability of student role-models for each other;
- the provision of opportunities for faculty and students to interact outside the classroom;
- student cultures in which students interact with each other and discuss issues in a competent manner;
- assistance for students in clarifying and maintaining goals;
- involvement of students in their college learning experiences;
- opportunity to "give back" to their communities.

The small amount of published research on Hispanics in S&E is too generalized to be of use in evaluating the effectiveness of computer science curricula, although we can structure curricula to address persistence factors. Exit interviews of students who "dropped out" of computer science at UTEP during Fall 2005 revealed the following motivations that are consistent with the hypotheses motivating our proposal.

- saw computing as isolating;
- felt that the assignments were not motivating – would have liked more graphics;
- felt that CS did not foster creativity; and
- wanted to enter another program, e.g., management.

While studies have not focused specifically on why Hispanic students drop out of computing programs, studies of why students in general drop out of these programs (or even not choose computing as a program of study) point out that introductory courses that teach programming are "narrow," "lacking creativity," and "technology for its own sake."

1.2 Our Approach

> " *The first challenge is to embed the foundational practices of innovation into the curriculum, so that students learn innovation by doing, without necessarily being aware that they are engaged with systematic process." (Denning and McGettrick, 2005)*

To address the declining number of Hispanic students prepared to work in industries that require computation-related skills, the University of Texas at El Paso (UTEP) and Texas A&M Corpus Christi (TAMU-CC), in consultation with Georgia Tech and an external evaluator, proposes to investigate the techniques developed by Mark Guzdial for his innovative course titled *Introduction to Media Computation.* (Guzdial, 2004) Henceforth, we will refer to this course as *Media Computation*.

Media Computation has successfully engaged female students by presenting material that is relevant and result-driven as well as promoting social interactions and creativity (Tew et al., 2005). This project will refine and test this model on students enrolled in a variety of arts & sciences, science & technology, health sciences, and engineering colleges within both Ph.D. and non-Ph.D. granting Hispanic-serving universities.

In order to broaden the impact of the Media Computation approach to a more diverse student body, we propose a three-year research effort to extend the techniques used in the media-computation course to motivate the interest of Hispanic students enrolled in pre-engineering, pre-science and healthcare programs in computer-related subjects.

This exposes two challenges: (1) integration into existing curricula at a variety of HSIs and (2) adjusting assignments to be motivational to students in different majors. To achieve this, we will engage faculty at several HSIs in curriculum adaptation and work with experts in career planning to develop alternate course modules that are suited to the proclivities and interests of students typically enrolled in various programs. We will evaluate the effectiveness of the extended program and disseminate best practices as they are proven to other members of the Computing Alliance for Hispanic-Serving Institutions.

1.3 Intellectual Merit

This effort will collect data and contribute to the presently sparse literature on the factors that affect Hispanic students' decisions to enter and remain in computing. We will document the role of highly accessible and motivational introductory programming courses for increasing computer literacy and encouraging future successful computing-related studies for Hispanic students.

UTEP and TAMUCC are founding members of the Computing Alliance for Hispanic-Serving Institutions, recently funded by the NSF Broadening Participation in Computing Program. Thus UTEP is well positioned to integrate findings and curriculum innovations from the proposed effort with those of other projects, and help determine and disseminate *best practice*.

1.4 Broader Impacts

The proposed work will result in models for attracting students to technology and engineering, retaining students in beginning computing courses, and providing meaningful engineering-related coursework for students in preparatory programs. The work will result in development of new course material and laboratory assignments that will be piloted in different settings and refined for dissemination. It is anticipated that these models will result in an increase in the number of students from under-served groups, in particular Hispanic students, who (1) graduate from college with meaningful computer literacy, (2) chose to continue study in technology and engineering areas and (3) graduate with computing-related degrees. While the lens is placed on students from these under-served groups, a positive result may indicate that that these highly accessible and motivational curricula are generally suitable for a more diverse range of under-served students.

2 Media Programming

The computer science education literature describes introductory courses around graphics effects (Marks et al., 2001), virtual reality (Zimmerman and Eber, 2001), and animation (Moskal et al., 2004). With the exception of Alice, these courses generally utilize complete *graphical application programs* and rarely involve real programming, i.e., to leverage media computation as an engaging context for learning programming skills. Programming exercises in Media Programming provide a deeper understanding of compelling media transformations. Furthermore, the programming skills gained in these exercises can be applied to other contexts and, thus, a student who attends such a course has gained skills that are potentially relevant to a variety of vocations. Finally, multimedia production activities *do* provide for the "creativity" that the AAUW report sought (AAUW, 2000) and has been reported as successful in the past (Kay and Goldberg, 1977).

2.1 Georgia Tech's Motivational Approach to Computer Literacy

In contrast to typical introductory computer science courses where typical programming assignments tend to be implementations of mundane information processing problems [1] Mark Guzidial's *Introduction to Media Programming* curriculum introduces students to foundational programming concepts through engaging labs that manipulate data within multimedia. Students are prepared (and encouraged) to experiment creatively. Thus, they gain practice in programming while creating novel image and audio transformations.

Students in the media course use the language *Python* to manipulate and create pictures, sounds, text, and video and animations (frames). Students shrink and change colors within images, reverse and splice sounds, generate HTML pages from data, and implement digital video effects such as chroma-key. These transforms are approachable to introductory students with without extensive backgrounds in mathematics. For example, the concept of iteration and its related language constructs are introduced in the context of a graphical transform over an entire raster image.

Python has a remarkably rich library and is commonly used as a fast prototyping and scripting language for a wide range of applications including scientific computing, interactive systems, device control, and the active generation of web content. Thus, students who develop competency in Python may be prepared for entry-level work and internships in a variety of academic and commercial settings.

This media programming course was developed at the Georgia Institute of Technology (Georgia Tech). Georgia Tech is predominantly an Engineering school with highly rated programs and competitive admission policies. Overall, Georgia Tech is about 24% female. Beginning in Fall 1999, all students have been required to attend a course in computing. For the first few years, only one course was provided to meet this requirement, and the average withdrawal-and-failure (WDF) rate during this time was 28.2%. In Spring 2003 a version of the introductory course were introduced for Architecture, Management, and Liberal Arts majors focused on using programming to manipulate media (Forte and Guzdial, 2004; Guzdial, 2003; Rich et al., 2004). Only 10-15% (WDF rate) of the students fail to complete the course each term (Forte and Guzdial, 2005).

This contextualized introductory computing course at Georgia Tech for non-engineers has dramatically better retention than its predecessor, a more traditional courses (Rich et al., 2004; Forte and Guzdial, 2005), e.g., an increase from a 72% success rate to near 90% in this course. A two-year college adopting this media course reports similar success (Tew et al., 2005). In particular, contextualized computing courses are more successful at retaining women than traditional introductory computing (CS1) classes. In the media computation class, women succeed at the same rate as men (Tew et al., 2005) and report finding the class to be relevant, motivating, and worth continuing study (Rich et al., 2004). In the Spring 2005, the follow-on computing course was 75% female.

[1] For example, in a popular computer science text, the first assignment asks the student to write a program that produces a line of text, akin to "Hello, World." The second places the text in a window. The next few programs produce numeric outputs in windows and then input numbers and generate calculator types of responses. While the objectives for these assignments can certainly be justified, one has to ask whether these programs address students' expectations for (a) what makes computer science interesting, or (b) the nature of potential IT/Computer Science careers.

A year after the first offering of the course, Georgia Tech conducted an email survey of the students that had taken the course. 27% of the class had manipulated new media since leaving the class. 19% of the respondents had actually written programs since class had ended, mostly to manipulate media (Guzdial and Forte, 2005). Students indicated that the course positively impacted their view of computing in general, for example:

> "*I have learned more about the big picture behind computer science and programming. This has helped me to figure out how to use programs that I've never used before, troubleshoot problems on my own computer, use programs that I was already familiar with in a more sophisticated way, and given me more confidence to try to problem solve, explore, and fix my computer.*"

2.2 Relationship to Courses at HSIs

UTEP and TAMUCC both offer computer literacy courses suitable for offering a meaningful introduction to programming. Since Spring 2005, modified versions of Guzdial's curriculum have been used in UTEP's CS1310 (Introduction to Computer Programming). This course satisfies a technical elective requirement of degree plans for students not in UTEP's College of Engineering (CoE). Unlike Guzdial's course, UTEP was not able to offer formal recitations in which students could practice, engage in problem solving, and discuss problems. In place of scheduled recitations, the students met in the lab once a week with the instructor and TA, and they were required to complete lab assignments independently. It was discovered that this was insufficient and, as a result, the course was taught in a computer lab in the subsequent semester. This allowed the students to interactively experiment with techniques taught during lecture.

The first semester's attendees drew from a diverse set of majors principally from liberal arts, health sciences, pre-engineering, and business. Unlike the first cohort of students, nursing students dominated the second group to attend this course. Like the students at Georgia Tech, approximately half of the students in this second cohort provided positive responses to questions regarding interest in further courses in computation. However, their degree of interest was dramatically greater: only 6% of students at Georgia Tech expressed strong agreement with a statement "I would like to take more courses in computer science."(Tew et al.,). In contrast, 25% of the UTEP attendees indicated strong agreement (Gandara, 2007). These nursing students were engaged by lab exercises that utilized media to illustrate techniques used to represent and manipulate data. However, unlike students at Georgia Tech who were highly motivated by advanced assignments to create electronic artwork, the UTEP cohort was uninterested and frustrated by the apparent irrelevance of this activity in regards to their intended career. Part of this may be explained by the fact that the average age of students at UTEP is 24.

Currently, students in the CoE can apply credit earned from this course towards their six credit-hour *free elective* requirement. Typical undergraduates in the CoE spend two-to-three semesters classified as a *pre-engineer* until they complete a modular "pre-calculus" sequence. Students in pre-engineering are not permitted to attend engineering courses. So, while students in pre-engineering are presumably interested in *how things work*, their early semesters of preparation can be devoid of coursework that would expose how their extensive preparation relates to their intended areas of study.

TAMUCC currently permits students to fulfill a computer literacy requirement by attending one of a wide variety of computer application courses or one of the three following courses:

- COSC 1315 - Computer Literacy
- COSC 1435 - Intro to Problem Solving with Computers 1
- COSC 1436 - Intro to Problem Solving with Computers 2

We observe that a course based upon Media Computation could be introduced as a new course, or replace the the curriculum for any of these courses. For the institutions of the Computing Alliance for Hispanic-Serving Institutions, it is clear that the degree plans among the institutions vary substantially and that adaptations will be required.

Table 1: Relationship of Holland traits to dominant professions.

Trait	Personality Attributes	Likely Proclivities	Dominant Professions
Realistic	frank, practical, focused, mechanical, determined, or rugged	manipulating tools, mechanical or manual tasks, athletic activities	craftsman, fitness trainer, optician, policemen, fire fighter, phys-ed teacher
Investigative	analytical, intellectual, reserved, independent, scholarly	working with abstract ideas, intellectual problems	biologist, chemist, historian, researcher, doctor, engineer, mathematician
Artistic	complicated, original, impulsive, independent, expressive, creative	using imagination and feelings in creative expression	artist, musician, actor, designer, writer, photographer
Social	helping, informing, teaching, inspiring, counseling, serving	include interacting with people and concerned with the welfare of people	teacher, clergy, coach, therapist, nurse, counselor, sociologist
Enterprising	persuasive, energetic, sociable, adventurous, ambitious, risk-taking	leading, managing, and organizing	manager, producer, lawyer, business/marketing, executive, entrepreneur, principal
Conventional	careful, conforming, conservative, conscientious, self-controlled, structured	ordering activities paying attention to details	accountant, banker, editor, office manager, librarian, reporter

2.3 Consideration: Dominant Student Traits

Other things being equal, people experience more satisfaction in environments where the mix of reinforces matches their salient personal characteristics, that is, their interests and specific skills or abilities (Gottfredson, 1996).

John Holland has conducted the seminal research on career selection and satisfaction. (Holland, 1958; Holland et al., 1994; Holland, 1997) He observed that individuals whose inherent *traits* (see Table 1) and interests match their environment and vocational setting are more motivated towards their work and experience greater job satisfaction. We will invert these relationships by inferring likely traits and therefore interests from major. We develop a learning environment that will cater to their interests and proclivities. This is anticipated to result in students being more interested in material presented and, thus, more engaged in the learning process.

Table 1 summarizes the *traits* identified by Holland and a set of vocations for which they were generally observed. Individual workers will possess a combination of traits, and this simplified table only associates vocations with traits most commonly possessed by its workers.

According to Table 1, a cohort of students with traits similar to those correlated with successful visual and performing artists and journalists are likely to have many members who possess Holland's *artistic trait*. Students with this trait are likely to be motivated by aesthetic-based projects as exemplified by the advanced labs in Dr. Guzdial's curriculum. In contrast, many students with characteristics similar to those measured for nurses, counselors and educators are likely to possess Holland's *social* trait, implying that they are likely to be motivated by activities that help people find useful guidance.

Holland's theory, which is widely used by the career counseling community, correlates well to the experiences of nursing majors who attended the Media Computation course offered at UTEP during the Fall of 2006. Recall that nursing students at UTEP were disinterested in aesthetically focused assignment. This is not surprising given the traits associated with students counseled to enter this profession. Section 3 describes our approach to designing modular replacements for these assignments based on student population profiles for these assignments that we anticipate will result in greater student engagement.

3 Approach: The Promise of Creatively Engaging Introductory Curricula

> *"We must broaden our horizons and think of our students not only as potential compiler or operating systems designers but also as implementors of computer-based solutions to non-computing problems."* Sharon Lawrence Pfleeger in (Pfleeger et al., 2001).

Evaluation of Guzdial's Media Computation course at non-HSI institutions has demonstrated that it (1) teaches the basics of computing, (2) motivates the practice of newly acquired technical skills facilitating transfer of knowledge outside of the classroom, and (3) encourages further study within computing. As described above, our initial results from teaching the course at UTEP to nursing students are encouraging: students who previously expressed little interest in computation indicated motivation to continue studies. However, their lack of interest in aesthetically oriented projects indicates a direction for improvement.

Media may not be the only approach for eliciting creativity in introductory computing courses. We notice, however, that media computation has the following characteristics that make it well suited for capturing and retaining the interest of introductory students while motivating them to pursue further study in computation and other technical areas. '

1. Lab assignments must expose students to how computers represent and manipulate data in a manner that is motivational. *Multimedia does this through manipulation of images and sound.*

2. The skills acquired in the course should be applicable to projects the students can immediately apply to useful tasks. *Because Python is a general-purpose language, assignments can be designed to demonstrate and motivate its continued use for projects that are engaging and relevant to students.*

3. The subject matter must illuminate the need for and motivate further study of computing. *Media Computation* exposes students to the power of abstraction and piques their interest in efficient and elegant design.

4. The subject matter must illuminate the need for and motivate further study of design, mathematics and engineering analysis. *Media programming can expose this both through the exercise of programming and exposure to simulation and rendering of dynamic systems.*

5. It is helpful if students should recognize the relevance of course skills to their careers. *Many students at HSIs are older (the average age of UTEP undergrads is 24) and work while attending college, thus are motivated to learn skills of practical utility to their intended careers.*

3.1 The Key: Motivating Inquiry

In *Recentering Computer Science* (Denning and McGettrick, 2005), Denning and McGettrick observe that "while IT job projections are positive ... the recent decreases in computer science programs signal a chasm between our historical emphasis on programming and the contemporary concerns of those choosing careers." They argue that, to capture and hold the interest of students, it is essential that their educational program engage their creativity by giving them both tools and opportunities to innovate.

Research in Learning Sciences & Technologies shows that students must be *engaged* in order to learn material well (Malone and Lepper, 1987; Blumenfeld et al., 1991; Paris and Turner, 1994). While it's possible for anyone to memorize just about anything, deep understanding and the ability to *transfer* knowledge (apply the knowledge in a circumstance or domain different than one learned in) requires students to be motivated to explore the material and reflect on it (Bruer, 1993; Collins et al., 1989). While the evidence is still mixed on whether *consumption* of multimedia facilitates learning (Kozma and Russell, 1997), there is growing evidence that open-ended creative projects such as the *construction* of multimedia can facilitate learning (Resnick et al., 1996; Hay et al., 1994). This approach is related to Seymour Papert's *constructivism*, where student exercises include the design and construction of public artifacts.

There is evidence dating back to 1977 indicating strong student motivation to study media programming. In that year, Alan Kay and Adele Goldberg reported on their success in teaching programming by having students build a wide range of multimedia projects: animations, computer music compositions, computer games, and even simple forms of music videos (Kay and Goldberg, 1977). Kay and Goldberg report that students were excited and successful. This is not surprising given the dramatic nature of these projects that provide immediate illustration of generalizable computing concepts. Since the cost of media-capable computers has dropped from astronomical to affordable, these kinds of projects can become universally accessible.

3.2 Adaptation and Extension of Media Computation Course

The adaptation at UTEP and TAMUCC will be applied to two categories of courses. The first is a computer literacy for non-engineering majors, and the other is for studenets in pre-engineering (our use of this term includes pre-Computer science).

3.2.1 Computer Literacy for Non-Majors

Recall that we observed that most nursing students enrolled in Media Computation were not motivated by the same aesthetically focused assignments that liberal arts students at Georgia Tech found compelling. If substantial fraction of students in an academic program possess Holland's *social* trait, an alternate assignment could be designed that many of them are likely to find more engaging. For example, a lab project depicting the effects of various forms of colour-blindness in a manner that would be useful to guide the selection of colours used in signage might be more compelling to this cohort of nursing students.

These adaptations can also be extended to other majors. For example, students of engineering end physics are likley to have Holland's *investigative* trait, they are likely to be engaged by assignments that require abstract reasoning. A potential assignment appropriate for such students that extends concepts already included in the course might involve discrete event simulation such as examining tradeoffs related to selection of sampling intervals for simulations of planets orbiting a star.

In addition, these adaptations can lead to students gaining insight into their natural proclivity and interest in their intended field of study. Students can be informed of the correspondence between assignment characteristics and the nature of work performed by people in related vocations. As a result, students will gain evidence of good or poor fit with a variety of professions including their intended majors and a range of computing categories as a result of attending the modified course. In addition, we will address mismatches of assignment characteristics and traits typical of students enrolled in various degree plans at HSIs by developing modular replacements for advanced assignments.

We will evaluate impact of these introductory Media Computation curricula at increasing basic literacy, interest, and academic success in computer-relevant (and other SMET) fields for Hispanics. Dr. Guzdial and an external evaluator will assist us in employing and extending the language-neutral evaluation materials created by Guzdial's NSF-funded effort *Assessing Concept Knowledge and Attitudes in Introductory Computer Science Courses*. A letter from Dr. Guzdial indicating his intention to support the proposed effort is included within this proposal submission.

3.2.2 Computer Literacy for Pre-Engineering

Recall that a typical undergraduate in UTEP's CoE (which includes Computer Science) spends two-to-three semesters classified as a *pre-engineer* prior to attending any engineering courses. It is not surprising that attrition is high among students in pre-engineering – approximately 20% do not continue after their first year. However, we observe that students in pre-engineering are fully prepared to attend a course in Media Computation.

We are presently working with the CoE to incorporate a Media Computation course in the pre-engineering program that will incorporate engineering methodologies. This course would provide basic understanding of computation that is useful throughout the engineering specializations while creatively engaging students. To support this transition, the course would include minor curriculum adaptations designed to increase their interest and motivation towards other preparatory coursework.

For example, a project in a dedicated pre-engineering course might involve construction or modification of a discrete-event modeled simulation of of an oscillating spring or a planet's orbit, potentially generating plots or movies depicting the motion patterns. The former can be compared to the motion of a real spring (provided to students for comparison). As a result, a student who attends this course would not only gain generalizable *computer literacy* skills, and they are also likely to obtain a intuitive understanding of the utility of mathematical abstraction. [2]

3.2.3 Cooperative Learning and Community Involvement

We propose to adapt laboratory and in-class assignments for *media computation* to incorporate *cooperative learning* techniques and to provide pre-engineering students problems that exposes and motivates them to the methodology of engineering analysis through modeling and simulation of dynamic systems.

The benefits of creating goal-oriented cooperative groups are that participants create higher quality products, achieve mastery or competence of a task, develop a social network, and increase their self-esteem (Johnson et al., 1990). Process improvement allows the instructor to evaluate the progress of the students and to refine activities accordingly, and it allows the students to evaluate their progress and interactions in their group and to refine their behavior accordingly. The key to successfully using the cooperative learning paradigm (Johnson et al., 1990; Johnson et al., 1991; Johnson et al., 1992) is to incorporate the following basic elements:

- building positive interdependence within the group,
- supporting each member's progress and involvement through promotive interaction and constructive critique,
- developing a strong individual by ensuring that each student is responsible for his or her deliverables,
- teaching and practicing professional skills, and
- reviewing on a regular basis how well the group is functioning and achieving its goals.

Media Computation can provide students in introductory courses with opportunities to collaborate in efforts that contextualize and gain practice with their newly acquired technical skills through the creation of educational and promotional multi-media products ultimately intended for such ends. We will follow the successful track record of educational projects that engage junior students in team-based technical work oriented towards the goal of supporting community projects that apply their nascent technical skills towards socially constructive efforts. In (Rodriguez, 1993; Seymour and Hewitt, 1997), Rodriguez, Seymour, Hewitt, describe the importance students, especially Hispanics, place on contributions to their communities. For example, students may be encouraged to create graphics useful for publicizing activities of a neighborhood community center.

[2] We observe that Matlab is commonly used in engineering programs. Python is increasingly used in engineering (e.g. NASA, Google, NOAA) because it is freely available without license costs, Python has subtantial similarities to Matlab, and the Python libraries are extensive. The Media Computationcurriculum can be easily adapted to use Matlab if desired by instructors.

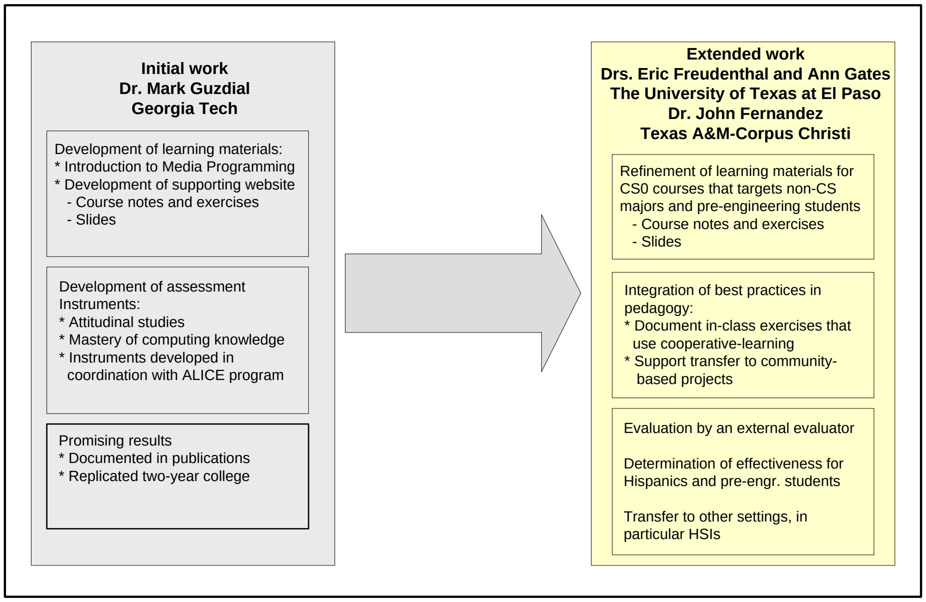

Figure 1: Relationship of Proposed Effort to Initial Work by Mark Guzdial

3.3 Plan of Study

The **key hypothesis** behind our proposed effort is that a creatively engaging introductory course in media computation will *substantially increase computer literacy, motivation to continue, and further success in studies related to computation and engineering for Hispanic and female students.* The research component of the proposed effort will focus on the evaluation of this hypothesis.

An illustration of our adaptation to Dr. Guzdial's effort is illustrated in Figure 1. The left side of this figure shows Dr. Guzdial's effort. The right side of this figure summarizes our proposed work including both extension of his course and an externally supervised evaluation. In collaboration with Georgia Tech, we will refine and test this model on students enrolled in a variety of arts & sciences, science & technology, health sciences, and engineering colleges within both Ph.D. and non-Ph.D. granting Hispanic-serving universites. The overarching goal of this project is to contribute useful refinements to currculum that will increase the number of students who achieve meaningful computer literacy and the number of students who are motivated to continue studies in computation-related fields.

We will examine the effectiveness of media-centric introductory courses in increasing student understanding of, competency in, and motivation for future study in computation. Co-PI Ann Gates directs the Computing Alliance for Hispanic-Serving Institutions and is a founding member the Academic Alliance of the National Center for Women in Information Technology. These alliances develop, evaluate, and disseminate best-practices in education for under-served populations. They will be engaged in the assessment and dissemination of the results from our research and curriculum development efforts.

The logic map presented in Figure 2 describes the organization of the proposed effort. The columns on the right side of this figure illustrate the expected short- and long-term outcomes that motivate the project. The left side of this figure illustrates activities designed to achieve these outcomes. A closed-loop feedback model is used to achieve continuous quality improvement.

The principal activities of this project given in the left column are grouped as development, deployment, and evaluation and assessment. These are arranged as a closed loop continuous-quality-improvement model. The activities motivate the expected short- and long-term outcomes of the effort. Curriculum, research results from our evaluations, and other lessons learned will be disseminated via traditional academic forums. During the second and final years, we will expand our study by disseminating portions of the evaluated curriculum

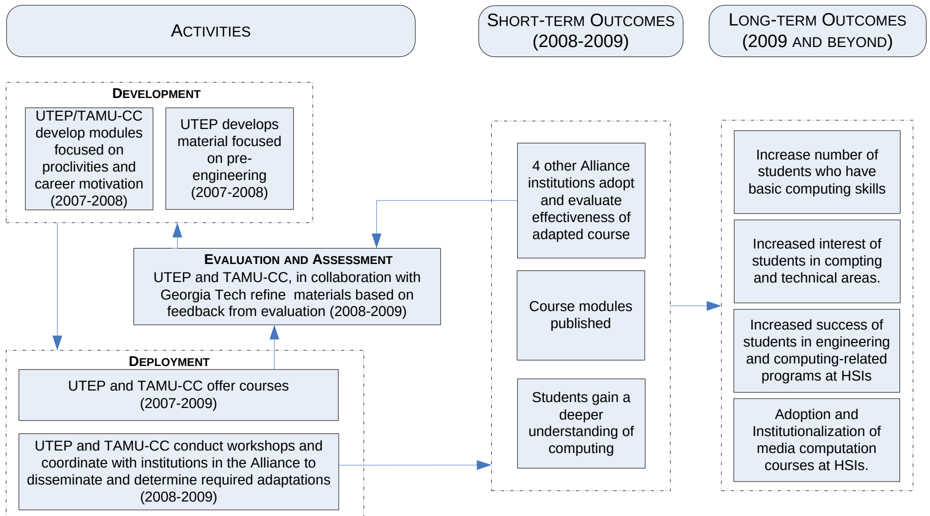

Figure 2: Iniital Logic Map illustrating relationship of activities to outcomes.

that are demonstrated to be effective to other members of the alliance.

A letter of support from Dr. Steve Stafford, Interim Dean of Engineering, is included in this proposal submission. This letter indicates enthusiastic support for the proposed research plan.

3.3.1 Research Questions

The following research questions will be addressed by our proposed research effort:

1. Can the success of Georgia Tech's Media Computation course be replicated at HSIs?
2. Which elements of the Media Computation course that made it attractive to women also serve to attract Hispanic students?
3. What elements of the Media Computation require augmentation when targeting different groups of students at HSIs. Is proclivity identification useful in this assessment?
4. What are compatible groupings of student cohorts (by major) that result in motivational computer literacy course curricula.
5. Are students who attend these courses more likely to continue studies in computer-related field?
6. What factors make computing attractive and unattractive as a field of study to Hispanics who (1) have and (2) have not attended this introductory course in Media Computation?
7. Are students who attend a media-centric introductory course more likely to succeed in a traditional computer-science program than students who have not?
8. Will the pre-engineering adaptation of this course increase student motivation and retention in engineering programs at HSIs?

Diagnostic instruments will be conducted prior to and immediately following attendance in the media-centric courses described above. In addition, the academic performance and future course selections by students who attend these courses will be tracked and compared with students who either attend existing courses in media literacy or introduction to programming.

3.3.2 Evaluation Plan

The evaluation plan will utilize a mixed method approach to assess the influence of each unique course in (1) affecting attitudes and interest in computation and (2) attracting and retaining students in computer science.

We have established collaborations with the Computing Alliance for Hispanic Serving Institutions and Georgia Tech and anticipate that our evaluations will principally utilize instruments that have already been prepared or are in the process of being revised. We will engage an independent evaluator to assist in the determination of any modifications or extensions required to evaluate and assess our project.

Longitudinal student performance data will be collected to permit comparison of the long-term academic success and trajectories of students who attend these media-computation courses with students who do not. While only limited historical data is available, our evaluation will include interviews with students who attended the existing program over the past several years to determine factors leading to their choices to continue study in CS or to switch majors.

The evaluation will begin with the refinement of the *logic map* represented as the *causal* network illustrated in Figure 2. While there are many practical guides currently for developing the logic map, some of the key sources that emphasize theory and verifiability are (Chen, 1990; Miles and Huberman, 1994; Weiss, 1998; Wholey et al., 1994). What is in common is the resulting diagrammatic representation of how the project is intended to work or how it expects to link outcomes (both short- and long-term) to the preceding inputs, activities, and processes. The final representation will be developed through an inductive analysis of course materials, previous course evaluations, interview of the designer and a sample of students, and interview of the project PI and other project staff. An evaluation plan will be designed based on this preliminary assessment and vetted with program staff. The evaluation will include a mid-course and end-of-course evaluation survey for students and faculty with a follow-up interview in each case. Classroom observation will be designed to sample phases of the instruction. For example, the course experience will likely contain overviews, demonstration with participation, students working alone, students working in small groups, summation, and student products development. To be sensitive to the entire cycle, the evaluation must be planned closely with instructors in order to capture the phases of instruction. A product evaluation will also be carried out using expert judgment ratings on dimensions vetted with the instructor and the program staff.

The first year of evaluation will result in a descriptive account of the program logic with verification based on observation, interview, and document analysis including development of a questionnaire survey with methods for verification. These measures will then be used to follow up the initial cohort and to refine metrics used to assess later years' observations.

Results from this research will be presented at academic meetings and compared with research conducted by other members of the Alliance and compared with other curricula being evaluated.

3.3.3 Dissemination Plans

The Computing Alliance for Hispanic-Serving Institutions, funded by NSF's Broadening Participation in Computing program, will serve as an avenue for dissemination of the results of the course as well as the course materials. The core of the Alliance are the following eight founding HSIs of the Alliance: California State University-Dominguez Hills (CSU-DH), Florida International University (FIU), New Mexico State University (NMSU), Texas A & M University-Corpus Christi (TAMUCC), University of Houston Downtown (UHD), University of Puerto Rico-Mayaguez (UPR-M), University of Puerto Rico-Rio Piedras (UPR-RP), and the University of Texas El Paso (UTEP).

The goals of the Alliance are to: (1) increase the number of students who enter computing fields; (2) support the retention and advancement of Hispanic faculty in computing; and (3) develop and sustain competitive education and research programs at HSIs. The strategy to accomplish this is threefold. The Alliance is promoting interventions that target the recruitment, retention, and advancement of Hispanics, it is promoting social science research in these areas, and it is promoting dialogue among industry, R1 institutions, and other stakeholders. The results from this research effort will contribute significantly to the goals of the Alliance.

4 The Research Team

4.1 The Institutions

The proposed research will be conducted at UTEP and TAMUCC, both Hispanic-Serving Institutions (HSI) with commitments to academic accessibility and excellence. UTEP is the second oldest academic component of the University of Texas System. From its inception as a mining school, UTEP has grown into a comprehensive urban university offering baccalaureate, master's and doctoral programs to the residents of far west Texas and northern Mexico. In particular, the Colleges of Science and Engineering at UTEP are poised to substantially increase the numbers of minority (mainly Hispanic) scientists and engineers.

4.1.1 UTEP

UTEP's Engineering and CS programs are accredited through ABET. Because of its location and the quality of its academic programs, UTEP is in a unique position to contribute significantly to the production of Hispanic professionals and to develop the future Hispanic leadership of this country. In Fall 2005, UTEP enrolled 19,264 students. More than 82% of the University's students come from El Paso County. UTEP's ethnic composition has come to mirror that of the community it serves: more than 70% of UTEP's students are Hispanic and approximately 55% of UTEP's students are women. UTEP receives national visuibility for its efforts to combine increased access to underrepresented groups while improving the quality of its instruction and insuring the competitiveness of its graduates. The University has been recognized for both in "Achieving Quality and Diversity: Universities in a Multi-Cultural Society."

Despite UTEP's successes, more than 20% of the students who enter pre-engineering drop out (Della-Piana et al., 2003) Furthermore, few students in UTEP's liberal arts programs attend courses that provide a meaningful level of computer literacy.

4.1.2 TAMUCC

TAMUCC is one of the fastest growing universities in Texas as the South Texas Gulf Coast begins to take advantage of this young institution. TAMUCC has seen a steady growth in enrollment in the past six years. In the Fall 2000 semester, just over 6,800 students enrolled. The student population as of Fall 2005 semester totaled more than 8,300 students with 55% white, 38% Hispanic, 4% African-American, and 3% other (international students were not included in the percentages). TAMUCC is ideally situated to bring Hispanics into computing fields since it is a Hispanic-serving urban university in a region in which 56% of the population is Hispanic and where approximately 30% of the population lives below the poverty line.

A survey of seniors slated to graduate in May 2005, showed that 55% of the students surveyed were first-generation college attendees. By 2010, TAMUCC is expected to be the second fastest-growing public university in the state, with 78% of its students being first-generation college attendees. One of the biggest challenges facing first-generation college attendees is bridging the cultural and technological gap. Problem-based learning, provided by the introductory course CS0, has a track record of helping students to succeed with this type of pedagogical strategy.

4.2 The Investigators

UTEP's academic programs have significant dual commitments to accessibility and excellence. As is common, a large number of students in UTEP's largely Hispanic and female student population are not being motivated to study computation. Thus, the investigators are uniquely positioned to conduct the proposed research. Our team has complementary strengths that will lead to the success of the project.

Dr. Eric Freudenthal joined the faculty at UTEP in Fall 2004. Previously, he held the position of Associate Research Scientist at NYU's Courant Institute where he actively engaged undergraduates in sponsored research. His engagement of junior students in research was recognized through the Institute's granting to him of the "Henning Biermann" award in 2003. At UTEP, Dr. Freudenthal participates in the computer science department's graduate and undergraduate curriculum committees and on a project team examining the development of core introductory curriculum that will span multiple departments of the engineering school. He has also lead curriculum reform efforts related to the foundational course sequence in the Computer Science department. Dr. Freudenthal's principal role in this project will be the adaptation of Media Computation to be suitable for entering students who are considering studies in a range of engineering disciplines.

Dr. Ann Gates (UTEP) was one of the original investigators in the development of the Affinity Research Group model (Gates et al., 1999b; Gates and Piana, 2001; Gates et al., 1995; Teller and Gates, 2000; Teller and Gates, 2002a; Gates et al., 1997; Gates et al., 1999c; Teller and Gates, 2002b), a model for developing undergraduate students who are involved in research, and continues to play a key role in its implementation and refinement. She has published with others over twenty papers on the model. Ann is a member of the IEEE-Computer Society (IEEE-CS) Board of Governors (2004-2006) and is a current member of the Executive Board; IEEE-CS, Educational Activities Board (1997-present); the National Academy of Engineering's Committee on Engineering Education (2002-2004); steering committee for the Frontiers in Education Conference (2000-2002; 2003-2006); IEEE-CS Certified Software Development Professional Certification Committee; and founding member of the Academic Alliance for the National Center for Women in Information Technology and the Computing Alliance for Hispanic-Serving Institutions. In addition, she is a program evaluator for the Computing Accreditation Committee of ABET. She was involved in the development of the *CyberCarrers for the Net Generation*, an outreach video for attracting middle and high school students to computing.

Dr. John Fernandez, Associate Professor of Computer Science at TAMUCC, is a retired military leader and business executive who brings a wealth of experience into the classroom. He is a native of South Texas and a first generation college graduate who understands the challenges faced by Hispanics who desire to enter the computing field. Dr. Fernandez is the TAMUCC director of the CS recruiting program which primarily consist of having undergraduates visit regional high schools on a weekly basis to recruit students. The success of this program is seen in the increase of CS freshmen over the last two years. He has conducted research related to using community-based projects for his capstone courses and regularly assigns real-world projects to his students. Besides CS education, his research interests are in human computer interaction and software engineering .

5 Management Plan

Dr. Eric Freudenthal will provide oversight and coordination for all aspects of the proposal and will lead the work. His responsibilities include ensuring that all timeline targets and budget limitations are met, organizing and planning meetings with TAMUCC and Georgia Tech, preparing project reports, and coordinating work with others on the project team including monthly teleconferences and annual meetings co-located with the Computing Alliance for Hispanic-Serving Institutions' (CAHSI) annual meetings. He will oversee modifications to the model course for a range of students in pre-engineering and coordinate the introduction of the curriculum with stakeholders in engineering departments as well as advisors of students in pre-engineering.

Dr. Ann Gates, who has extensive experience with cooperative learning, will be responsible to structuring and documenting activities based on cooperative learning. She will oversee the dissemination of the course to other members of the CAHSI.

Dr. John Fernandez will oversee the adaptation of the course at TAMUCC. In particular, he will be responsible for refinement of courses targetting Liberal Art students at HSIs. Dr. Fernandez will assist in the dissemination of the course to other members of the CAHSI.

Dr. Brian Sneed will identify characteristics of student groups and assist in (1) refining the design of motivational projects related to student career choices, (2) creating a module on career selection information, and (3) coordinating development of relevant evaluation metrics.

6 Results from Prior NSF Support

1. R. Keller (PI) with V. Kreinovich and . Q. Gates (co-PIs) in collaboration with San Diego Supercomputer Center, Virginia Tech, Cornell, et. al

   (a) NSF ITR, $11.5M (UTEP's portion: $900,000), 9/1/02-9/1/07

   (b) Collaborative Research: ITR: GEON: A Research Project to Create Cyberinfrastructure for the Geosciences

   (c) Summary: The GEO-science Network (GEON) project represents a collaborative effort among researchers from a broad cross section of information technology and earth science disciplines. The information infrastructure created by GEON will enable scientists to share databases and tools, enabling the interdisciplinary research required to discover relationships among Earth science disciplines. The information technology challenges relate to formulating, designing, and implementing data modeling and semantic integration formalisms, distributed data and computational grid techniques, and visualization methods that are directly applicable to the GEON domain science goals. The research products and services arising from GEON will be available to the entire scientific community and will provide opportunities for research and collaborations that are spatially and temporally independent.

   (d) Selected publications and workshops from CS efforts: (Araiza et al., 2002; Salayandia and Gates, 2005; Salayandia et al., 2005; Kreinovich and Starks, 2001; Keller et al., 2004)

   (a) NSF CISE CDA, $300,000, 01/1/05-12/31/09; A. Q. Gates (PI) with S. Roach.

   (b) The Affinity Research Group Model: Developing Students Beyond Academe

   (c) Summary: The Affinity Research Group Model has been demonstrated as an effective approach to recruiting and retaining students in computer science who come from under-represented groups. NSF is supporting the effort to disseminate the model to other institutions and other fields to encourage students to persist in STEM fields, participate in undergraduate research, and prepare to enter the workforce. The investigators have give

   (d) Publications and dissemination efforts: (Gates et al., 2007; Gates, ; G06, ; NM0, a; NM0, b)

2. Ann Q. Gates (PI) with Andrew Bernat, Patricia Teller, and Sergio Cabrera

   (a) NSF EIA-9522207, $1,200,000 September 1995- August 2000.

   (b) Building Affinity Groups to Enable & Encourage Student Success in Computing

   (c) Summary: The goal of the Affinity Research Group project was to address retention and participation of traditionally underrepresented groups in the computing areas by defining a framework that involved undergraduate and graduate students in research and outreach programs. The objectives included: to provide an environment that supports persistence; to define activities that develop the student's research, technical, group, and communication skills; to document and disseminate the infrastructure for creating and managing effective research groups that involve students with a wide range of abilities and experiences; and to develop a formative evaluation instrument.

   (d) Summary of results: All objectives were met. The major deliverables were development of the Affinity Group Handbook and dissemination of the model through publications, presentations, and workshops. Indicators of success of the model include an increase in student research participation, publications and invited presentations on the model, adoption of the model in other departments and universities, and grant awards. With respect to success in student development and persistence, success indicators are student conference attendance, publications, presentations, outreach involvement, retention, continuation to graduate school, awards, and scholarships.

   (e) Selected publications and workshops: (Gates et al., 1997; Gates et al., 1998; Gates et al., 1999b; Gates et al., 1999a; Della Piana and Bernat, 1999; Aspray and Bernat, 2000; Bernat et al., 2000; Gates and Piana, 2001)

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ganizational programs associated with programming arbitrary models. Of course the computer itself can be so modeled. î‰ink of it: the behav-. ior of the smallest physical switching element is modeled by quantum.Â Lisp is a survivor, having been in use for about a quarter of a cen-tury. Among the active programming languages only Fortran has had a longer life. Both languages have supported the programming needs of important areas of application, Fortran for scientic and engineering computation and Lisp for articial intelligence. î‰ese two areas con-tinue to be important, and their programmers are so devoted to these two languages that Lisp and Fortran may well continue in active use for at least another quarter-century. It covers heterogeneous computing architectures, data-parallel programming models, techniques for memory bandwidth management, and parallel algorithm patterns. All computing systems, from mobile to supercomputers, are becoming heterogeneous, massively parallel computers for higher power efficiency and computation throughput. While the computing community is racing to build tools and libraries to ease the use of these systems, effective and confident use of these systems will always require knowledge about low-level programming in these systems.Â The course is unique in that it is application oriented and only introduces the necessary underlying computer science and computer engineering knowledge for understanding. Additional programming and periodization considerations will also be discussed with respect to other variables such as anaerobic glycolytic system contribution (as inferred from blood lactate accumulation), neuromuscular load and musculoskeletal strain (Part II). Discover the world's research. 19+ million members. 135+ million publications. 700k+ research projects. Join for free. Public Full-text 1. Spatial spread of SARS-CoV-2 across cities is captured by the daily number of people traveling from city j to city i and a multiplicative factor. Specifically, daily numbers of travelers between 375 Chinese cities during the Spring Festival period (â€œChunyunâ€) were derived from human mobility data collected by the Tencent location-based service during the 2018 Chunyun period (1 Februaryâ€“12 March 2018) (7). Chunyun is a period of 40 daysâ€”15 days before and 25 days after the Lunar New Yearâ€”during which there are high rates.Â During the 2018 Chunyun, 1.73 billion travel events were captured in the Tencent data, whereas 2.97 billion trips were reported by the Ministry of Transport of the Peopleâ€™s Republic of China (7). To compensate for underreporting and reconcile these two