1 Introduction

New Mexico is a largely rural state with a widely dispersed population. Of 1.85 million total population, only some 778,000 persons living in or around Albuquerque, Las Cruces, Silver City, and Socorro are adequately served by state universities with 4-year computer science degree programs: the University of New Mexico, New Mexico State University, Western New Mexico University and New Mexico Institute of Mining and Technology. The rest of the population is scattered around the state in many smaller towns such as Farmington and Artesia. Students from these communities, unless they come from wealthy families and are willing to relocate, generally do not have adequate access to higher education. Leaving their home communities for extended periods of time also conflicts with the traditions and habits of life in Native American reservations. In particular, students from these diverse groups:

- have a strong sense of family loyalty and the belief that all family members should be responsible for the financial stability of the family. National statistics indicate that over 70% of minority students are employed, typically off-campus, and often for more than 20 hours a week. This work ethic is often viewed as more important than higher education aspirations and represents an incredible obstacle to access to higher degrees.
- mostly feel a strong appreciation for and commitment to this region, since many family members live nearby and have historical or marital ties to the area;
- because of a strong cultural emphasis on respect for authority, many students may lack assertiveness skills, individuality, and self-confidence, elements often taken for granted in a higher education environment.
- many students are first-generation university students and are uncertain about career aspirations and educational requirements. They often lack study, problem solving, and time management skills.
- a significant proportion of minority students arrive inadequately prepared to do college level work, especially in mathematics and scientific disciplines.

In high demand fields such as computer science, the number of professionals produced, particularly from demographic groups such as Native Americans who prefer not to relocate, is exceedingly low. These communities need access to opportunities for advanced training in computer science, both to serve their own community needs and to provide improved career paths for their youth.

We propose to establish a New Mexico Computer Science Community consortium with selected two year community colleges around the state to promote computer science education through regular visits and distance education offerings

from the NMSU department of computer science. The Consortium would establish several components at member institutions, including supplements to their lower-division offerings in Computer Science (CS), a third-year CS program offered by NMSU via distance education, face to face tutoring on each campus, and virtual community software to augment conventional distance education technologies with a three-dimensional graphical environment.

NMSU and NMSU CS are well qualified to work with the consortium schools on the proposed activities; NMSU has a long-standing tradition and experience in providing educational programs that are tailored to the needs of a diverse student population. NMSU is a Federally recognized Hispanic-serving institution, with a total enrollment of over 23,000 students, and a minority enrollment of more than 49%. NMSU's student population well reflects the diverse backgrounds that coexist in the state of New Mexico—where more than 51% of the population is of ethnic minority heritage (40% Hispanic and 9.1% Native American). This gives NMSU a unique opportunity to draw from the talent present in this large pool of minority students. NMSU offers a number of educational programs aimed at promoting recruitment, training, retention, and graduation of students from traditionally underrepresented backgrounds—such as MARC (Minority Access to Research Career), RISE (to increase minority participation in the biomedical sciences), NM-AMP, NMSU ADVANCE, NM-AGEP, and NMSU NA-CS (Native Americans in Computer Science). The program described in this proposal is designed to integrate with and complement these existing efforts, providing the consortium institutions with instruments to develop and strengthen their CS programs, and facilitating the transition of their students to a 4-year program at NMSU (where they will be directly served by the existing educational activities).

2 Program Components

The overall structure of the program we propose to develop is illustrated in Figure 1.

NMSU will lead the creation of a consortium, composed of various community colleges in the region. The community colleges selected for this project share the following characteristics:

- they serve prevalently rural regions of New Mexico;
- they have a significant presence of Native American and Hispanic students;
- they share a vision for the development of a coordinated curriculum in Computer Science.

The consortium will assist the community colleges in building their capacity of providing a range of Computer Science classes adequate to:

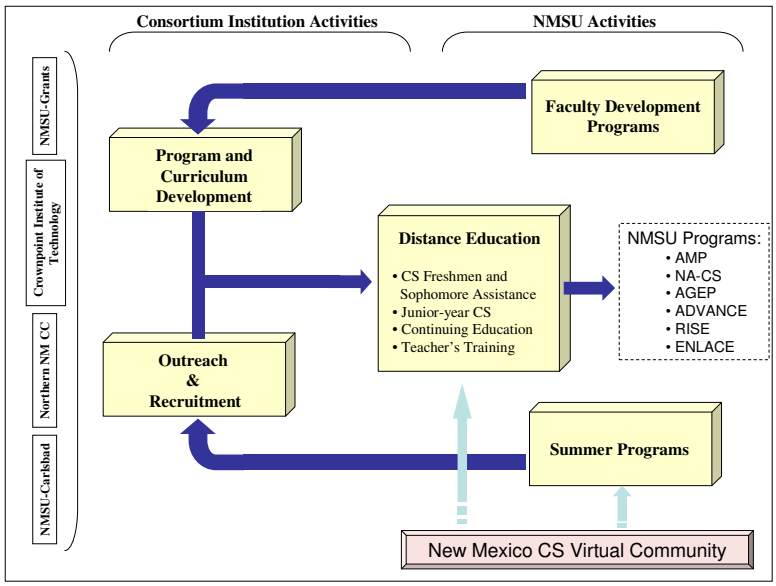

Figure 1: Overall Program Organization

- provide students with a solid background in Computer Science,
- prepare students for a smooth transition to a 4-year Computer Science program at NMSU main campus.

This capacity building activity will be achieved through a specialized Faculty Development program, conducted through summer workshops and through distance education efforts.

The delivery of the renovated 2-year curriculum will be complemented by a range of distance education material, aimed at helping students in overcoming the local lack of resources.

The transition from the 2-year to a 4-year program will be realized through a 3+1 tranfer program; the junior year of the program will be offered to the students at remote locations completely based on distance education delivery methods. NMSU Computer Science liasions will be deployed periodically to the remote institutions to assist students and faculty.

Faculty at NMSU Computer Science will assist incoming students from the consortium institutions, provide mentoring, and facilitate their access to the support programs already present on the NMSU main campus. Summer camps will be offered to provide students from the cooperating institutions with campus experience during their first years of college.

A vital component underlying this whole project is the creation of novel ed-

ucational technologies to provide more effective distance education capabilities. The NMSU CS virtual community will offer an on-line access to the resources and organization of the NMSU CS department to participating students.

The next section describes New Mexico's Community Colleges, and presents the institutions that are the primary participants in the grant. In the successive sections we explore in detail these different components.

3 New Mexico's Community Colleges

New Mexico has approximately thirteen community colleges of which four are serving as founding members of the CS consortium and participants in the grant. The schools are:

name	location	enrollment	current CS program
Clovis C. C.	Clovis	2700	AS in CIS
Crownpoint Institute	Crownpoint	300	computer tech.
Dine College	Shiprock	1900	AS in CS
Dona Ana Branch C. C.	Las Cruces	4700	computer tech.
Luna C.C.	Las Vegas	2000	programming
New Mexico Jr. College	Hobbs	3200	AS in CS
New Mexico Military Inst.	Roswell	400	none
NMSU Alamogordo	Alamogordo	1800	info. tech.
NMSU Carlsbad Campus	Carlsbad	1200	computer tech.
NMSU Grants Campus	Grants	1100	computer tech.
Northern New Mexico C.C.	Espanola	2100	AAS in CS
Santa Fe C.C.	Santa Fe	5000	AS in CS
San Juan College	Farmington	5500	AS in CS
Southwestern Indian Poly.	Albuquerque	600	AS in CS

Four institutions, representing the diversity of these many community colleges, are playing primary roles in this proposal. Aside from their interest in being founding members of the consortium, the selection of schools to receive initial consortium funding under the grant is influenced by national and local priorities to increase the level of access and participation in computer science by Native American and Hispanic students. Our pilot institution, Northern New Mexico Community College, is a mainstream public community college located north of Santa Fe. Our co-pilot institution is Crownpoint Institute of Technology, a small tribal school. Two additional institutions, NMSU's Carlsbad and Grants campuses, are two-year colleges in rural communities.

The pilot and co-pilot institutions will play lead roles in implementing, testing,

and debugging the proposed distance education versions of NMSU CS courses, deploying new CS distance education software under the grant, and developing (along with NMSU) the campus liaison system before it is deployed more widely.

4 Supplementing New Mexico Community Colleges' Lower Division Computer Science Programs

New Mexico's community colleges vary widely in their current offerings in computer science, depending on availability of qualified faculty and funding levels. A first goal we wish to provide for consortium members is a solid lower-division CS curriculum.

New Mexico's two year colleges vary widely in their current CS course offerings and level of sophistication. In some cases, existing courses will be enhanced to improve articulation, in others, NMSU may offer its lower-division courses at remote sites or by distance education. The CS courses at which further articulation work or distance education course offerings will be needed are *Algorithmic Computation* (CS1), *Introduction to Data Structures* (CS2), and *Machine Programming and Organization* (CS3).

5 Junior Year Computer Science Courses

We will develop distance education versions of the junior year CS courses. These courses are *Compilers and Automata Theory*, *Software Development*, and *Data Structures and Algorithms*. As a result, consortium institutions will be able to offer a 3+1 transfer program to NMSU CS. The junior year CS courses depend heavily on the lower-division courses described in the previous section, so the success of this component depends upon successful articulation or implementation of strong lower-division courses.

We anticipate that junior year course offerings will increase consortium members' ability to recruit students to their CS programs. In addition, it will make computer science a more attractive option to students who are location-bound, for example because of family or tribal ties.

6 Summer Program

In other efforts, we have found that summer programs can be an effective way to recruit potential students, and establish ties between distant students and the CS department serving them. A 5+ week summer program will reinforce students'

academic year studies and help them adjust to the NMSU environment and the CS department. Students will receive hands-on training for the distance education and communication software they will use. The summer program will span one of the NMSU summer sessions. Participation in these summer institutes before and after their junior year (spent at home) will allow students to take additional NMSU courses to facilitate their timely graduation after they transfer.

The summer program we are proposing in this grant also includes funds for *faculty development*: consortium members' faculty will be offered funding to come to NMSU during the summer and further their CS education. This is a vital part of creating a strong lower-division CS program at partner community colleges.

7 Computer Science Liaisons

The New Mexico Computer Science Consortium will take a novel approach to augmenting distance learning for computer science that is particularly designed for increasing the success of rural students. However, a large portion of the grant's overall budget is devoted to placing graduate teaching assistants at each member institution every week. Despite the availability of distance education software tools, many students will benefit from face-to-face tutoring, labs, and discussion sessions.

Campus liaisons are NMSU CS graduate students who spend one or more days a week on location at a consortium campus. The budget for campus liaisons includes substantial travel, meals, and lodging expenses, and assumes a greater time commitment than the 20 hour appointment given to regular teaching assistants.

8 The New Mexico CS Virtual Community

The NMSU CS department proposes to construct custom software to enhance distance education technologies for the Computer Science curriculum. The goal for this software is to bring the NMSU CS department experience to remote locations, including as many aspects as possible of the freshman-through-junior year experience.

The proposed virtual community will be modelled after the appearance and actual dynamic content of the 1st floor of Science Hall at NMSU. We want remote students to have access to our tools and expertise (such as CS software tools, seminars and meetings, lab assistants) and to already know the environment by the time they arrive at NMSU. This will help students and faculty correlate distance education experiences with on-campus NMSU CS education experiences, and ease their orientation into the NMSU CS department.

A virtual community both complements and contrasts with traditional video teleconferencing, and with web-based tools such as WebCT. While it is impossible to set up cameras from every angle in every room, it is very possible to supplement the traditional distance-learning cameras and digital capture devices in key locations with a 3D model of the department. Special-purpose Internet-based collaborative versions of CS laboratory software, such as text editors and compilers, will be part of this Virtual CS Community. Integration of existing distance-education technology into this 3D virtual community will also be important.

To the student, this "community" will look and feel like an interactive 3D application on their PC, within which they can move around, examine signs and notices, go to class or to an instructor's office hours, and go to a virtual lab to work on assignments. Within the virtual lab, the view may shift to a higher-resolution 2D view of the tools, but the collaborative nature of the environment (chatting, asking the TA or instructor questions, etc.) will remain.

The custom software we will develop includes the following properties:

- Audio stream access between selected locations, allowing hands-free verbal communication.
- An immersive 3D graphical environment, in lieu of video. This environment is described in Section 7.1 below. Similar to many popular on-line games, this allows interaction and requires substantially lower investment in hardware and bandwidth than does video teleconferencing. A 3D environment will provide a much higher sense of presence in NMSU's CS program than would traditional web-based tools such as WebCT.
- Dynamic classroom projector and electronic board output to be integrated into the 3D environment
- A Collaborative Software Development Environment, developed to include special purpose, multi-user shared-view versions of the software tools used in *Compilers and Automata Theory*, *Software Development*, and *Data Structures and Algorithms*. These include compilers (for C, C++, and Java), programmer's editors, debuggers, and software design (UML) diagramming tools. This environment is described in Section 7.2 below.

8.1 An Immersive 3D Graphical Environment

The graphical environment we envision is cartoon-like (similar to popular games), rather than aiming at being photorealistic. We believe there will be cultural side-benefits compared with traditional distance learning: for example, students will

not have to engage in eye contact, and will have less fear of embarrassment while asking questions. Figure 2 shows an example scene students might see in this environment.

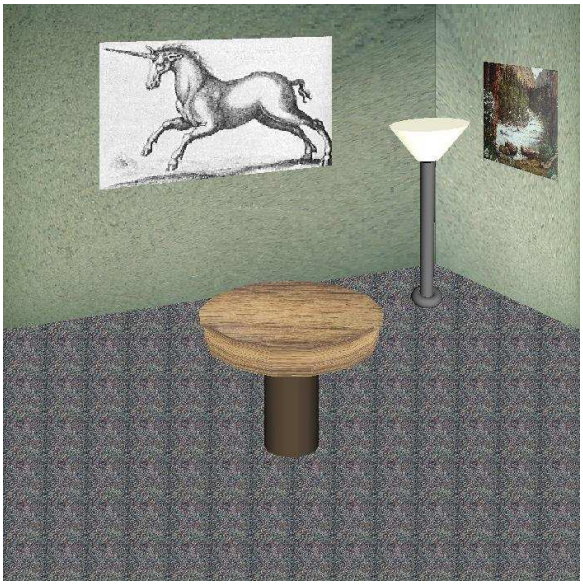

Figure 2: A 3D Graphical View of the CS Department

8.2 A Collaborative Software Development Environment

Computer Science instructors and teaching assistants working with students at a distance need more than a bulletin board or chat facility, they need to see the contents of the software development tools that are running on the student's screen, to advise the student about compiler errors and runtime errors they may be experiencing, and show them how to perform problem solving tasks such as debugging. Collaboration software such as Centra and NetMeeting allow shared views of documents, but not within the context of software development. The remote-control genre of commercial software (such as PC Anywhere) can achieve shared views of software tools, but only if the PC's involved are running compatible software (such as: Windows) and only at a considerable cost in bandwidth. For Computer Science instruction, a cross-platform solution (for Linux, UNIX, and Windows) is needed; specifically, one that is open source, allowing it to be integrated into the virtual community environment described above.

A collaborative development environment prototype called Pegasus is shown in Figure 3. The prototype allows users to edit text and chat with one another over

the Internet. The tool we wish to deploy for consortium use should also incorporate hands-free audio communication, and support collaborative views of many other areas of software development including UML design diagrams, compilation, execution, and debugging output. Pegasus should also be integrated into the 3D environment in the preceding section. Instructors will be able to walk around a virtual lab, talk with students, and look at their virtual screens, zooming in to the high resolution collaborative environment view when questions require on-screen details.

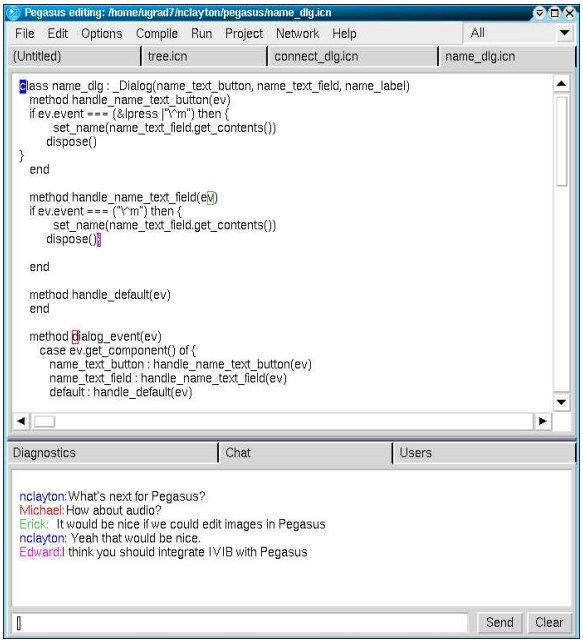

Figure 3: A collaborative development environment

8.3 Related Work

Generic uses of the phrase “virtual community” can refer to any form of shared on-line communication, including web pages, mailing lists, newsgroups, bulletin boards, and chat rooms. This document uses the term to refer more specifically to domain- or subject-oriented communications mediums which feature both real-time interaction and persistent state (locations and content remain available for extended periods and are consistent from user session to session).

Early virtual communities were based on text adventure games in which users moved through a connected but discontinuous series of ”rooms”, each of which

contained a part of a story or a piece of a puzzle to be solved. Text adventure games evolved into multi-player internet applications called by various acronyms including MUDs and MOOs. These applications eventually migrated to the web, and added (static) graphic images. One example where this class of virtual community has been applied to a specific educational domain is VRoma (www.vroma.org), where classics is taught in a Virtual Rome circa 150. The interface looks similar to a conventional website, but each page corresponds to a geographic location in Rome, and it is easy to notice and chat with other on-line users (say, in Latin) in the same location.

Several commercial projects have moved beyond a series of discontinuous rooms and static images to feature three-dimensional graphical spaces. Even on PCs, these systems provide a strong sense of immersion; of actually being within the virtual space. Many games (such as EverQuest, www.everquest.com) have demonstrated the popularity and scalability of the approach, supporting up to thousands of simultaneous users and working adequately over phone lines with 28.8K modems. The bandwidth efficiency compared with video conferencing is important, as broadband will not be available in many smaller sites in New Mexico anytime soon. Digital Space Traveler (www.digitalspace.com/avatars/traveler.html) demonstrates the potential for voice and 3D sound in virtual environments. Adobe Atmosphere, Apple QuickTime VR, and Meet3D are other current efforts.

Commercial packages are attractive, but without source code it will be impossible to customize them to meet our needs in terms of integration with CS programming tools such as compilers and editors. For this reason, the New Mexico CS Community virtual environment will be built as custom software using a open source virtual reality system such as VR Juggler (www.vrjuggler.org), University of Manchester's Maverik (aig.cs.man.ac.uk/maverik/), or Alice (www.alice.org). One related CS education project that is using Alice is Saint Joseph University's JABRWOC project, which uses virtual reality as an instructional domain, in contrast to this proposals intended use as a virtual community for distance education. The criterion in selecting between these VR frameworks for the proposed project will be: the estimated difficulty of integrating required networking, audio, and the computer science toolset into the VR framework. Should none of these frameworks prove suitable, another option is to use NMSU's own 3D graphics engine called Unicon 3D, which was written on top of industry-standard OpenGL by NMSU student (now alumna) Naomi Martinez.

The term "collaborative programming environment" can refer generically to any tool that assists programmers to work in teams, such as the (asynchronous) document revision features found in Microsoft Word, or the set of software tools provided by Source Forge (www.sourceforge.net). The collaborative software design and programming environment we envision for the virtual community is more

closely related to fully interactive systems from the field of computer supported cooperative work (CSCW). Similar systems from that domain include Microsoft's NetMeeting, NetEdit [Zaf01], RECIPE [SS00], and others. We are not aware of any systems that integrate a collaborative programming environment into an immersive 3D virtual environment as we are proposing.

9 Member Institution Commitments and Benefits

To support the success of the New Mexico Computer Science Community consortium, member two-year institutions would commit to:

- Developing as needed (with assistance from NMSU) lower division curriculums appropriate for articulation with NMSU's CS program.
- Providing laboratory space, PCs, and Internet bandwidth. Machines would need to meet certain requirements, including reasonably current processor with adequate memory, 3d graphics cards, and microphones/headsets.
- Providing office space for NMSU campus liaisons

In return, these institutions will share in the tuition revenues generated by the program, gain prestige from offering their students higher level courses through distance education, and receive technical assistance with their computing laboratories and curriculum. An additional benefit is the opportunity for faculty/staff development: faculty/staff at member institutions will be allowed to take an NMSU CS distance course offering each semester for reduced or free tuition.

10 Consortium Advisory Board

The consortium will have an advisory board consisting of a member from each participating institution, plus invited members from selected higher education organizations in our state (such as the American Indian Program Advisory Council). The board will meet 2-3 times a year including one meeting per year with a National Visiting Committee of five prominent computer scientists, providing input on improvements that can be made to the program and where to extend the program to meet additional constituent educational needs.

11 Pilot and Co-Pilot Institutions

Northern New Mexico Community College will serve as the pilot institution for this project. The consortium will develop and deploy program components and

work out problems on site at NNMCC prior to implementation at other consortium schools. The pilot institution will receive course offerings and be assigned a campus liaison in year one. Crownpoint Institute of Technology will serve as a second pilot, and will receive course offerings and be assigned a campus liaison in year two. NMSU Carlsbad and Grants branch campuses will receive course offerings in year three. By that time, the efficacy of the program can start to be measured, and the economics will be understood well enough to ascertain what enrollment levels are required in order for consortium membership to be self supporting.

12 Evaluation and Dissemination

Informal evaluation by the Steering Committee, leading to minor adjustments of the project, where necessary, will be conducted continuously during each semester of activity. Formal evaluation of the project activities will take place at the end of each semester. We expect to observe

- an increase in the number of students at the participating Consortium Institutions enrolled in CS programs;
- an increase in the number of students transitioning from the 2-year college to a 4-year program at NMSU;
- an increase in the retention and graduation rates at NMSU for these incoming students.

The formal evaluation plan, designed to assess how effectively the activities progress towards the set goals, will develop in parallel with the main program. Since the development of the program will be carried out according to a rigorous time-line, the evaluation activity will need to focus on the long term effectiveness on the students formative process. Evaluation data collected in each evaluation phase will be used to validate the methodologies and support dissemination. The evaluation process will be articulated in three stages. The first two stages provide *concurrent evaluation*. The *Implementation Stage* will evaluate the establishment of the proposed educational infrastructure. The *Development Stage* will evaluate the components of the educational processes as they progress towards their goals. Formative design evaluation procedures [Lan95] will be used to inform changes in the methodologies, allowing design changes to be made continually during implementation process [Nie93]. The *Output Evaluation Stage* will measure the final outcomes of the educational infrastructure. Dissemination of results and feedback from all program participants will be part of this stage. Evaluation of the educational components will be accomplished through the use of a comprehensive database systems, to track progress of students in the program. Various parameters will be tracked, e.g., retention, students' progress and grades, and performance after graduation. The

evaluation process will be integrated in the departments' own outcome assessment plans.

External evaluation will also be accomplished through our *Board of Advisors*, composed of representatives from industry and academia. We will also develop a plan to disseminate educational accomplishments from this project. The mechanisms employed include: *(i)* reports to sponsoring entities; *(ii)* written reports to the educational communities; *(iii)* local presentations (e.g., workshops open to researchers and educators); *(iv)* Web sites, outlining description and reports on educational activities; *(v)* events to increase public awareness about our activities (e.g., open houses).

13 Grant Activities Schedule

13.1 Year 1

- Setup pilot lab at NNMCC
- Setup COTS distance ed capabilities
- Develop CS-customized virtual community software
- Offer one or more CS courses, supplemental instruction, and CS tutoring at pilot institution via conventional distance ed
- Offer Summer program, including consortium faculty development program

13.2 Year 2

- Deploy and refine virtual community software at NNMCC.
- Offer distance ed lower division CS courses at NNMCC.
- Offer freshman CS courses at Crownpoint.
- Provide summer program, including consortium faculty development program.

13.3 Year 3

- Transition most CS coursework to virtual community software toolset
- Offer junior year at NNMCC.
- Offer freshman and sophomore CS courses at all member institutions.
- Disseminate program
- Provide summer program.

14 Program Management and Investigators' Expertise

The proposed effort will be coordinated by a team composed of the NMSU investigators and representatives from the different institutions belonging to the consortium.

The PI, Dr. Carmen Gonzales will bear the responsibilities for day-to-day administration of the consortium. She will also be responsible for development of articulation and tuition agreements with consortium member schools. Dr. Gonzales, in her role as NMSU Vice-Provost for Distance Education, will provide the resources and experience necessary for the development and implementation of the distance education CS junior year.

Co-PI Dr. Clinton Jeffery will bear the primary responsibility for development of the virtual community software as well as the junior year distance education curriculum. These tasks will involve substantial time commitments, for which the budget includes summer support.

Co-PI Dr. Enrico Pontelli will assist with CS curricular elements, as well as summer program activities and integration of the consortium program activities with other activities of the NMSU computer science department. Dr. Pontelli is currently leading the development of the *pathways* system in the NMSU CS department, an educational program providing alternative forms of support to better suit the needs of our diverse student population.

15 Investigators' Expertise

Dr. Gonzales holds a Ph.D. in Curriculum & Instruction in Multicultural Teacher Education (1995) and is currently Vice-Provost for Distance Education at NMSU. She is Project Director for the Regional Educational Technology Assistance (RETA) Program at NMSU, and has been involved in numerous large-scale educational technology and distance education projects funded by the US Department of Education, the New Mexico Department of Education, and NSF.

Dr. Jeffery holds a Doctorate in Computer Science (1993) and is currently an Assistant Professor of Computer Science. He was project co-Director for a Minority Institution Infrastructure grant at the University of Texas San Antonio from 1996-1999. His research interests are in software engineering and programming languages; he invented the Unicon programming language (unicon.sourceforge.net) and the Alamo program monitoring architecture. His research has been supported by the NSF RIA, MII, and CRI programs, and by the National Library of Medicine at NIH.

Dr. Pontelli holds a Doctorate in Computer Science (1997) and he is currently

an Associate Professor of Computer Science. He is the recipient of the 2002 Roush Award for teaching excellence. He is one of the main investigators in the Minority Institution Infrastructure grant which supports the NACS Summer Camps, and he has been actively involved with students recruitment, mentoring, and advising. He is the director of the Laboratory for Logic and Databases, created with NSF RIMI and instrumentation grants with the goal of providing research opportunities to Hispanic students. His research interests are in Programming Languages and his research has received support from AITEC Japan, Fulbright, Department of Education and NSF (including a Career Award).

16 Cost Sharing and Program Sustainability

Cost Sharing is provided on the only equipment in the grant, which are $10,000 for audio equipment upgrades for computer science classrooms at the NMSU main campus. NMSU will match this amount with another $10,000. This will allow us to provide passive streaming audio to the virtual community from the classrooms, and to record audio from specific classes for later playback.

By encouraging articulation and program development at the consortium schools, the overall cost of a computer science education under the program will be kept affordable despite costs inherent in distance education. Bringing an NMSU CS liaison to a remote campus each week adds from six to twelve thousand dollars per semester to the cost of having a teaching assistant on site. This will be sustainable on those campuses with sufficient enrollment, where the campus liaison will be a resource shared across several courses. The long-term sustainability of the program will come from the success of the virtual CS community itself–after the virtual community software achieves its primary goals, the necessity for an on-site liaison will decrease.

17 Results from Prior NSF Support

The PI was Project Director for the *Digital Desert Library*, an NSF-funded educational resource for K-12 classrooms. This content has been widely disseminated through sites such as the Eisenhower National Clearinghouse (www.enc.org).

Co-PI's Jeffery and Pontelli have been investigators on research grants under the RIA, CAREER, and other programs; the Co-PI's have also played prominent roles on three different NSF Minority Institution Infrastructure grants at NMSU and UT San Antonio. These projects have produced multiple Ph.D. students (Sandra Dykes, Karen Villaverde), many Master's students, journal articles in ACM TOPLAS, Journal of Visual Languages and Computing, and others.