COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S)
(Indicate the most specific unit known, i.e., program, division, etc.)
DUE/EHR

FOR NSF USE ONLY
NSF PROPOSAL NUMBER

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/If not in response to a program announcement/solicitation enter GPG, NSF 95-27
Course and Curriculum Development NSF 97-29 June 9, 1997

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	FILE LOCATION

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
IRS #381381271N

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL OR
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Hope College

AWARDEE ORGANIZATION CODE (IF KNOWN)

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING ZIP CODE
Hope College
P.O. Box 9000
Holland, MI 49422-9000

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

PERFORMING ORGANIZATION CODE (IF KNOWN)

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING ZIP CODE

IS AWARDEE ORGANIZATION (Check All That Apply)
(See GPG II.D.1 For Definitions) ☐ FOR-PROFIT ORGANIZATION ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS

TITLE OF PROPOSED PROJECT Developing an Integrated, Web-based Learning Environment for Computer Science General Education

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE
$149,975	27 months	May 1, 1998

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.A.3)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.D.1)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG II.D.10)
☐ NATIONAL ENVIRONMENTAL POLICY ACT (GPG II.D.10)
☐ HISTORIC PLACES (GPG II.D.10)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.12)
☐ GROUP PROPOSAL (GPG II.D.12)
☐ VERTEBRATE ANIMALS (GPG II.D.12) IACUC App. _____
☐ HUMAN SUBJECTS (GPG II.D.12)
Exemption Subsection____or IRB App. Date _____
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES _____
☐ FACILITATION FOR SCIENTISTS/ENGINEERS WITH DISABILITIES (GPG V.G.)
☐ RESEARCH OPPORTUNITY AWARD (GPG V.H)

PI/PD DEPARTMENT
Computer Science

PI/PD FAX NUMBER
616-395-7123

PI/PD POSTAL ADDRESS
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Holland, MI 49422-9000

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CO-PI/PD				
CO-PI/PD				

NOTE: THE FULLY SIGNED CERTIFICATION PAGE MUST BE SUBMITTED IMMEDIATELY FOLLOWING THIS COVER SHEET

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE NSF INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators

I certify to the best of my knowledge that:

(1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and
(2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this application.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Date
PI/PD Herbert L. Dershem		June 9, 1997
Co-PI/PD Michael J. Jipping		June 9, 1997
Co-PI/PD Gordon A. Stegink		June 9, 1997
Co-PI/PD		
Co-PI/PD		

Certification for Authorized Organizational Representative or Individual Applicant

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding Federal debt status, debarment and suspension, drugfree workplace, and lobbying activities (see below), as set forth in the *Grant Proposal Guide (GPG)*, NSF 95-27. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution implemented a written and enforced conflict of interest policy that is consistent with the provisions of *Grant Policy Manual* Section 510; that to the best his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Debt and Debarment Certifications (If answer "yes" to either, please provide explanation.)

Is the organization delinquent on any Federal debt? Yes ☐ No ☒

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal Department or agency? Yes ☐ No ☒

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant or cooperative agreement exceeding $100,000 and for an award of a Federal loan a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer employee of any agency, a Member of Congress, and officer or employee of Congress, or an employee of a Member of Congress in connection with Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME/TITLE (TYPED) James E. Gentile, Dean for the Natural Sciences		June 9, 1997

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
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NATIONAL SCIENCE FOUNDATION
Division of Undergraduate Education

NSF FORM 1295: PROJECT DATA FORM

The instructions and codes to be used in completing this form are provided in Appendix II.

1. Program to which the Proposal is submitted: CCD
2. Type of submission: PR
3. Name of Principal Investigator/Project Director (as shown on the cover sheet):
   Herbert L. Dershem
4. Name of submitting Institution (as shown on cover sheet):
   Hope College
5. Other institutions involved in the project's operation:
   none

ATE and CETP only:
Preliminary Proposal Number(s) that led to this proposal _____

PROJECT CODES

A. Major Discipline Code: 3 1 Subfields: _____
B. Academic Focus Level of Project: L O
C. Highest Degree Code: B
D. Category Code: I C
E. Business/Industry Participation Code: _ _
F. Audience Code: _ _ _ _
G. Institution Code: P R I V
H. Strategic Area Code: _ _

Estimated number in each of the following categories to be directly affected by the activities of the project during its operation: _____

J. Undergraduate Students: 288
K. Pre-college Students: 0
L. College Faculty: 3
M. Pre-college Teachers: 0
N. Total Non-NSF Contribution: $77,290

Project Summary:

The Summary of Proposed Work should be a concise description of the project limited to 22 lines of 12 point (standard pica type) or larger font on plain white paper.

Project Summary

The present approach to Computer Science learning provides very different environments for each of four learning modes. These four modes are characterized by the classroom, the laboratory, the textbook, and individual problem solving in homework or examinations. The separation of these environments prevents students from making useful connections between the learning that occurs in the four different modes.

This project will develop an Integrated Learning Environment that will encompass all four modes of learning. This environment will be web-based and provide features for effective teacher-student and machine-student interaction. It will also support integrated animation and the compilation and testing of sample code.

A course that introduces computer science through graphics to general education students will be designed and implemented completely within this Integrated Learning Environment. This course will provide an effective introduction to problem solving and the discipline of computer science to undergraduate students in the setting of graphics and the Java programming language. The environment will also be applied to portions of two lower-level core Computer Science courses and a non-technical First Year Seminar course on cyberculture.

The Integrated Learning Environment and the course materials will be disseminated through professional papers, presentations, and workshops and distributed via the World Wide Web. The full materials for the general education course will be presented to commercial publishers for possible publication.

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Hope College Computer Science
Narrative

1.0 Results from Prior NSF Support

The three investigators have received four NSF grants related to undergraduate education over the past five years. These grants are listed in abbreviated form below:

Grant Number	CDA-9200118	Amount of Award	$86,550
Support Period	April 1, 1992 until September 30, 1995		
Title: REU: An Undergraduate Research Participation Program in Computer Science			
P.I.	Herbert L. Dershem		
Grant Number	DUE-9550902	Amount of Award	$52,601
Support Period	June 1, 1995 until May 31, 1998		
Title: A Laboratory for Experimenting with Operating Systems and Networking Concepts			
P.I.	Michael J. Jipping		
Grant Number	CDA-9423923	Amount of Award	$114,393
Support Period	March 1, 1995 to February 28, 1998		
Title: REU: An Undergraduate Research Participation Program in Computer Science			
P.I.	Herbert L. Dershem		
Grant Number	DUE-9650129	Amount of Award	$46,356
Support Period	June 15, 1996 until May 31, 1998		
Title: An Integrated Classroom/Laboratory for Introducing Students to Object-Oriented Concepts			
P.I.	Michael J. Jipping/Herbert L. Dershem/Gordon A. Stegink		

The two REU grants have supported undergraduate research within the department during the summers of 1992-1997. In these summers, 45 students have participated in 22 different research projects. Fourteen of our past participants have attended graduate school. Eighteen papers and presentations have been written or co-written by participants in this program. A bibliography follows.

The first ILI grant was to support the development of web-based, interactive laboratories in support of courses in Operating Systems and Computer Networks. In the two years of this

project, the laboratory experiences developed under this grant were positively received by students and colleagues at other institutions, and evidence has indicated learning has been enhanced.

The second ILI grant, which is still in progress, supports the establishment of a combination classroom and laboratory environment to support the seamless integration of large group (classroom) and small group (laboratory) learning. The equipment purchased with this grant is presently being used in all Hope College computer science classes and will play an important role in the project being proposed here.

Papers presented and published that have cited the above four grants:

McFall, R. 1992. Using the Computer to Visualize and Simulate Abstract Models of Computation. Pew Midstates Consortium Undergraduate Research Symposium. Grinnell, IA., October

Shu, M. 1992. An Object-Oriented Application/Programmer Interface. Pew Midstates Consortium Undergraduate Research Symposium. Grinnell, IA.

Matthews*, E. and M. Shield*. 1992. Photosynthesis: An Object-Oriented Test Bed for Parallel Ray Tracing. Argonne Symposium on Undergraduate Research. Argonne, IL.

Howell, J., R. Wohlfarth, and M. Shu. "An Object-Oriented Application/Programmer Interface for Network Programming," Proceedings of the 1993 Symposium on Applied Computing, 1993.

Engel, G., H. Dershem, R. McFall, A. Lopez, and S. Wiltz. 1993. Research Experience for Undergraduates Panel. SIGCSE Technical Symposium on Computer Science Education. Indianapolis, IN.

Nelson, R. and B. Showers. 1993. The Genetic Algorithm Parallel Programming Project. Pew Midstates Consortium Undergraduate Research Symposium. Chicago, IL.

Barth, W. and C. Bowsher. 1993. AdaVision and THREADS: Algorithm Animations and Experimental Laboratories for Teaching a Data Structures Course in Ada. Argonne Symposium for Undergraduate Research. Argonne, IL.

Dershem, H. 1993. Algorithm Animation for Data Structures. United States Air Force Academy Computer Science Colloquium. USAF Academy, CO.

Jipping, M., S. Hallyn, M Crider, N. Rahn, and J. Beard. 1993. An Empirical Case Study of Software Integration Techniques. NASA Langley Space Flight Center Symposium. Langley, VA.

McFall, R. and H. Dershem. "Finite State Machine Simulation in an Introductory Lab," SIGCSE Bulletin, 26,1 (1994), pp. 126-130.

Dershem, H., C. Bowsher, D. Brown. 1994. AdaVision and THREADS: Algorithm Animations and Experimental Laboratories for Teaching a Data Structures Course in Ada. Argonne Symposium for Undergraduate Research. Argonne, IL.

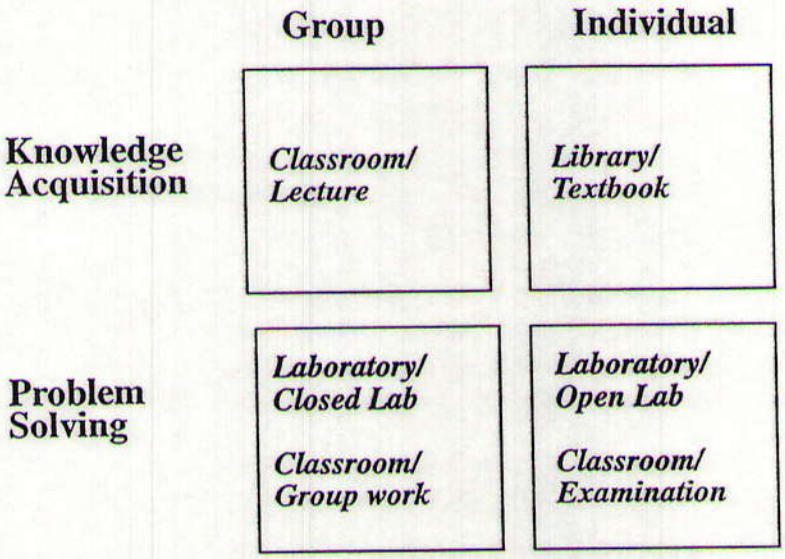
Jipping, M. 1996. New Perspectives on Laboratories for Upper Level Classes. Poster at SIGCSE Technical Symposium on Computer Science Education. Philadelphia, PA.

Dershem, H.L., W. Barth, C. Bowsher, and D. Brown, "Data Structures with Ada Packages, Laboratories, and Animations," Proceedings of the First Australasian Computer Science Education Conference, (July, 1996).

McFall, Ryan and Stegink, Gordon, "Introductory Computer Science for General Education: Laboratories, Textbooks, and the Internet," SIGCSE Bulletin, Mar. 1997, Vol. 29, no. 1, pp. 96-100.

2.0 Problem or Question

We have observed that a primary problem in Computer Science education is the separation of learning into four different environments associated with four different modes of learning. We classify the four modes of learning as illustrated in the figure below.



Here learning is classified by whether it is in a group or individual and whether the primary mode of learning is knowledge acquisition or problem solving. Typical locations and vehicles for each of the four learning paradigms is found in the figure. In addition, the fact that the four boxes above are distanced from each other illustrates the fact that these four are typically separated from each other both physically and chronologically.

This separation often negatively affects students who generally have a difficult time connecting the learning that takes place in one mode to that which occurs in another. For example, we have found that our students have all but abandoned the use of their textbooks. They fail to make a connection between the learning that takes place by reading a textbook to that which takes

place during class, in the laboratory, or in individual problem solving.

Students also have difficulty making the connection between group knowledge acquisition in the classroom and group problem solving in the laboratory. In our experience, this is difficult because of the chronological separation between the two. A topic discussed in the classroom on Friday may not be reinforced in the laboratory setting until the following Thursday. This and the fact that the classroom and the laboratory are very different settings make the connection between the two learning situations more difficult.

Allen Tucker in his recent position paper made the following observations:

> Specific issues that need to be addressed by the teaching faculties of colleges and universities are the following:
> - The large lecture class is still the dominant model for teaching, amidst a preponderance of evidence that students do their best learning in individual and small group settings.
> - Textbooks as a medium are often unhelpful, overpriced, and unattractive to students (and faculty), who increasingly prefer alternative styles of teaching and learning.
> - Labs above the introductory level are usually unstructured, and lab assignments and methods are too often haphazardly designed and executed.
> - Most teaching methods and learning materials are strongly biased toward a male, individual, isolated work ethic. Lectures, texts and lab assignments favor the learning styles that are dominant within this narrow group. [1]

Tucker observes that learning in three of the four modes from our classification are in need of serious attention to improve computer science education. We believe this improvement can be made through an integration of the environments of the four modes into a single environment that will encourage structured, active, and cooperative learning. This will lead toward what Guzdial and Soloway have referred to as the "24 Hour Classroom" [2] where learning opportunities are available at all times in a variety of modes and locations.

Statement of Problem

1. The present approach to Computer Science learning provides very different environments for each of the four modes of learning. The four are widely separated both chronologically and physically. This separation frequently prevents students from making useful connections of learning across environments.

We propose to address this problem through the design and implementation of an **Integrated Learning Environment.** This environment will be developed in the context of the World Wide Web and support all learning activities of the course including activities normally associated with lecture, discussion, closed laboratories, open laboratories, textbook, homework, and examinations. It will be accessible from a wide variety of locations and platforms.

2. Computer Science general education courses fail to hone student skills in problem solving, abstraction, critical thinking, and clear communication of ideas and fail to educate the public about the discipline of computer science. [3]

The present project proposes to address this problem through the development of a general education course that is based on computer graphics and focuses on the development of problem solving skills in that context. Furthermore, this course will attempt to expose students to the nature of the discipline of computer science.

Several projects at other institutions address these or related problems. For example, the Classroom 2000 project at Georgia Tech[4] is developing an environment that will permit electronic presentations and note taking. This project focuses on student learning through electronic interaction with course materials. It does not duplicate the environment we propose as it focuses on providing tools for electronic presentations and notetaking. The results of the

Classroom 2000 project will be useful in extending the project proposed here to utilize these classroom capabilities.

Project CaMILE[5], also at Georgia Tech, is producing a tool that will enhance collaborative learning through electronic communication. It is somewhat similar to the Annotation Engine within our Integrated Learning Environment but does not include the feature of connecting the communication directly with course content.

CAT[6] is a project which focuses on web-based algorithm animation, and rather than duplicating the proposed project, also supplements it. The algorithm animations will likely become a part of the materials that are developed within a given course environment. The investigators will continue to monitor this and many other algorithm animation projects for animations that can be embedded within course materials of the Integrated Learning Environment and tools that can be used to produce such animations.

Finally, the Michigan State University CPS 101 project is developing a web-based, regulated mastery model, general education course. The course being developed there, Computing Concepts and Competencies, is quite different from the general education course that we are developing. The Michigan State course focuses on computer literacy and computer applications whereas our general education course is intended to address problem solving and the discipline of computer science. Furthermore, the Michigan State course only addresses learning through problem solving and does not integrate the knowledge acquisition components. Ryan McFall, who is a project assistant for the proposed project, is a member of the design team for the Michigan State course.

Related Problems

This project will also address the following associated problems, though these will not be part of the primary focus of the activities.

- Computer science learning is not sufficiently active and collaborative.[7] While studies indicate that active and collaborative learning is more effective than learning that is passive and non-interactive, much of computer science is still taught using the conventional lecture/textbook approach.

- Computer Science classes are often unfriendly to women and those with disabilities. [8,9] Ample evidence for this is found in the small number of women and students with disabilities enrolled in Computer Science courses. This national problem is exhibited at Hope College as well. Whereas 59% of Hope's total enrollment is female, only 38% of the enrollment in the Computer Science General Education Course is female and less than 10% of Computer Science majors are female.

- Assessment of Computer Science learning is inadequate. In a discipline where testing and verification are important issues for scientific study, little has been done to apply scientific techniques to the assessment of the learning process.

3.0 Proposed Project

3.1 Goals and Objectives of the Project

1. Integrated Learning Environment

1.1. The Integrated Learning Environment will enhance the ability of students to integrate their learning among the four modes in the context of the general education course in computer graphics. This environment will include text material, lecture support material, student laboratory activities, and individual problem solving activities integrated into a single package that can be accessed through the World Wide Web. It will be tested by completely implementing the general education course, Introduction to Computer Science through Graphics, within this environment.

1.2. The Integrated Learning Environment will be transportable to other courses and other institutional environments. The transportability of the environment to other courses will be established by implementing selected modules in an introductory computer science course, a core computer organization and architecture course, and a non-technical First Year Seminar course. Transportability to other institutions will be examined by establishing test sites at other schools for the general education computer graphics course and for development of new curricular materials using the Integrated Learning Environment.

2. General Education Course, Introduction to Computer Science through Graphics

2.1. Students completing the general education computer graphics course will exhibit improved problem solving ability. The students will better meet the course objectives of the general education course through the use of the environment to integrate the practice

of problem solving with the presentation of knowledge and through interaction with other students and the course instructor supported by the environment. It has already been established that the computer graphics approach stimulates interest and improves student problem solving skills[11] and the implementation of the course in the integrated environment will result in further improvement through better connections between the four modes of learning.

2.2. Students completing the general education computer graphics course will be able to demonstrate an understanding of the nature of computer science as a discipline and show an increased interest in pursuing further study of the field. The general education course will promote better student understanding of the field of computer science by allowing students to participate in the fundamental process of computer science, problem solving, in a context (graphics) that is intuitive and enjoyable. The environment will provide the opportunity to include links that will expose the students to the ideas and experiences from many areas of computer science, and stimulate student interest in further study.

3.2 Procedures and Methods

3.2.1 The Integrated Learning Environment

A key component in this project is the development of an environment that will integrate the four learning modes. This environment will reside on the World Wide Web, and will incorporate the features of the web to great advantage. Such features include:

- Hypertext links to related material, both within and outside of the local site.
- Access to multimedia capabilities including graphics, sound, and video.
- Platform independence permitting access from a variety of locations including the classroom, campus computer labs, dormitory rooms, and remote locations.

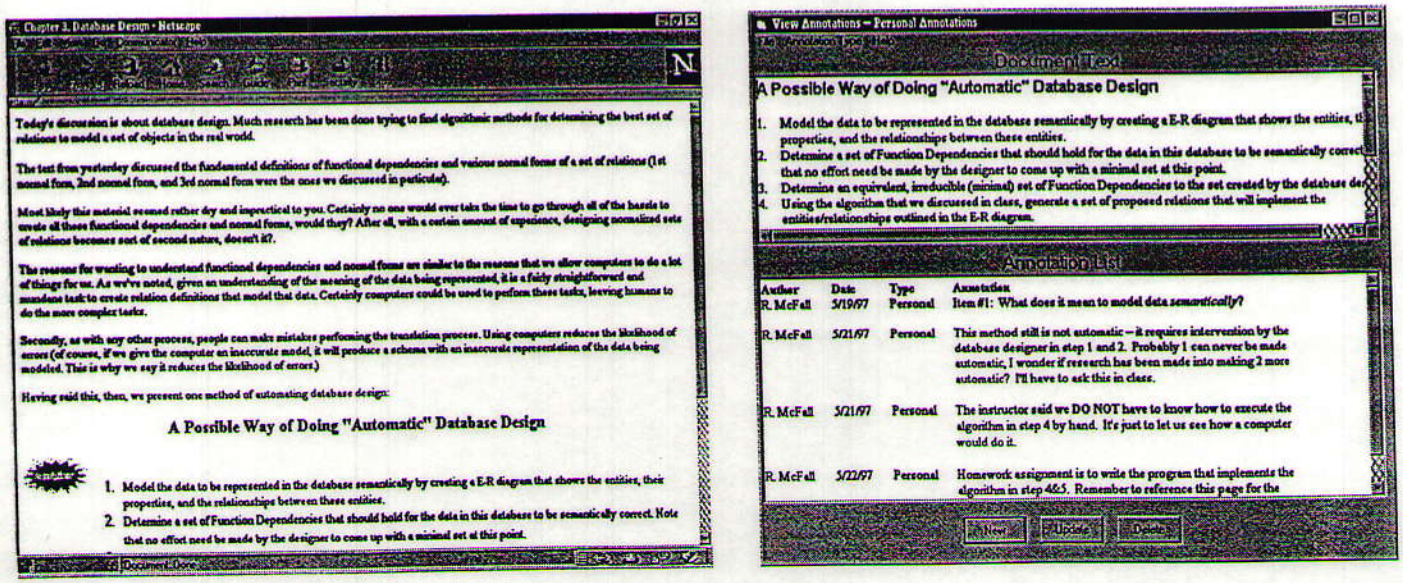
In addition, we will develop several enhancements to the web environment. The first of these is a **Program Development Environment.** This environment will provide a window within the web page that will permit the student to enter complete programs or edit programs provided within the page. After the editing process has been completed, the student can select the run button and the program will be compiled, with compiler messages presented in a separate window. If the compile is successful, the program will be run with the resulting output also appearing in a separate window. Although the original implementation of this environment will be in support of the programming language Java, we plan to extend this to make it as language independent as possible. A possible view of the Program Development Environment is found in Appendix D.

A second important tool within this environment is the **Annotation Engine.** The purpose of this engine is to provide easy and effective communication between students and the instructor and between the student and herself. This tool will permit the learner, when working with each

page of the course materials, to make an annotation on that page. When the annotation is made, it can be directed to one of two destinations: the instructor or the learner. If the annotation is directed to the instructor, it will appear on the instructor's annotation window for the active page the next time the instructor views that page. If the destination is the learner herself, the annotation will appear on the learner's annotation window the next time she views that page. Annotations for a page appear as an icon which indicates whether the annotation text is empty or not. Clicking on the icon results in the annotation window for that page appearing. Any user may then read the text in her personal annotation window, edit it in any way, and perhaps delete it.

The Annotation Engine will have many uses within the class related to each of the four modes of learning. Annotations by the instructor directed at the students allow the instructor to provide special instructions or explanatory information. Student annotations to the instructor can be used to raise questions or present solutions to exercises. Student annotations to themselves will permit the students to take margin notes or place special reminders.

An example of a prototypical view of the Annotation Engine is given below, where the right-hand screen shows what might appear if the annotation icon is clicked in the left screen:



3.2.2 General Education Course - Introduction to Computer Science through Graphics

The Course Components

- **Graphics:** All computer output in the course is graphical. All problems and projects use graphics objects. There is ample room for mathematical analysis, but students never compute columns of numbers. This approach has broad appeal. Within just a few days students can generate complex patterns, and shortly after that they can construct animations. Students gain experience with abstraction, complex problem solving, and algorithmic design, analysis, and testing in an intuitive context.
- **Projects:** There are six programming projects, all graphical, open-ended, and gender-neutral. Video games or competitive simulations are avoided. Instead projects require students to make deliveries around a virtual town, design quilts, construct a college dance (different groups of people do different actions), or draw a picture of a city skyline. Projects are designed to be done in groups and all are flexible and open-ended so that each group produces a product that is different from those of the other groups. Groups often present the results of their projects to classmates.
- **Homework:** The course is designed so that some computer work is required of the student almost every class day. There are fifteen homework exercises which illustrate and implement class material. They are all small programming problems, and all use graphics. Each student produces her own solution, but collaboration with other students is important in the discovery of key ideas.

- **Laboratories:** Laboratory work is distributed throughout the course in short modules. There will be approximately 50 such modules, with at least one used during each class meeting. Some of the modules deal with aspects of learning the programming language, and others with general computer science topics appropriate to the course: simulation; cellular automata; software testing; and fractals. All of the modules require team effort. Rather than isolating the laboratories in a single time period during the week, they will be embedded within the course at various points. Examples of two laboratories are found in Appendix B.

Outline of the course

1. Introduction: Course goals, Java, and the environment
2. Move/Draw graphics: lines, circles, rectangles, ovals, pixel coordinates and dimension
3. Repetition: for loops, variables, functions, random numbers
4. Motion: animation, color, operators, data types
5. Conditionals: if, nested loops, DeMorgan's Laws, fill, circular functions, if structures, distance, abs
6. I/O and Text: Event loops, strings, conditional loops, simulation, optimization loops
7. Arrays: operations on arrays, parallel arrays, indirect addressing, cellular automata
8. Algorithms: Shuffling, sorting, searching, recursion, fractals

Use of Integrated Learning Environment

An objective of this project is to implement this course within the previously described Integrated Learning Environment to strengthen the connections between the four modes of learning. Features of the Integrated Learning Environment in this course are presented here.

Classroom presentations and demonstrations will be placed within the context of the

Integrated Learning Environment. These presentations may then link to other component such as the text or lab components. The classroom presentations and demonstrations will also be available to the student outside of the classroom for use during other modes of learning.

Laboratory activities will also be placed in this environment. This permits the laboratories to easily link to appropriate classroom and text material. Laboratory activities will be done in groups of two in the classroom/laboratory and this in-class environment will permit seamless integration of presentation and lab activities. It is anticipated that the instructor will never present for more than 7 minutes before some kind of lab activity will occur. The Program Development Environment will be used heavily in labs. Typically code to be modified or skeletal code will be provided for students to modify or complete in the lab setting. Teams will present their solutions to the entire class through big-screen projection in the classroom, through web page links, or through instructor-distributed annotations. Homework, text, lectures, and exams will be linked within the environment to laboratory activities.

The **text** material for this course will be written as a part of this project and become a part of the Integrated Learning Environment. This text will include links to laboratories, homeworks, and classroom presentation materials. It will also utilize the Program Development Environment for demonstration and practice, the Annotation Engine for personal and instructor annotations, and links to various animations and external sources such as language reference material or tutorials. Stegink and McFall have previously implemented part of the language reference material for this course on the web. See Appendix C for a sample page.

Homework exercises will be intended for individual problem solving and will be linked to the appropriate information in presentations, text, or laboratories. Annotations associated with

homework will permit easy communication between instructor and student.

Examinations will also be within the Integrated Learning Environment, again with appropriate links. Policies and formats for exams have not yet been determined, but various alternatives will be explored during the course of this project.

Course **assessment** information will also be obtained through the Integrated Learning Environment. Each web page will contain a field that will identify the course objective that is being addressed by that page. In this way, coverage of all objectives will be verified, while both student and instructor can focus on the objective being addressed by every learning activity. As student mastery is assessed, a record will be kept by objective so that an overall assessment of each objective will be available. In addition, assessment data will be collected by measuring the activity on each web page by student and by date, and students will be asked to provide assessment information at various points in the course via annotation submission or email.

Overview of General Education Course Development

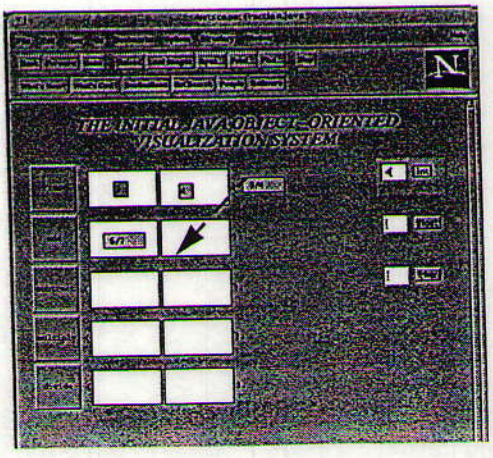
Prior to May, 1997	• Design of graphics-based general education course using Turbo Pascal, including projects and homework exercises • Development of extensive laboratory activities used within closed lab setting • Development of a web-based textbook for reference to Pascal features
May, 1997 - May, 1998	• Adapt course to combined classroom/laboratory including short modules for lab activities • Convert language used in course from Pascal to Java • All course material placed on web and accessible both in and out of class • All work in class done cooperatively
After May, 1998 funded by proposed project	• Full integration of text material with lab/lecture material in Integrated Learning Environment • Submission and evaluation of work using Annotation Engine • Use of Program Development Environment within course materials • On-line assessment of student learning and effectiveness of environment will be integrated into the environment itself

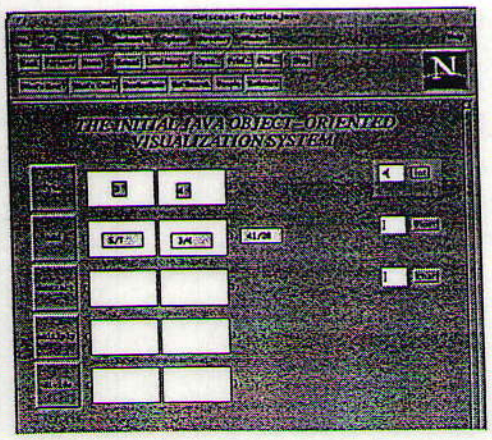
3.2.3 Use of Integrated Learning Environment in Other Courses

In order to evaluate the applicability of the Integrated Learning Environment to other types of courses, three courses in the Hope College curriculum will be used to further test this environment.

Computer Science 225, Software Design and Implementation, is the CS1 course offered at Hope College. It introduces problem solving through the object-oriented model and the C++ programming language. It is presently being adapted to the NSF ILI-funded combined classroom/laboratory environment, meets for five 50-minute periods per week and fully integrates group knowledge acquisition (lecture and discussion) and group problem solving (laboratory activities) in a unified time and location. To examine the usefulness of the Integrated Learning Environment in this course, we propose the development of 3 modules using the environment.

The first module will be the introduction of classes and the object-oriented model. Integrated text and animations will be used where the animations will represent classes by containers that show the value of the components of the object. Functions will be represented by a container for each parameter. When objects are dragged into the parameter boxes of a function and the function's activation button is clicked, the result object appears to the right. A view of how this animation might appear follows:





A second module of Computer Science 225 that will be implemented using the integrated environment will be the introduction of C++ language features such as assignments, conditionals, and iterations, using the Program Development Environment adapted to the C++ language.

The third module implemented will be a module on recursion that will make use of animations to illustrate the concept of recursion. Activations of functions will appear in the animation at each recursive call, showing code text and parameter values. The activation stack will be animated.

Computer Science 283, Introduction to Computer Systems, is a sophomore level requirement for majors in Computer Science at Hope College. This course includes computer organization, digital logic, machine architecture, and assembly language. We propose the development of materials in three areas of this course.

The first area is in computer organization and machine architecture. Here, students will use simulations to experiment with architecture configuration and organization. By using simulation techniques and software packages, student experiments will include altering various cache sizes, changing the speed of buses, or altering the characteristics of instruction pipelines. By gathering information and tabulating results in class, students will participate in discussions about the effects of architecture design.

The second area is in digital logic. Chip design software and simulated architectures will stimulate class discussions about digital components and logic circuits. Topics like circuit reduction and signal propagation will make much more sense when small experimental activities are started in class.

The third area is assembly language. The use of demonstrations and examples will

improve student understanding and skills. Students use both the SPARC architecture and the Java Virtual Machine in class investigations, and participative activities within the Integrated Learning Environment can be more meaningful to students than reading a book.

A third course whose adaptation to this environment will be examined in this project is a new course at Hope College. It is a Computer Science offering of the **First Year Seminar**. The First Year Seminar is a newly established general education requirement of every student at Hope College and must be taken during the first year of study. First Year Seminars will be offered with a wide variety of topics, but all will require students to:

- Explore an intellectually important topic with an instructor and with peers.
- Investigate specific topics and write up their conclusions in an expository paper.
- Present ideas for discussion and critical reflection.
- Where appropriate, engage in problem-solving in a small group context.
- Learn about the purposes of a liberal arts education, including personal and intellectual development as well as professional and career preparation.

The Principal Investigator will offer a course entitled "Culture and Cyberspace" during the 1998-99 academic year. This will be a new offering and it will be offered using the Integrated Learning Environment The tentative outline of the course is as follows:

Culture and Cyberspace

1. Definition and history of culture
2. Impact of technology on cultures of the past
3. Impact of technology on present cultures
4. Impact of technology on future cultures
5. The concept of cyberculture

The Integrated Learning Environment will be used in this course in the following ways:

- Topics will be introduced through the "textbook" environment with full use of hyperlinks and the Annotation Engine.
- Students will set up among themselves experimental "societies" on the web within the class environment and observe and analyze the results.
- Students will be required to develop their own modules for this course and place them within the course "textbook" in the web environment.

3.2.4 Expected Impact on Women and Persons with Disabilities

The investigators expect that the results of this project will encourage more women to become computer science majors. The emphasis on collaborative, cooperative learning should make the course more female-friendly.[14] Also, studies have shown that women tend to be less aggressive in classroom participation. The interaction via the Annotation Engine through the World Wide Web will encourage more interaction with the instructor and other students.

Since two of the courses are general education, more women who do not see themselves as potential computer scientists may be introduced to the field and consider computer science as a career. It has been our experience that as the amount of cooperative work in computer science general education offerings increases, more women continue from general education to computer science courses. We expect that the present project will have an even greater impact on this trend.

The results of this project should make computer science study significantly more accessible to students with disabilities. The integrated environment will make full participation in the class less dependent on location and time and will permit interaction with instructor and classmates from virtually any location, greatly benefiting students with disabilities that limit their mobility and hence their physical access to other participants in the class. In addition, students with communication limitations will more fully participate through specially adapted stations.

3.3 Experience and Capabilities of the PIs

The investigators have many significant related experiences and accomplishments to bring to this project. In addition, Mr. Ryan McFall will be employed as a project assistant to participate in the development of the technology and pedagogy. Mr. McFall has been both a student and a colleague of all three of the investigators. His Curriculum Vitae is found in the appendix. McFall is a member of the design team for a new general education Computer Science course at Michigan State University that features cooperative, interactive learning.

The assignments of the investigators and the project assistant will be as follows:

Project Component	Responsible Investigator(s)
Integrated Environment • Program Development Environment • Annotation Engine	Jipping and McFall
General Education Course - Computer Science through Computer Graphics	Course Design: Stegink Web-based Course Materials: Dershem
CS1 Course - Software Design & Implementation	Dershem and Stegink
Computer Architecture Course - Introduction to Computer Systems	Jipping
First Year Seminar - Culture and Cyberspace	Dershem

The proposed project makes use of the web to integrate learning that occurs in the classroom, the laboratory, and the textbook. The investigators have prepared for this project through a variety of professional experiences that have directly effected each of these four components as well as many of the interfaces between them. All of the experiences described below have occurred in the past five years.

Through work on a DARPA grant, investigator Dershem has developed algorithm animation facilities that are presently being converted to the web. [12] These and other animations will be embedded within the web-based material that will be developed during this project.

Investigator Jipping has developed web-based, interactive laboratories for Operating Systems and Networking classes with support from NSF ILI grant DUE-9550902.[13] These laboratories integrate individual and group problem-solving and give Jipping experience in the development of web-based, interactive, group laboratories.

Investigator Stegink was a participant in the NSF/CLUB project (NSF grant USE-9150562) for the development of Computer Science laboratory materials, where he developed an extensive set of graphics-based laboratories for an introductory Computer Science. These laboratories form a core of the lab experiences included in the general education course.

All 3 investigators are developing a combined classroom/laboratory environment (NSF ILI grant DUE-9650129) that facilitates the seamless movement between lecture and laboratory work and eliminates the chronological and physical separation of these two modes of learning.

The three investigators have a combined total of 53 years of computer science teaching experience at Hope College.

Investigator Stegink and project assistant McFall have developed web-based text materials for the course that is the predecessor of the proposed general education course.[11] This work has provided valuable experience in the use of the web for the presentation of text.

Investigators Dershem and Jipping have written an undergraduate programming language textbook[10] that has now appeared in two editions.

3.4 Time Table and Plan for Executing the Project

Time Period	Activity	Personnel Assigned	NSF Funded?
Summer 1997	Initial development of Integrated Learning Environment including Annotation Engine and Program Development Environment.	Jipping McFall	No
	Initial development of general education course materials integrating classroom presentation and lab activities. Presentation of laboratories and homeworks in the Integrated Learning Environment.	Stegink Dershem	No
Acad Yr 1997-1998	Refinement of the Integrated Learning Environment based on usage in all Hope College computer science classes.	Jipping	No
	Initial offering of the general education course using materials developed the previous summer.	Stegink	No
Summer 1998	Enhancement and further development of Integrated Learning Environment.	Jipping McFall	Yes
	Preparation of the fully integrated version of the general education course, particularly the preparation of the textbook material and the integration of text with the other components.	Stegink Dershem	Yes
	Design of modules for Computer Architecture Course	Jipping	Yes
	Design of modules for First Year Seminar.	Dershem	Yes
Acad Yr 1998-1999	Offering of general education course using fully integrated materials.	Stegink	No
	Modules using Integrated Learning Environment tested in First Year Seminar (Fall Semester)	Dershem (half-time release)	No
	Modules using ILE tested in Computer Architecture course (Spring Semester)	Jipping (half-time release)	No
	Workshop presented at SIGCSE Symposium to present Integrated Learning Environment and general education course. This workshop will be used to recruit volunteer testers	Dershem Jipping Stegink McFall	No

Time Period	Activity	Personnel Assigned	NSF Funded?
Summer 1999	Final revisions to Integrated Learning Environment and preparation for dissemination	Jipping McFall	Yes
	Final revision of general education course materials and presentation to publisher(s).	Stegink Dershem	Yes
	Design of modules for CS1 course. Preparation of paper on First Year Seminar.	Dershem	Yes
	Revision of Computer Architecture modules	Jipping	Yes
Acad Yr 1999-2000	External testing of Integrated Learning Environment and general education course materials by volunteer testers at other institutions	Dershem	No
	Modules using Integrated Learning Environment tested in CS1 course (both semesters)	Dershem (half-time release Fall) Stegink (half-time release Spring)	No
	Revised modules tested in Computer Architecture course	Jipping	No
	Presentation of paper on First Year Seminar	Dershem	No
Summer 2000	Final revisions of general education "textbook" for publisher	Stegink Dershem	Yes
	Preparation of publications and dissemination information on Computer Architecture course	Jipping	Yes
	Preparation of publications and dissemination materials for CS1 course	Dershem	Yes
	Preparation of final report for project and publications on Integrated Learning Environment and final revisions based on external testing	Dershem Jipping	Yes

3.5 Facilities Available for Realizing Project's Objectives

The main facility related to this project is the Computer Science Department combination classroom and laboratory, called the clabroom. This room was developed with funding from an NSF ILI grant. It contains twelve Sun Ultra-1 workstations in a classroom setting. These stations are all part of the computer science department's network of 35 Sparcstations. This room also contains big-screen projection facilities with the ability to project any station's screen at a given time.

In addition, the department has an instructional laboratory that contains 9 Sparcstations. This will be used for out-of-class access to the Sun network. Since access to the network is possible through the World Wide Web, any of the over 200 general use computer stations on campus could be used by students to access the materials we will develop in this project. These include a mixture of Intel-based machines, Macintoshes, Decstations, and Sparcstations. These are located in classroom buildings, residence halls, the library, and in laboratories. At the present time one-half of all dormitory rooms on campus are wired with in ethernet connections. In the summer of 1998 another quarter of the campus rooms will be wired and by the end of the summer of 1999, all rooms on campus will be wired with ethernet. This will allow all students living on campus to have access from their rooms.

4.0 Evaluation

4.1 Evaluation Activities

A. **Pre and post test of student group problem solving** - Professor Green, Director of the Hope College Carl Frost Center for Social Science Research, will conduct a pre-test and post-test of the students enrolled in the general education course. The purpose will be to measure the improvement in group problem solving skills during the students' enrollment in this course. These tests will be based on previous work that Professor Green has done in comparative testing of group problem solving.

B. **Focus Groups** - Focus groups designed and conducted by Professor Green will assess the effectiveness and usefulness of the Integrated Learning Environment, active/ collaborative learning, instructor-student interaction, and interest in future computer science study. These focus groups will be conducted in each of four semesters of the 1998-99 and 1999-00 academic years.

C. **External reviews** - Three external reviewers will be used to review the material developed for all of the courses. Since the materials will all be web-based, the reviewers will be able to review from a remote location and submit written reviews to the investigators. Review of the general education materials will be conducted during the summer of 1999 and review of the modules developed for the other three courses will occur during the summer of 2000.

D. **Student evaluative comments** - Part of the required responses from students will be evaluative comments on the effectiveness of the material they are using. Such

opportunities will be embedded periodically within the web-based material and responses from students will be analyzed and used to determine revisions.

E. **Usage data generated by the environment** - The environment will automatically record usage data, such as the number of times each student accesses each page. Such data will be collected for each student enrolled and by date.

F. **Demographic and enrollment data** - Data will be kept on students enrolled in each course, recording demographics about the students and courses for which they enroll after the observed course. This data will also be examined and analyzed by gender.

G. **Reports from volunteer testers** - Volunteer testers from other institutions will be asked to submit a report on their experience with the Integrated Learning Environment and the course materials. These volunteers will be recruited at a SICSE 1999 Symposium workshop.

The above activities are associated with the objectives of the project as indicated below:

Project Component	Objective	Activities
Integrated Learning Environment	1.1 Integrate four modes of learning	*B D E*
	1.2 Transportable	*C G*
General Education Course	2.1 Improved problem solving	*A C*
	2.2 Increased understanding of and interest in computer science	*B C D F*

4.2 Qualifications of Evaluators

The following three individuals have agreed to serve as external reviewers for this project.

- Charles Kelemen, Professor of Computer Science, Swarthmore College. Professor Kelemen is an acknowledged expert in computer science general education. He was a

contributor on this subject to the Strategic Directions in Computing Research project of ACM Computing Surveys. [6]

- Professor Ted Sjoerdsma, Professor Emeritus of computer science, Washington & Lee University. Professor Sjoerdsma is nationally recognized as a leader in computer science education, a CSAB evaluator, and a former NSF program officer.

- Professor Lynn Ziegler, Professor of Computer Science at the College of Saint Benedict/ St. John's University, is a leader in cooperative learning in computer science.

The Carl Frost Center for Social Science Research is an interdisciplinary and cooperative endeavor of the students and faculty of the social sciences division of Hope College. It's purpose is to foster collaborative student-faculty research in social science and promote the interdisciplinary study of organizational development and well-being.They offer financial and methodological support to a wide variety of student-faculty research projects. They have human resources in the form of highly-trained faculty and bright, motivated students. They also have access to a wide array of computer hardware and software, a system for generating survey sheets that can be scored by an optical scanner, and other related facilities.

The professional staff includes Charles W. Green, Director and Associate Professor of Psychology at Hope College. He received his Ph.D. in Social Psychology from the University of Florida in 1983 and has taught at Hope College for thirteen years. His research interests include race/ethnic relations and the academic and social development of college students. He became director of the Frost Center in 1992 and has supervised numerous research projects with governmental, non-profit and corporate organizations. Barbara J. Neper has been Research Associate at the Frost Center since August, 1995. She completed her M.S. in Educational Psychology at the University of Wisconsin-Milwaukee in 1994. She has experience in the fields of community, medical, and educational research. She is knowledgeable in survey design, sampling, focus group moderation, and data collection and analysis.

5.0 Dissemination of Results

Project Component	Dissemination plan
Integrated Course Environment	• A workshop will be proposed for the 1999 SIGCSE Symposium to present the ILE and recruit external testers for it. • A paper describing this environment will be submitted for publication and presentation at the SIGCSE Technical Symposium or to a Conference of the Small College Computing Consortium. • Environment will be demonstrated and distributed on the World Wide Web
General Education course material	• The 1999 SIGCSE Symposium workshop will include information about these materials and recruit external testers for it. • Efforts will be made to make the course material commercially available through a publisher. • A demonstration of the material will be placed on the World Wide Web. • A paper describing this course will be submitted for publication and presentation to SIGCSE or SCCC.
Other course modules	• A demonstration of the material will be placed on the World Wide Web with download capabilities included. • Papers describing the modules developed in these courses will be submitted for publication and presentation to SIGCSE or SCCC.

The Web-based course materials developed for the CSCI 120 course will be presented to commercial publishers to solicit their interest in commercially publishing these materials.

The software supporting the integrated environment will be made freely available on the World Wide Web. Also, a web-based manual will be made available to assist others in constructing courseware within this environment. The availability of these materials will be listed in appropriate directories on the web.

The investigators have contacted three publishers about their interest in publishing the CSCI 120 course materials for commercial distribution. All three have indicated a strong interest in participating in this project.