INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.B. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Gerry Stahl

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.B. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Curtis LeBaron

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☐ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☐

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 01-2		FOR NSF USE ONLY
PD 98-6850	02/15/01	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)		
IIS - COMPUTATION & SOCIAL SYSTEMS		

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				007431505	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYMS(S)
846000555	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Colorado at Boulder	Admin. & Res. Center - East Campus 3100 Marine Street, Room 481, 572 UCB Boulder, CO. 80309
AWARDEE ORGANIZATION CODE (IF KNOWN) 0013706000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

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

TITLE OF PROPOSED PROJECT **CSS: Perspectives on Collaboration**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PREPROPOSAL NO., IF APPLICABLE
$ 307,718	36 months	09/01/01	

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

- ☐ BEGINNING INVESTIGATOR (GPG I.A)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.B, II.C.6)
- ☐ NATIONAL ENVIRONMENTAL POLICY ACT (GPG II.C.9)
- ☐ HISTORIC PLACES (GPG II.C.9)
- ☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.C.11)
- ☐ VERTEBRATE ANIMALS (GPG II.C.11) IACUC App. Date ____
- ☐ HUMAN SUBJECTS (GPG II.C.11) Exemption Subsection ____ or IRB App. Date ____
- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED ____
- ☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.E.1)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
ICS/Computer Science, Campus Box 430	University of Colorado at Boulder Boulder, CO 803090430 United States
PI/PD FAX NUMBER 303-492-2844	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Gerry Stahl	Ph.D.	1993	303-492-3912	gerry.stahl@colorado.edu
CO-PI/PD Curtis LeBaron	Ph.D	1998	303-492-7488	curtis.lebaron@colorado.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

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 proposal.

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 a criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Social Security No.*	Date
PI/PD Gerry Stahl		SSNs are confidential and are not displayed *ON FASTLANE SUBMISSIONS*	
Co-PI/PD Curtis LeBaron			
Co-PI/PD			
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 made 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 if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 01-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuring award is a criminal offense (U. S. Code, Title 18, 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 has 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 of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflict which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Debarment Certification

(If answer "yes", please provide explanation.)

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 or 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 in 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 cooperative 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 or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure Form to Report Lobbying,'' 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 accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this 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) Laurence D. Nelson, Director, OCG		02/01/01

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
303-492-6221	Larry.Nelson@colorado.edu	303-492-6421

*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 INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

Perspectives on Collaboration:
a Micro-ethnographic Study of Computational Perspectives in Computer Support for Collaborative Knowledge-Building at a Virtual Biology Laboratory

Project Summary

Collaborative Knowledge-Building

This project undertakes a study of small groups constructing scientific understanding as a process of collaborative knowledge-building. It designs, develops, deploys, and studies computer support for such collaboration, especially under conditions in which participants are not co-located and cannot engage in face-to-face interaction. Collaborative knowledge-building is conceived as a set of related activities through which a group develops a gradually deepening understanding of some area of inquiry. It contrasts both with cognitivist views of learning focused on the individual and with support for exchange of personal opinions or short-term decision-making.

Computational Perspectives

A key structure of collaborative knowledge-building is perspectives. Collaboration proceeds largely through the making and taking of personal and group perspectives. This project investigates the support of such a knowledge-building structure through the use of "computational Perspectives," which represent or support the evolving network of personal and group perspectives. The central research question is whether participants in computer-mediated collaboration can effectively and intuitively make use of a computational Perspectives mechanism.

Cognitive Artifacts

The ability to engage in scientific knowledge-building is dependent upon the ability to understandingly use a variety of scientific artifacts. Artifacts such as simulations, analysis tools, and data sheets significantly extend the power of native human cognitive abilities; they also serve as persistent communication media to express and preserve insights for others. This project conceptualizes computer support systems as sets of cognitive artifacts. It conducts micro-analyses of how people – individually and as communities – develop a practical understanding of these artifacts.

Micro-ethnographic Analysis of Interaction

Micro-ethnography is a rigorous social science that incorporates recent methods and findings from the analysis of verbal and visual human interaction. It uses digitized video to study interpersonal behavior at a detailed level. Micro-ethnography will be used in this project (a) to analyze the structure of negotiation in small group meetings in order to design software support of negotiation of ideas in personal and group Perspectives; (b) to study how people learn to use computer-based and internet-based cognitive artifacts that are part of a virtual biology laboratory; (c) to study specific distance-collaboration software as effective media for supporting perspectives in knowledge-building.

Study of a Virtual Biology Laboratory

The project will ultimately study collaborative knowledge-building at a virtual biology laboratory used in geographically distributed high schools for advanced placement biology courses. A website containing the virtual biology lab is currently being developed at the University of Colorado; this project will assess its effectiveness in use by college freshmen and contribute to its iterative design (in Year I). The project will also develop a collaborative knowledge-building environment (in Year I) and integrate this with the lab (in Year II). Then (in Year III), micro-ethnographic methodology will be used to assess the use of this software – especially the use of computational Perspectives – by distributed high school students, and contribute to its iterative design.

Building on Previous Research

The project PIs and Advisory Board members have conducted research projects (including a three-year CSS grant) and specific pilot projects that form a foundation for the proposed research. The PIs have previously developed knowledge-building environments with computational Perspectives for designers and students, have studied the theory of cognitive artifacts, and have engaged in micro-ethnographic analysis of students learning to use a scientific simulation. This and related work by others motivate new features and research issues. A previous Perspectives system will be extended with additional functionality and re-structured for integration with the virtual biology lab, for release as Open Source, for use in distance collaboration, and for micro-ethnographic analysis.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.C.

Section		Total No. of Pages in Section	Page No.* (Optional)*
Cover Sheet (NSF Form 1207) (Submit Page 2 with original proposal only)			
A	Project Summary (not to exceed 1 page)	1	
B	Table of Contents (NSF Form 1359)	1	
C	Project Description (plus Results from Prior NSF Support) (not to exceed 15 pages) **(Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**	15	
D	References Cited	5	
E	Biographical Sketches (Not to exceed 2 pages each)	5	
F	Budget (NSF Form 1030, plus up to 3 pages of budget justification)	6	
G	Current and Pending Support (NSF Form 1239)	2	
H	Facilities, Equipment and Other Resources (NSF Form 1363)	1	
I	Special Information/Supplementary Documentation	2	
J	Appendix (List below.) **(Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**		

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Perspectives on Collaboration:
a Micro-ethnographic Study of Computational Perspectives in Computer Support for Collaborative Knowledge-Building at a Virtual Biology Laboratory

PROJECT DESCRIPTION

1. Collaborative Knowledge-Building

This project undertakes a study of small groups constructing scientific understanding as a process of collaborative knowledge-building. It designs, develops, deploys, and studies computer support for such collaboration, especially under conditions in which participants are not co-located and cannot engage in face-to-face interaction. Collaborative knowledge-building is conceived as a set of related activities through which a group develops a gradually deepening understanding of some area of inquiry. It contrasts both with cognitivist views of learning focused on the individual and with support for exchange of personal opinions or short-term decision-making.

Learning as Collaborative Knowledge-Building

The term "learning" can refer to a wide range of phenomena, from the accumulation of facts to the development of deep understanding; from the experience of something new to the mastery of specific complex skills. Attempts to assess learning range correspondingly widely, from assumptions that people are always learning to frustration that people cannot transfer what they have learned to new circumstances (Russell, 1999). For the assessment of learning in the sciences, we prefer the term "knowledge-building" (Bereiter, 2000). This refers to the progressive creation or construction of knowledge about a specific topic of inquiry (Dewey & Bentley, 1949/1991). For instance, a group of students may gradually propose tentative answers to a scientific question, accumulate relevant data, debate alternative arguments, and converge toward a deeper understanding of the phenomenon (Donald, 1991). This process of knowledge-building takes place within a community of inquiry, in which experiments can be replicated, assumptions questioned, and insights discussed (Scardamalia & Bereiter, 1996). Knowledge-building is an interpersonal process that can be observed and documented (e.g., using the micro-ethnographic methods described below), unlike learning, that is generally taken to be a psychological phenomenon that can at best be inferred indirectly through tests or other outcomes (Lave, 1991).

Knowledge-building is inherently collaborative. By "collaborate" we simply mean "to work together" (from the Latin *com laborare*). To build knowledge is to formulate theories and similar bodies of knowledge that are (or at least could, in principle, be) shared by a group of people and that meet criteria for contributions to knowledge that are accepted within a scientific community (Latour & Woolgar, 1979). A high school biology class, for instance, must develop knowledge of biological phenomena and theories that meet criteria that gradually approach the standards of the field of biology. Although knowledge may necessarily involve the minds of individuals, it is generally the result of interactions with other people, with cultural artifacts, and with shared language (Vygotsky, 1930/1978). It is therefore often useful to conceptualize and analyze learning as distributed across "units of analysis" or activity structures that include small groups, their tools, and their language (Engeström, 1999; Hollan et al., 2000; Hutchins, 1996).

This project is guided by a theory of collaborative Knowledge-Building Environments (KBEs) that we are developing (Stahl, 2000c). The theory proposes the following principles:

- Collaborative knowledge-building is a particular view of group learning that focuses on a range of activities that take place within communities, as opposed to focusing on learning as the transmission of bits of information to individual learners.
- Collaborative knowledge-building takes place largely through the interaction among people with different understandings from multiple personal and group perspectives.

- Such knowledge-building within groups can be helped by appropriately designed computer technology that supports various knowledge-building activities and supports interaction among alternative perspectives.

In the following sections, we discuss our model of knowledge-building, the potential of computer support, and the role of perspectives.

A Model of Collaborative Knowledge-Building

One approach to better understanding how to design computer support for collaborative knowledge-building in social settings is to conceptualize the various constituent activities involved in individual and social knowledge-building. Figure 1 from (Stahl, 2000c) provides a starting point for this, combining aspects of activity theory (Cole, 1996; Engeström et al., 1999; Nardi, 1996), situated learning (Lave & Wenger, 1991), practice theory (Chaiklin & Lave, 1993), hermeneutic philosophy (Gadamer, 1960/1988), and distributed cognition theory (Hollan et al., 2000; Hutchins, 1996).

The idea of this diagram is that knowledge-building can proceed through many different activities. The sequential structure of the model is only illustrative of a typical activity series. We understand that these activities overlap in practice. The possible relationships among the individual activities – and particularly the interactions between the personal and social – can be complex and varied. The purpose of the diagram is to suggest a number of distinct activities that could be supported by software with multiple functionality; the sequential flow is not intended to imply a necessary order to the activities.

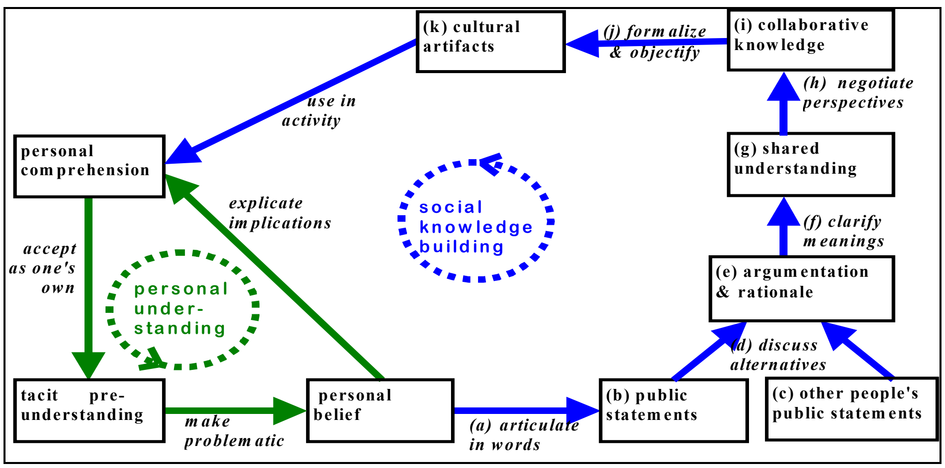

Figure 1. *A model of personal understanding and social knowledge-building*.

A set of seminal books and articles in computer-supported collaborative learning (CSCL) has formulated a view of learning as a social process of collaborative knowledge-building within communities of practice (Brown & Campione, 1994; Brown & Duguid, 1991; Koschmann, 1996; Lave, 1991; Lave & Wenger, 1991; Pea, 1993; Scardamalia & Bereiter, 1996; Wenger, 1998). However, these texts do not make the set of cognitive and social activities that underlie such a view explicit in the manner attempted in our theory.

Starting in the lower left corner, Figure 1 shows a cycle of personal understanding. The rest of the diagram depicts how personal beliefs can be articulated in language and become part of social interaction. Note that the results of social knowledge-building eventually feed back into personal understanding, providing the evolving toolkit of culturally-based individual cognitive capabilities. The collaborative knowledge-building process begins with (a) the articulation in language and (b) the confrontation of these statements with (c) alternatives from other perspectives. The interplay of perspectives proceeds through various interactional mechanisms, potentially culminating in the reduction of shared knowledge to a text or other persistent artifact (d-k). Computer support for collaboration could support many of the activities represented in the model, including the roles of perspectives.

The Potential of Computer Support

Based on our own experiences with software in classrooms, we have found that computer-supported collaborative learning has a vast – and largely untapped – potential (Kintsch et al., 2000; Stahl, 2000d; Stahl & Sanusi, 2001; Steinhart, 2000). Access to global sources of information is just one facet. In addition, computer simulations can transform conceptual representations into interactive worlds for inquiry. They can transcend real-world barriers of time, expense, geography, scale, expertise, etc. to allow students to engage with and experience phenomena that have until now been unapproachable – such as Nobel prize-winning biology experiments. Hypertext systems of information can personalize presentations to meet individual learning needs, providing links to both remedial and supplemental information. Communication media can promote collaboration in ways never before possible, as well as among people who could not hitherto interact, allowing students to work with other students with similar interests far away. Structured curricular databases and shared knowledge-building environments can support student learning processes by providing access to ideas of scientists and fellow students in persistent forms that can be thought about and inter-related.

However, we have seen that people always use computer artifacts in ways not envisioned by the designers. So, careful study of the artifacts in naturalistic settings is critical to the development of effective collaboration technology. This project will develop and integrate a VIRTUALBIOLOGYLAB Web-based system that embodies these potentials, and will study the degree to which these potentials are achieved in practice.

We have also seen from extensive studies of experimental knowledge-building environments by other researchers – like CSILE/KNOWLEDGEFORUM (Scardamalia & Bereiter, 1996), KIE/WISE (Cuthbert, 1999), and COVIS (Pea, 1993) – that collaboration support for learning can be powerful. Environments like these transcend rote learning of isolated facts by engaging groups of students in discussions and explorations of challenging and meaningful scientific issues. They provide more than generic chat windows to encourage students to engage in scientific inquiry through discussion with other students, and scaffold the exploration of leading scientific themes. Like anyone developing scientific understanding, students should also have knowledge management tools to organize, categorize, revise, summarize, question, and propose. If they are to learn how to approach a topic using scientific modes of thought that are new to them, then their interactions with other students should be scaffolded and supported. We will develop WEBPERSPECTIVES software that supports collaborative knowledge-building activities, and we will integrate WEBPERSPECTIVES with VIRTUALBIOLOGYLAB, incorporating some of the scaffolding mechanisms explored in the systems mentioned earlier in this paragraph.

Knowledge-Building Environments

The form of computer support that we are interested in – a collaborative Knowledge-Building Environment (KBE) – represents a distinctive approach that overlaps related work in educational technology, computer-supported collaborative learning (CSCL), and computer-supported cooperative work (CSCW). Support for learning has traditionally been oriented toward the transmission of information to individual students. Even where it is based on a view of student construction of knowledge, as with Intelligent Tutoring Systems (ITS) for algebra or physics, the goal is measured by testing the incorporation of pre-defined content or methods into the individual's understanding (Wenger, 1987). A more student-centered, constructivist approach is taken by Interactive Learning Environments (ILE), that might, for instance, allow students to create ecologies in SIMLIFE to learn biology, or programs in TURTLE LOGO to explore math concepts (Papert, 1980). In contrast, a KBE primarily supports the group process and leaves matters of content up to the participants (that may include a teacher who raises particular content issues and helps maintain focus, or a website with content and scaffolding). In this way, it applies CSCW approaches to CSCL.

A review of CSCW technology for groups (Kraemer & Pinsonneault, 1990) distinguishes group communication support systems (GCSSs) from decision support (GDSSs). GCSSs are generic communication media like email, chat, threaded discussion, and video-conferencing. KBEs need functionality that is more specifically designed to support knowledge-building activities. GDSSs add tools for specific types of group interactions (e.g., voting) in providing computational tools for group decision making, but tend to support isolated, focused activities that collate the work products and opinions of individual members of a group. Whereas knowledge-building is generally an open-ended evolution, GDSSs focus more on supporting short-term, well-defined decisions. In contrast, a KBE aims to support a broad spectrum of knowledge-building activities – such as activites (a) to (k) in our model – in a way that allows deep knowledge to evolve and emerge over time. Rather than just exchanging participants' existing personal opinions, it supports the construction and interaction of alternative formulations of knowledge. It also supports the interplay of individuals and groups more comprehensively, through integrated mechanisms of divergent computational Perspectives and convergent negotiation processes that treat a group as more than just the sum of its individual members.

Assessments of CSCL and CSCW systems have defined a number of key issues for evaluating the problems and successes of such systems. For instance, in simple threaded discussion forums common problems include: short threads (a tendency for discussions to die quickly), low participation (lack of motivation to participate), few cross-references (little convergence of ideas), and superficial content (minimal depth of investigation) (dePaula, 1998; Guzdial & Turns, 2000; Hewitt & Teplovs, 1999). On the other hand, GDSSs and GCSSs have been shown to decrease communication barriers within the group, while increasing task-oriented focus, depth of analysis, and decision quality (Connolly, 1997; Kraemer & Pinsonneault, 1990). Social informatics studies raise additional issues of software deployment and adoption as well as questions of usability and utility (Kling, 1999). These are some of the dimensions along which we will assess our software within naturalistic learning and working social contexts.

In summary, we want to design, develop, and assess KBEs that go beyond generic chat and discussion systems (that tend to encourage exchange of personal opinions or isolated facts, but not deep shared understanding and critical inquiry). Such systems should include specific tools and structures to promote on-going debate, knowledge management, and group decision-making; however, knowledge-building should go beyond the management and dissemination of existing knowledge to support the emergence of qualitatively new, increasingly shared knowledge within a community (Engelbart, 1962; Engelbart, 1995). The following sections discuss tools to support this within the proposed project.

2. Computational Perspectives

A key structure of collaborative knowledge-building is perspectives (Stahl, 1993a). Collaboration proceeds largely through the making and taking of personal and group perspectives (Boland & Tenkasi, 1995). This project investigates the support of such a knowledge-building structure through the use of "computational Perspectives," that represent or support the evolving network of personal and group perspectives. The central research question is whether participants in computer-mediated collaboration can effectively and intuitively make use of a computational Perspectives mechanism.

Perspectives in Knowledge-Building

Our theory claims that collaboration centrally involves interaction among multiple personal and group perspectives. According to the philosophy of interpretation (hermeneutics) human understanding is fundamentally perspectival. We construct knowledge from our situated perspective in the world: our historical position, cultural tools, and practical interests (Gadamer, 1960/1988; Habermas, 1981/1984; Heidegger, 1927/1996; Stahl, 1975). Computational support for knowledge-building can represent our interpretive perspectives with computational Perspectives (Boland & Tenkasi, 1995; Nygaard & Sørgaard, 1987; Winograd & Flores, 1986). (In this proposal, Perspective–with-a-capital-P refers to the proposed computational mechanism that mirrors human interpretive perspectives-with-a-lower-case-p.) In this sense, *Knowledge-Building Environments (KBEs) with computational Perspectives are designed to support the essential structure of collaboration*. A key working hypothesis of the proposed project is that KBEs benefit from an approach that represents the perspectival nature of collaboration. A goal of the research is to facilitate the incorporation of a computational Perspectives mechanism in KBEs and study its use in settings of distance collaboration.

Computational Perspectives have been explored by the PI in a number of software prototypes, in his dissertation system, and in his theoretical publications (Fischer et al., 1993a; Fischer et al., 1993b; Stahl, 1993a; Stahl, 1993b; Stahl, 1998; Stahl & Herrmann, 1999; Stahl et al., 1995a; Stahl et al., 1995b). In a single-user system, computational Perspectives may correspond to different domains or professional viewpoints on a design problem, such as electrical, plumbing, structural, and heating concerns in architecture (Fischer et al., 1993b). In a KBE to support collaboration, computational Perspectives typically provide personal or group workspaces for the development of different sets of ideas. In this way, they can model the relationships among the various personal and group interpretive perspectives at work in the construction of collaborative knowledge. This project will introduce computational Perspectives into distance collaboration for the first time.

The project will develop a KBE with support for personal and group perspectives. This WEBPERSPECTIVES software will extend functionality we have already developed and deployed in WEBGUIDE (Stahl, 2000d), adapting its architecture for distance collaboration systems. Most communication, conferencing, and collaboration media provide no support for organizing contributions according to who made them, or for building group perspectives from selections out of personal perspectives. Some systems provide two fixed levels: personal and group – either by limiting access to various pieces of information or by defining personal and group workspaces. WEBPERSPECTIVES will be the first system that enables multiple levels of groups and subgroups, and allows new subgroups to be added interactively. Moreover, WEBPERSPECTIVES automatically includes information from certain perspectives in other perspectives (according to a user-defined "content inheritance" lattice of perspectives), so that all information accepted by a group is incorporated in the perspectives of that group's subgroups and members. This provides a computationally supported knowledge management and knowledge-building approach appropriate to the structure of interpersonal collaboration.

Software Support for Perspectives

The core of WEBPERSPECTIVES is a Perspectives server that queries a database of textual contributions to the on-going discussion and provides user interface clients with the notes that are to be displayed in the Perspective requested by the user. The Perspectives associated with a particular knowledge-base form a non-cyclical lattice (each Perspective may have multiple parents or super-groups and multiple children or subgroups). The knowledge-base for a biology class would typically have a Perspective for questions and ideas shared by the whole class, several subgroup Perspectives for teams of students who work together, a personal Perspective for each student, and comparison Perspectives that bring together contributions from the Perspectives of all members of a group. A Perspective defines an electronic workspace in which a person or group can develop ideas and manage information that belongs together – for instance because it represents the beliefs and viewpoint of a particular person, group, domain, or intellectual position. Perspectives structure a shared information space so that special coherent views can be built up and displayed. The mechanism of computational Perspectives is very general and flexible.

The design philosophy behind computational Perspectives as implemented in WEBPERSPECTIVES is that *users have complete control over the content in their personal Perspectives*. Thus, if my personal Perspective inherits conflicting ideas from different team Perspectives that I belong to, I can delete, edit, and rearrange those ideas at will – without affecting how those ideas appear in other Perspectives. Other users can view the contents of my personal Perspective (except for content that I have designated as private) and they can copy items, link to them, initiate public discussions of them, and propose them for incorporation in team Perspectives – but none of this affects how the content of my Perspective is displayed to me. This allows me to build my own Perspective on the topics that are under consideration by the group. I can see what knowledge others are building, incorporate that knowledge into my Perspective, or join in with others to share, discuss, and negotiate. The same design philosophy applies of course to team Perspectives: team members jointly (through negotiation processes) have complete control over the content of their team Perspective.

Inheritance is a central defining mechanism of computational Perspectives as used in this proposal. The ability to define arbitrarily complex networks of Perspectives with multiple layers of sub-groups between the group Perspective and the individual personal Perspectives, and to have the automatic inheritance of content through the network distinguishes this approach from all other systems of "views" and "perspectives." Inheritance in this sense is not class inheritance, but "content inheritance." A given Perspective can inherit content from multiple other Perspectives. This content is aggregated (logical union) in the given Perspective, where it can be over-ridden with edits, deletions, rearrangements, virtual-copying (linking), and additions. The inheritance mechanism is derived from efficient approaches explored in hypermedia, including "delta memory" and "transclusion" (Boborow & Goldstein, 1980; McCall et al., 1990; Mittal et al., 1986; Nelson, 1981; Nelson, 1995). For a discussion of related work, see (Stahl & Herrmann, 1999).

Because new Perspectives can be defined (either in advance or during system use) to inherit from any (non-cyclical) other Perspectives, it is generally useful to define "comparison Perspectives" that aggregate the ideas from team members, including those ideas that have not been agreed upon and migrated to the team Perspective. This is handy for keeping an eye on what one's fellow team members are thinking. Typically, we have set up the inheritance network of Perspectives to have a diamond-shaped profile, diverging out from the total group Perspective via teams to all the personal Perspectives, and then converging back via team comparisons to the group comparison Perspective. This models a collaborative knowledge-building process that combines divergent brainstorming and convergent negotiation.

3. Cognitive Artifacts

The ability to engage in scientific knowledge-building is dependent upon the ability to understandingly use a variety of scientific artifacts. Artifacts such as simulations, analysis tools, and data sheets significantly extend the power of native human cognitive abilities; they also serve as persistent communication media to express and preserve insights for others. This project conceptualizes computer support systems as sets of cognitive artifacts. It conducts micro-analyses of how people – individually and as communities – develop a practical understanding of these artifacts.

Mediated Cognition

We start from three principles enunciated by Vygotsky (1930/1978; 1934/1986):

1. *Mediation by artifacts*. Modern human cognition is thoroughly mediated by physical and symbolic artifacts such as tools and words. We extend this to the use of computer-based artifacts like simulations, data analysis tools, and collaboration media.

2. *Social cognition*. Meanings and practices are first established interpersonally and may then be internalized in individual minds. We take advantage of this by analyzing the interpersonal interactions, that are largely observable to the trained analyst as well as to the participants.
3. *Zone of proximal development*. A student learns most productively when guided somewhat beyond his or her current developmental level by peers or a mentor. We use this principle to design experimental situations in which a small group of students is challenged to engage in a scaffolded scientific task.

The Role of Artifacts

It is possible to re-conceptualize learning (both individual and collaborative) through a focus on the artifacts that are involved. Artifacts – including software artifacts – embody intentionality, meaning, and experiences of their creators and preserve these for future users (Donald, 1991; Hall, 1996). The problem is for users of artifacts to know how to reactivate this stored wisdom. This requires complex skills of interpretation (Gadamer, 1960/1988; Stahl, 1975; Stahl, 1993a; Winograd & Flores, 1986). Education can be viewed as largely the effort to socialize children and other new-comers into a practical understanding of the artifacts and practices that constitute a society's or a community's culture (Lave & Wenger, 1991). The written word and the symbols of mathematics, for instance, are cognitive artifacts that take years of schooling to master. While people have been producing and using artifacts forever (Donald, 1991; Geertz, 1973), we have little experience designing and teaching *computational* artifacts.

Artifacts play an absolutely central role in learning and understanding according to the philosophic roots that underlie the contemporary cognitive theories that Koschmann (1996; 1999) has identified as influential for theories of collaborative learning: situated action (Suchman, 1987), situated learning (Lave & Wenger, 1991), activity theory (Engeström et al., 1999), distributed cognition (Hutchins, 1996), dialogicality (Bakhtin, 1986), and critical inquiry (Dewey & Bentley, 1949/1991). This pivotal role of artifacts can be traced back to Hegel and Marx.

According to Hegel (1807/1967, p. 234 ff), the very basis of self-consciousness and sociality in mutual recognition is thoroughly mediated by the creation and use of artifacts – that embody human consciousness or meaning in their imposed form or design. Marx (1867/1976) argues that the production, circulation, and consumption of artifacts as commodities is both affected by the prevailing social relations and reproduces those relations – and influences how we understand and learn about contemporary artifacts; these commodities are essentially stored labor – physical and intellectual – that comes alive in use. Marx traces the social history of artifacts from simple tools through machinery to computational automated industry. For Husserl (1936/1989), meaning is established and historically sedimented in the form of artifacts; Heidegger (1927/1996) expands this analysis to argue that the life-world of our everyday involvements is structured as networks of meaningful artifacts. More recently, software is seen as a new form of stored meaning or intentionality (Keil-Slawik, 1992; Stahl, 1993a; Winograd & Flores, 1986). For instance, effects of "artificial intelligence" are accomplished by embedding human intelligence in software procedures and knowledge-bases.

Engelbart (1995) and Norman (1993) claim that it is artifacts that make us smart, by amplifying our very limited native abilities like short-term memory and attention. Others (Cole & Griffin, 1980; Pea, 1985) counter that these artifacts change our tasks, rather than simply increasing our powers, but this still places artifacts centrally in our attempts to increase our intellectual capabilities. Donald (1991) argues that the entire enterprise of modern knowing and science only became possible with the development of artifacts like books, that provided external memories that could be circulated and that might outlive their creators. Papert (1980), reflecting on his own learning history, believes that playing with automobile gears as a young child "did more for my mathematical development than anything I was taught in elementary school. Gears, serving as models, carried many otherwise abstract ideas into my head" (p. vi).

If one looks closely at learning – from infancy to kindergarten, formal schooling, and on-the-job – one sees that artifacts (now including computational artifacts) are pervasive. While it is clear that a primary function of education (and socialization into culture generally) is to teach new-comers how to understand and use the available artifacts of one's society or of its specialties, we have only narrow studies of how this takes place. For instance, Bruner (Bruner, 1990) discusses how children acquire the ability to follow and generate narratives as verbal cognitive artifacts, and Hall (Hall & Stevens, 1995) investigates how young students use design tools.

How Artifacts are Understood

In our pilot study of the use of a rocket simulation, it is clear that the process of coming to understand a computer simulation that models a scientific phenomenon is a complex process, that strains the cognitive abilities of middle school students. Without strong guidance from a teacher, the students would at best have treated the simulation as a video game, perhaps competing to get the highest rocket flight, but not investigating the scientific factors that might lead to success.

Although students often make statements that sound like they understand how to construct certain kinds of knowledge, when one watches them struggling through the steps that are actually required one gains a much more detailed understanding of what is involved for a novice, what supports are helpful, and where problems typically arise. For instance, while the students in a pilot study we ran were proficient at taking averages of sets of numbers in a traditional math lesson, they ran into many problems when averaging their rocket simulation data. A major problem had to do with the organization of the data and of their averages on a data sheet. The two teams of students became confused about which rocket heights had been observed by which team, and which averages were associated with them. While an adult experienced with scientific experiments can keep these things straight without thinking about it, the students had to learn this skill. They did this partially by negotiating with the teacher, who alerted them to problems and guided them back on track, and partially by collaboratively applying their own intellectual and communicative skills.

Our work and that of our current and past colleagues explores the use of gesture as well as language in understanding artifacts and in constructing shared understanding of artifacts. Our micro-ethnographic method (see below) is explicitly adapted to making learning visible by systematically attending to the sorts of gestures and bodily interactions that people use to co-construct the meaning of artifacts. In his seminal examples of micro-ethnographic analysis, Streeck (1983; 1993; 1996) focuses on the roles of gesture in making social understanding visible. LeBaron analyzes different forms of gesture that are successively used to build a shared vocabulary of meaningful gestural artifacts (LeBaron, 1998; LeBaron & Hopper, 1997; LeBaron & Koschmann, 1999; LeBaron & Koschmann, 2001; LeBaron & Streeck, 2000). Koschmann also highlights the role of gesture in educational settings (Koschmann et al., 1997; Koschmann & LeBaron, submitted; Koschmann, Ostwald & Stahl, 1998; Koschmann & Stahl, 1998).

Making Knowledge-Building Visible

According to our theoretical framework, learning through interaction with artifacts is an inherently social process, involving either interaction with other people through the artifact or at least interacting with an artifact that was made by other people and that incorporates their intentions. For our research, collaborative interactions have an important characteristic: *in order to collaborate, participants must make their ideas and their relationships visible to each other as part of their communication*. That is, they *make learning visible*. As researchers, we can capture this in video or computer logs and analyze it. That way, we can see how students are relating to computational artifacts and what they are learning in the process. This overcomes the traditional problem of educational assessment, where it is assumed that learning is invisible to researchers and must be inferred from learning outcome measures. Thus, our approach avoids the restriction of educational assessment to the kinds of analyses of pre/post-test statistics and after-the-fact interviews that so often lead to "no significant difference" (Russell, 1999) results, which are of little value for software design purposes.

Of course, not all learning is made visible, so other methods to indirectly measure learning outcomes are necessary and complementary. But focusing on the visible displays of learning prevents the common tendency to lose track of the learning in favor of secondary phenomena that seem easier to describe or quantify. For instance, much of the traditional literature on cooperative learning focuses on small group facilitation, rather than on cognitive and group learning processes. For a recent review of this literature, see (Brody & Davidson, 1998) reviewed by the PI (Stahl, 2000a). Even recent CSCL studies often miss the interesting learning phenomena, e.g., (Hakkarainen & Lipponen, in prep) and (Jong et al., in prep), reviewed by the PI (Stahl, in prep).

4. Micro-ethnographic Analysis of Interaction

Micro-ethnography is a rigorous social science that incorporates recent methods and findings from the analysis of verbal and visual human interaction. It uses digitized video to study interpersonal behavior at a detailed level. Micro-ethnography will be used in this project (a) to analyze the structure of negotiation in small group meetings in order to design software support of negotiation of ideas in personal and group Perspectives; (b) to study how people learn to use computer-based and internet-based cognitive artifacts that are part of a virtual biology laboratory; (c) to study specific distance-collaboration software as effective media for supporting perspectives in knowledge-building.

Micro-Ethnography

For assessing software functionality and usability in this project, we adopt a recent tradition of human interaction analysis (Jordan & Henderson, 1995) that we refer to as "micro-ethnography." This methodology builds on a convergence of conversation analysis (Sacks, 1992), ethnomethodology (Garfinkel, 1967), nonverbal communication (Birdwhistell, 1970), and context analysis (Kendon, 1990). An integration of these methods has only recently become feasible with the availability of videotaping and digitization that records human interactions and facilitates their detailed analysis. It involves close attention to the role that various micro-behaviors – such as turn-taking, participation structures, gaze, posture, gestures, and manipulation of artifacts – play in the tacit organization of interpersonal interactions. Utterances made in interaction are analyzed as to how they shape and are shaped by the mutually intelligible encounter as a holistic context – rather than being taken as expressions of individuals' psychological intentions or of external social rules (Streeck, 1983).

Micro-ethnographic research typically involves the following components:

- A specific setting, or research site – such as several students gathered around a computer running VIRTUALBIOLOGYLAB.
- A detailed analysis of both audible and visible micro-behaviors, that are to be understood in terms of their embeddedness within the particular social and material environment – such as a biology class.
- A recognition that culture (which includes the meaning and use of shared artifacts) is a product and a process of naturally-occurring communication, simultaneously co-constructed and experienced by participants – and thereby made available for empirical study and interpretation by researchers.
- A use of recent technologies, like digitized video, that allow researchers to look at in detail the orderly performance of social life – such as the negotiation of learning between teacher and student or among collaborating peers.

Micro-ethnography can be adapted from the study of human-human interaction to that of human-computer interaction or computer-mediated collaboration. Our pilot studies suggest that such an adaptation of the methodology can be accomplished effectively.

Micro-ethnography and Human-Computer Interaction

Our research approach brings together software designers and micro-analytic researchers. We use micro-ethnography to analyze empirical student interactions with software artifacts. Techniques related to micro-ethnography, such as video analysis and conversation analysis, have previously been used to analyze human-computer interaction in limited cases (Bødker, 1989; Bødker, 1996; Frohlich & Luff, 1990; Hollan et al., 2000; McIlvenny, 1990; Nardi, 1996; Roschelle, 1996; Suchman, 1987; Suchman & Trigg, 1991). However, these cases typically did not analyze interactions at the micro-behavior level, including such things as gesture and posturing, that are important means of making understandings visible in face-to-face communication – suggestive exceptions include (Hutchins & Palen, 1998; Streeck, 1996). But, most importantly, these studies did not investigate learning technologies. Nor did they investigate learning taking place through the interactions. Those that did look at learning, like Roschelle (1996), did not use this to feed back into the design of the technology. Thus, our project is undertaking an approach that is unique in combining all three:

- Analysis of interaction at a micro level.
- Analysis of the learning taking place.
- Application of the analysis to revision of the technology.

Our own past work using micro-ethnography has begun to align this methodology with our project goals. Co-PI LeBaron (1998) shows through micro-ethnography how an architecture teacher goes through four stages of successive abstraction to define meaningful gestures, that the students then gradually adopt in their own presentations. By freezing key video frames and relating them to the speech and bodily behaviors of the teacher and students, LeBaron makes the teaching and learning process – that the participants are only tacitly aware of – visible to researchers. We also work with Koschmann, who has been engaged for almost 10 years in fine-grained studies of collaboration among medical students in a problem-based collaborative learning (PBL) curriculum (Glenn et al., 1999; Koschmann & Glenn, submitted; Koschmann et al., 1997; Koschmann et al., 2000; Koschmann, Ostwald & Stahl, 1998; Koschmann & Stahl, 1998; LeBaron & Koschmann, 2001). In particular, we have shown how group discussions raise learning issues for further study and how the status of these issues is negotiated by the students and a tutor. While we have investigated the role of a tutor in face-to-face PBL sessions, we have only recently begun to study the role of computer-based artifacts and media in distance-PBL sessions (Koschmann & LeBaron, submitted). The proposed project will build upon the isolated pioneering efforts of ourselves and others, and put these methods together in a systematic way to apply them to the design of collaboration software.

Data Gathering and Analysis

Project staff, including Project Advisory Board members, will meet in workshops held monthly. The workshops not only review project progress and plan next steps, but they importantly include group data sessions for the analysis of data. The data gathering and analysis process for the VIRTUALBIOLOGYLAB trials will typically proceed through the following steps:

- Videotaping of students. Two or three students are gathered around a computer to interact asynchronously and remotely with other students. Cameras and microphones are set up to capture the facial expressions and body movements of all participants. The monitor image is also captured. Microphones are arranged to capture all speech as clearly as possible and to distinguish the speakers.
- The video is combined (picture-in-picture) and time-code is burned in to provide a frame-by-frame reference system. A minute-by-minute record log is created, describing in a sentence or two what takes place each minute.
- A list of interesting episodes is created. Episodes are meaningful interactions lasting up to several minutes. Selected episodes are digitized and made available electronically. This allows them to be replayed easily, looped, freeze-framed, slowed down, and studied by project members at distant locations.
- A detailed transcript is created. It transcribes both speech and visible behaviors. Speech of different participants is color-coded. The transcripts are printed and posted on the Web with the digitized clips.
- Each episode is assigned to a project team member who "owns" that piece of data. The owner watches the clip many times to understand what is happening there.
- A data session is conducted at a group workshop. This is a collaborative analysis of the data's empirical details. Usually, about two hours are spent on a single episode. The session is led by the owner of the data, who presents the episode and raises issues. The owner may audio-tape this session to preserve ideas and interpretations that come up.

The owner of the episode returns to a study of the video clip. At this point, the transcript may be revised and extended to include more details of interaction. The owner may invite other project team members to view and discuss the clip. The owner may present the clip at another data session. Finally, the owner drafts a micro-ethnographic analysis of the episode. This is distributed for comment. The analysis includes:

- A detailed description of the actions of all participants and their interactions.
- A discussion of what learning is evidenced in the data.
- A discussion of the role of any artifacts.
- A discussion of problems with the software, learning problems, etc.

The analyses of the episodes are reviewed by the project team, and various suggestions are made based on this:

- Proposed revisions to the software.
- Changes to the list of interesting episodes, such as the inclusion of additional episodes.
- Alterations to the research plan, such as scheduling additional usage sessions or changing the way they are conducted.
- Revisions to the research methodology and theoretical framework.

5. Study of a Virtual Biology Laboratory

The project will ultimately study collaborative knowledge-building at a virtual biology laboratory used in geographically distributed high schools for advanced placement biology courses. A website containing the virtual biology lab is currently being developed at the University of Colorado; this project will assess its effectiveness in use by college freshmen and contribute to its iterative design (in Year I). The project will also develop a collaborative knowledge-building environment (in Year I) and integrate this with the lab (in Year II). Then (in Year III), micro-ethnographic methodology will be used to assess the use of this software – especially the use of computational Perspectives – by distributed high school students, and contribute to its iterative design.

Software Artifacts for a Virtual Biology Laboratory

The VIRTUALBIOLOGYLAB is a complete one-semester curriculum on the Web, intended to replace biology wet labs for college non-major freshmen and for high school advanced placement (AP) students. Each of 10 planned labs takes an estimated three hours for a student to work through – and enables students to conduct seminal experiments from the history of biology that would not be feasible in traditional physical wet labs (see attached letter of support from the developer). There are multiple kinds of artifacts composing the software: a guiding narrative, animations of lab equipment, simulations of lab procedures, data collection / analysis / graphing / display tools, background materials (theory, history, remedial text), links to related websites, and interactive assessment exercises. The virtual lab is designed to be used by students independent of any teacher guidance, although it is loosely coordinated with a biology theory course. Because biology AP students are sparsely scattered around a school district, it is convenient to have students conduct their labs on the Web.

Distance Negotiation

WEBPERSPECTIVES will be a software re-write of WEBGUIDE, a knowledge-building environment with Perspectives that the PI has been developing for several years (Stahl, 2000d). WEBGUIDE was always intended to have a negotiation component that would support the proposal, discussion, and decision by a group of users to promote a note from one Perspective to another (Stahl & Herrmann, 1999). Thus, a student could propose that a note from her personal Perspective be accepted by her team and be promoted to the team Perspective. After discussion and agreement by team members, the note would appear in the team Perspective. Similarly, notes could migrate all the way up the Perspective hierarchy to the class Perspective and become part of the knowledge accepted by the whole class. The planned negotiation mechanism has not yet been implemented because we are lacking an adequate understanding of how collaborative negotiation is conducted and how it should be supported.

We are currently videotaping meetings of a research group run by Clarence (Skip) Ellis. (Coincidentally, his group is designing collaboration software.) In Year I of this project, we will conduct a micro-ethnographic analysis of these tapes to study the structure of small group negotiation. We will then design and develop software functionality to support such processes within WEBPERSPECTIVES.

Semantic Relevance Agent for Intelligent Hyper-Linking

Research in KBEs like CSILE has shown that it is difficult to locate related ideas within a shared database of discussion notes (Hewitt et al., 1998; Hewitt & Teplovs, 1999). Therefore, in Year I, we will add functionality to WEBPERSPECTIVES to automatically locate the notes most closely related to a given note, such as a new idea just entered into my personal Perspective or an old note proposed for inclusion in a group Perspective.

We will use Latent Semantic Analysis (LSA) (Landauer & Dumais, 1997; Landauer et al., 1998; Stahl & dePaula, 2001) to analyze the semantic content of notes and to measure the semantic relatedness of pairs of notes. LSA is based upon a statistical analysis (singular value decomposition) of co-occurrences of terms in a large corpus of text. It determines the relatedness of words even if they did not occur together explicitly – hence the term "latent". LSA incorporates some refinements that make its performance closer to that of humans than similar methods – see *Discourse Processes* (vol. 25, 1998) and *Interactive Learning Environments* (vol. 8, no. 2, 2000) for special issues of LSA assessment studies. The PI and his graduate assistant recently completed a four year project (sponsored by the McDonnell Foundation CSEP Program) that successfully uses LSA in a Web-based educational system tested in middle school classrooms (Kintsch et al., 2000; Stahl & dePaula, 2001; Steinhart, 2000).

Automated linking of related notes will involve a fairly straight-forward application of LSA. It will be handled within the Perspectives server, running on a computer with access to the necessary files for LSA. A corpus of biology text (including the content of VIRTUALBIOLOGYLAB and the associated theory course) will be subjected to LSA analysis to define a semantic space. Periodically (e.g., each night) the site's shared database of notes will be folded into this corpus to redefine the space and to compute the vector for each note within this space. In real time, when linking is requested for a new note, the new note's vector can be quickly computed and a list of existing notes with the closest vectors in the semantic space can be produced without noticeable delay.

With this hyper-linking, students will be pointed from the themes of their own notes to places throughout the system and throughout the interactive knowledge-building discussions where the same and related themes occur. We will experiment with different interfaces to try alternative approaches to incorporating this functionality into KBEs. For instance, it can be left to users to ask for lists of notes related to a given note. Alternatively, an agent can automatically check to see if there are notes within a given closeness to certain notes: newly entered notes, notes proposed for negotiation, notes being read or edited, etc. The agent can then suggest that links be established from the given note to similar ones. The different interfaces can be tried out in our software trials.

An Open Architecture for Software Integration

A specific task of the proposed project is to structure the Perspective computation as a self-contained module with a well-defined application programming interface (API). This will form a Perspectives server, a Java application that runs on the Web server along with the database system. It will be separate from a client that runs in a Web browser on the client's computer. This separation of functions into a server and a client will have many advantages. It will speed the functioning because the intensive computation of Perspective content will be done on a central server that is faster than typical student computers. Also, calls to the database system will take place locally rather than across the Internet. In terms of system development, it will mean that developers can build systems that incorporate Perspectives without having to worry about the Perspective algorithms or the database calls. They will use an API of the server that lets them request the data that should be shown to a given user in a given Perspective. They can then just focus on how best to display this data in the interface client.

The Perspectives server will be a self-contained Java application. It will be released as Open Source with clear documentation on how to use it to get Perspective data for display. The data will be delivered as an XML text stream that can be used by any Web technology, such as HTML, PERL, or JAVA. Although it is anticipated that the Perspectives server will generally be used as a black box, its Open Source availability will allow programmers to modify it if necessary. We have already had requests from Germany and California for the release of such a Perspectives server.

The Perspectives server will be a form of middle-ware, operating between the database and the client software (see Figure 2). It will instantiate a three-tier, model-controller-view architecture that defines independent layers for the data schema or model, the data computation or control, and the interface display or view. The database management system can be any standard relational SQL system like MYSQL or ORACLE. The middle layer can be the Perspectives server or a stripped down version that does not compute Perspectives. And the interface can be any kind of applet, Web page, or Web application that conforms to the API standard.

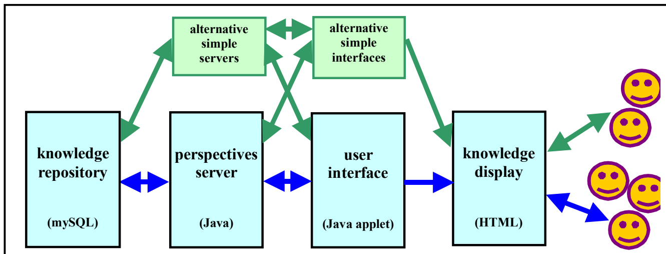

Figure 2. *Architecture for* `WebPerspectives`.

6. Plan for Proposed Research

We recently submitted an NSF ROLE proposal to conduct research related to that proposed here. NSF's staff review of our ROLE preproposal assigned it the highest possible ratings and suggested combining it with other NSF proposals. This CSS proposal and a related ITR proposal are in direct response to that suggestion. If both the ROLE and the CSS and/or ITR proposals are funded, then the grant budgets and scopes will be slightly renegotiated to support a fully-staffed, year-round project. The ROLE proposal focuses on development of the micro-ethnographic approach for analyzing computer support of learning and collaboration; the ITR proposal focuses on development of the required technology; the current CSS proposal focuses on studying collaborative knowledge-building achieved over distance and time with computer support. The three are closely complementary, although any one or two projects can be conducted independently. The following plan assumes that only this CSS proposal is funded.

The CSS project includes the design and development of WEBPERSPECTIVES, its integration with VIRTUALBIOLOGYLAB, and its eventual dissemination as Open Source software. Use of the software will be studied with small groups of college and high school students. Micro-ethnographic analyses will be conducted to understand how the software supports collaborative group knowledge-building over distance and time. Assessment of these trials will feed back into the software development. Project findings will be broadly disseminated.

Study of Collaboration

In order to study computer-supported collaboration, college and high school students will be videotaped in pairs or triads working at computers. They will be engaging in team tasks that are part of VIRTUALBIOLOGYLAB. They will interact with other pairs or triads in their team or class through WEBPERSPECTIVES functions, negotiating content for group Perspectives. The interactions will be captured on videotape and computer logs.

The speech and gestures on videotape and the interactions with the software on the computer logs will provide our primary data, although some interviews will be used to triangulate our analyses. We will be particularly concerned with how groups of people using our software take advantage of certain functionality of the software to conduct their collaborative activities. Here are the kinds of issues we will be interested in focusing on in our micro-analyses:

- Are important issues of biology raised in the collaborative discussions? Are insights effectively shared and knowledge deepened?
- What collaborative knowledge-building activities can be identified in the data? How are they supported by the software? How are they hindered by the software?
- Do the software functionality, affordances, scaffolding, and support contribute to the user experience, do they further the collaborative effort, and do they motivate participation so that the features are used?
- How does learning of the software artifacts proceed so that users get over initial barriers and begin to take advantage of the support to accomplish things that could not previously be done?
- Do individuals, pairs, teams, and the class develop personal and group Perspectives containing different versions of the evolving shared knowledge? Does this organization into different Perspectives seem to help the collaborative knowledge-building?
- Are negotiation mechanisms used to debate ideas from personal Perspectives and possibly promote them to team or class Perspectives? Do these mechanism seem to work intuitively? Do they help knowledge-building processes to converge on shared understanding?
- Does the semantic relevance agent provide useful suggestions of related notes? Are these suggestions used in future knowledge-building?

The approach of micro-ethnography differs from the hypothesis-driven approach of many other social science methods. It requires an openness to the data. The history of ethnomethodology, conversation analysis, context analysis, and micro-ethnography suggests that this open attitude generally results in discoveries of important structures of social interaction. By designing our project around specific kinds of collaboration – with given software and specific curricular tasks, for instance – and by looking for episodes in the data that might shed light on the above guiding questions, we expect to gain a great deal of insight into how collaborative knowledge-building is achieved by small groups over distance and time. We expect to see how computer support interacts with the collaborative activities and be able to iteratively modify our software to better support collaboration and knowledge-building.

Cognitive artifacts like the computational Perspectives structure take time for people to learn how to use effectively and intuitively. We will be particularly interested in looking at episodes that reveal how this process takes place. At the beginning, there will have to be some form of instruction (to-do lists, seeded examples, explanations, etc.) in how to use Perspectives: where to enter tentative ideas, how to compare someone else's ideas, when to propose the negotiation of an idea, and how to promote ideas to group Perspectives. Gradually, these activities will become natural and enter into the flow of collaborative exchanges. The guiding vision is that computational Perspectives will not only mirror or represent the personal and group perspectives that form the structure of normal collaboration, but that they will allow people to manage this form of complexity well enough that collaboration will become more successful than ever as people master the technology. Micro-analysis will let us see if this in fact happens.

Project Schedule

Below is a timeline for major phases of the software development, the collaboration study, and the dissemination of findings:

	Software Development	***Micro-ethnographic Assessment***	***Dissemination***
Fall '01	Development of WEBPERSPECTIVES	Study of group negotiation	Group 2001 in Boulder
Spring '02	Addition of negotiation	Pilot testing of VIRTUALBIOLOGYLAB	CSCL 2002 in Boulder
Summer '02	Addition of hyper-linking	Study of hyper-linking usage	
Fall '02	Revision of architecture	Testing of VIRTUALBIOLOGYLAB	Conference demo
Spring '03	Integration of WEBPERSPECTIVES with VIRTUALBIOLOGYLAB	Pilot testing of WEBPERSPECTIVES with VIRTUALBIOLOGYLAB	European conference
Summer '03	Iterative revision	Study of Perspectives usage	Conference paper
Fall '03	Iterative revision	Testing of WEBPERSPECTIVES with VIRTUALBIOLOGYLAB	Conference paper

Spring ’04	System clean-up	Study of cognitive artifact usage	Journal article
Summer ’04	Open Source version & docs	Report on micro-analysis studies	Open Source release

Data collection and analysis issues including sampling and confidentiality will conform to rigorous research conventions and University of Colorado Human Subjects standards.

Project Assessment

We will engage in formative evaluation of our project throughout. That will be an important function of our Advisory Board, that includes assessment experts, and will form a regular part of monthly project workshops. We will check that we are making progress toward our project goals in accordance with the project timeline and are following our data analysis procedures.

The project’s micro-analytic approach provides a built-in assessment process. By videotaping sessions of students working with software artifacts, we will derive a formative evaluation of the artifacts. By the end of the project, we will be able to compare in a detailed and documented way how well our revised versions of collaboration software perform as compared to how they worked in the pilot studies and in earlier phases of the project.

In addition to the micro-ethnographic analysis that examines both how students learn with computer technologies and their learning processes as revealed through their interactions (computer-mediated and face-to-face), it is important to understand how students relate to the technologies. In order to understand this, a triangulated approach to assessment will be adopted. Some students in the core trials of VIRTUALBIOLOGYLAB will be given a set of pre-assignment questions to gauge their prior knowledge and understanding of the concepts. Once they have completed the trial, they will be asked the same questions so that we can calculate their learning gains. In addition, we will interview these students in order to understand their perceptions of the artifacts as effective learning tools. This information will be gathered with each iteration and use of the software under development, and the comments and perceptions will be fed back into the development of software and the articulation of learning processes that involve computer software and computer-mediated collaboration. Understanding student perceptions of their experiences will also enable us to track our progress toward our research goals and to evaluate the effectiveness of the software by answering the critical question of, does it work: have we effectively supported distance collaborative knowledge-building?

Project Dissemination

We will establish a website for both internal use and broad dissemination. The website will collect and coordinate materials and findings of the project. It will include logs of our videotapes, digitized clips of selected episodes, detailed transcripts, analyses of interactions, etc. It will also include all papers submitted to journals and conferences.

This project and its findings will be broadly disseminated in the CSCL, CSCW, HCI, education, and communication research communities through conferences and journals. It will be particularly prominent at CSCL 2002 and subsequent meetings of CSCL, AERA, CSCW, Group, ICLS, and WebNet.

It will also significantly impact the release of a published VIRTUALBIOLOGYLAB curriculum at the college and the high school level. VIRTUALBIOLOGYLAB will be published by commercial textbook publishers in both college and high school versions. This project will significantly improve the quality of this distance education curriculum by subjecting it to detailed assessment in use situations. The addition of WEBPERSPECTIVES to this curriculum will add an important collaborative dimension to it. WEBPERSPECTIVES will be made available as an Open Source component – the PI has already had requests from California and Germany for this.

Project Context and Resources

The proposed project will have considerable institutional support from the University of Colorado. The PI is a Research Professor active in both the Institute of Cognitive Science (ICS) and the Center for LifeLong Learning and Design (L^3D). He is on the Steering Committee of the international ACM SIGGroup conference, GROUP ’01, and is Program Chair of the international CSCL ’02 conference (both being held in Colorado). These affiliations will provide support and visibility to this project.

Through its Advisory Board, the project brings together a valuable set of experienced professionals from education, communication, computer science, cognitive science, and project assessment.

7. Results from Previous Research

The project PIs and Advisory Board members (see Biographical Sketches) have conducted research projects (including a three-year CSS grant) and specific pilot projects that form a foundation for the proposed research. The PIs have previously developed knowledge-building environments with computational Perspectives for designers and students, have studied the theory of cognitive artifacts, and have engaged in micro-ethnographic analysis of students learning to use a scientific simulation. This and related work by others motivate new features and research issues. A previous Perspectives system will be extended with additional functionality and re-structured for integration with the virtual biology lab, for release as Open Source, for use in distance collaboration, and for micro-ethnographic analysis.

The proposed project builds upon a series of activities that we have already started to work on, and takes advantage of unique opportunities at the University of Colorado:

- The development of VIRTUALBIOLOGYLAB, that is currently underway in the Molecular, Cellular and Developmental Biology Department.
- The experience of the PI and his colleagues and students at the Center for LifeLong Learning and Design in the Computer Science Department in design and development of computer support for collaborative learning – including the Perspectives mechanism.
- The expertise of Advisory Board members and graduate students from the Communication Department in applying micro-ethnography to human interaction with technology.
- The participation of a number of people on the project Advisory Board, who bring complementary expertise in education, human-computer interaction, technology adoption, and project assessment.

Following are summaries of related work conducted by the PI and colleagues as preparation for this proposal and in related grants funded by NSF and other sources. Brief descriptions of Advisory Board members are given in the attached Biographical Sketches.

Pilot Studies

WEBGUIDE (http://www.cs.colorado.edu/~gerry/webguide)

WEBGUIDE is a knowledge-building environment for discussing topics via the Web developed by the PI and colleagues over the past two years. It has been used in a middle school environmental science class and in two college seminars on CSCL (Stahl, 1999c). WEBGUIDE goes beyond similar discussion-based systems by supporting the representation and development of personal and group Perspectives (Stahl, 1999a; Stahl, 1999b).

SIMROCKET (http://www.cs.colorado.edu/~gerry/previous/simrocket)

The PI designed and implemented SIMROCKET, a computer simulation of a rocket launch. The PI was invited to try it in a local Boulder school with five boys engaged in a model rocket science project. The teacher guided the students (grouped in front of two computers) to fire each of 7 virtual rockets with different characteristics six times and to average the resultant heights in order to predict the height of an 8th rocket. Project staff then engaged in micro-ethnographic analysis of this three-hour interaction – during data sessions in the Communication Department, the seminar on artifact theory, a summer workshop on micro-ethnography, and pilot sessions for this proposal (Stahl & Sanusi, 2001).

Artifacts Seminar (http://www.cs.colorado.edu/~gerry/readings)

The PI organized a seminar on artifact theory, primarily as a pilot project for this proposal. Core members of the project team met along with other faculty and graduate students from Communication, Education, Philosophy, and Computer Science. We reviewed theoretical texts on the nature of artifacts from cognitive science, CSCL, communication, cultural studies, psychology, philosophy, and social theory. We also held data sessions on episodes from the SIMROCKET tapes. Out-of-class discussions were held in WEBGUIDE and we conducted a SIMROCKET experiment mediated by WEBGUIDE.

STATETHEESSENCE (http://www.cs.colorado.edu/~gerry/projects/essence)

STATETHEESSENCE is Web-based software developed by the PI to help middle school students develop their text summarization skills. It relied centrally on latent semantic analysis (LSA) technology, as developed by the co-PIs of the McDonnell Foundation grant, Walter Kintsch and Thomas Landauer. It was used in an interdisciplinary four-year research project at a local Boulder public school. After undergoing considerable revision and refinement based on testing with students, the software was shown to improve text summarization, particularly in cases where the original text was somewhat difficult for the student to understand (Kintsch et al., 2000; Stahl & dePaula, 2001; Steinhart, 2000). Evaluation of this software was conducted by means of controlled experiments and teacher ratings.

VirtualBiologyLab (http://www.virtuallaboratory.net)

VirtualBiologyLab is a Web-based curriculum to substitute for biology wet labs in introductory freshman biology courses for non-majors. Currently under development, it will soon consist of ten labs, each of which takes approximately three hours for a student to work through. Project staff has begun to review this software with the designer, Professor Mike Klymkowsky, who is closely involved in this project (see attached letter of support).

Grants Funded by NSF

Environmental Perspectives in a Middle School Classroom

"Collaborative Web-Based Tools for Learning to Integrate Scientific Results into Social Policy," PIs: Ray Habermann, Gerry Stahl, November 1998 – July 1999, $89,338, NSF, #EAR-9870934.

This grant funded the initial implementation of WebGuide as an integrated Java applet KBE supporting personal and group Perspectives. It was a joint effort between the PI, a middle school teacher, and a research group at the National Oceanographic and Atmospheric Administration (NOAA) labs in Boulder. WebGuide was used by the students to collect notes on interviews and to formulate personal and team perspectives on a local environmental issue.

Organizational Memory and Organizational Learning

"Conceptual Frameworks and Computational Support for Organizational Memories and Organizational Learning (OMOL)," PIs: Gerhard Fischer, Gerry Stahl, Jonathan Ostwald, September 1997 – August 2000, $725,000, from NSF CSS Program #IRR-9711951.

This grant led to the current proposal's focus on Web-based learning environments. It started with a model of computer support for organizations as Domain-Oriented Design Environments in which both domain knowledge and local knowledge are stored in the form of artifact designs and associated design rationale. This CSCW model evolved into one of Collaborative Information Environments, that emphasized the interactive, asynchronous, persistent discussion of concepts and issues within an organization. Gradually, interest in organizational learning aspects led to involvement in CSCL and the model of collaborative Knowledge-Building Environments (KBEs). A number of software prototypes were developed to explore the use of the Web as a communication and collaboration medium, including:

- DynaClass: A discussion forum for use in college courses. It features ties to an interactive glossary and bibliography, as well as email notification and specialized displays.
- WebGuide: Differs from DynaClass in providing more control over management of notes; it features computational Perspectives.

Work on this grant led to the focus on KBEs as models of computer support for organizational memory and collaborative learning. In particular, it prototyped a number of different systems, each with useful functionality. As we tested and deployed these systems, we confronted serious issues of adoption and focused our concerns increasingly on socio-technical and social informatics issues: motivation, media competition, critical mass, social practices, seeding, management, re-seeding, convergence of ideas, peer-to-peer collaboration, deployment strategies. These issues led to a new research agenda (Stahl, 2000b), and ultimately to issues of this proposal. Results of WebGuide trials were analyzed and presented at AERA, CSCL, ICLS, CILT, WebNet, and Group conferences (Stahl, 1999a; Stahl, 1999b; Stahl, 1999c; Stahl, 2000c; Stahl & Herrmann, 1999). These findings led to a recognition of the need for software architectures and components for KBEs as proposed in the current proposal.

REFERENCES

Bakhtin, M. (1986) *Speech Genres and Other Late Essays,* (V. McGee, Trans.), University of Texas Press, Austin, TX.

Bereiter, C. (2000) *Education and Mind in the Knowledge Age*. Available at: http://csile.oise.utoronto.ca/edmind/main.html.

Birdwhistell, R. (1970) *Kinesics and Context,* University of Pennsylvania Press, Philadelphia, PA.

Boborow, D. & Goldstein, I. (1980) *An experimental description-based programming environment: Four reports,* Technical Report No. CSL-81-3, Xerox Palo Alto Research Center, Palo Alto, CA.

Bødker, S. (1989) A human activity approach to user interfaces, *Human-Computer Interaction,* 4 , pp. 171-195.

Bødker, S. (1996) Applying activity theory to video analysis: How to make sense of video data in HCI. In B. Nardi (Ed.) *Context and Consciousness: Activity Theory and Human-Computer Interaction,* MIT Press, Cambridge, MA, pp. 147-174.

Boland, R. J. & Tenkasi, R. V. (1995) Perspective making and perspective taking in communities of knowing, *Organization Science,* 6 (4), pp. 350-372.

Brody, C. & Davidson, N. (Eds.) (1998) *Professional Development for Cooperative Learning: Issues and Approaches,* SUNY Press, Albany, NY.

Brown, A. & Campione, J. (1994) Guided discovery in a community of learners. In K. McGilly (Ed.) *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice,* MIT Press, Cambridge, MA, pp. 229-270.

Brown, J. S. & Duguid, P. (1991) Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation, *Organization Science,* 2 (1), pp. 40-57.

Bruner, J. (1990) *Acts of Meaning,* Harvard University Press, Cambridge, MA.

Chaiklin, S. & Lave, J. (Eds.) (1993) *Understanding Practice: Perspectives on Activity and Context,* Cambridge University Press, New York, NY.

Cole, M. (1996) *Cultural Psychology,* Harvard University Press, Cambridge, MA.

Cole, M. & Griffin, P. (1980) Cultural amplifiers reconsidered. In D. Olson (Ed.) *The Social Foundations of Language and Thought,* Norton, New York, NY.

Connolly, T. (1997) Electronic brainstorming: Science meets technology in the group meeting room. In S. Kiesler (Ed.) *Culture of the Internet,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 263-276.

Cuthbert, A. (1999) Designs for collaborative learning environments: Can specialization encourage knowledge integration? In: Proceedings of *Computer Supported Collaborative Learning (CSCL '99)*, Palo Alto, CA, pp. 117-126.

dePaula, R. (1998) *Computer Support for Collaborative Learning: Understanding Practices and Technology Adoption*, Masters Thesis, Telecommunications Department, University of Colorado, Boulder, CO.

Dewey, J. & Bentley, A. (1949/1991) Knowing and the known. In J. A. Boydston (Ed.) *John Dewey: The Later Works, 1925-1953, Volume 16,* SIU Press, Carbondale, IL.

Donald, M. (1991) *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition,* Harvard University Press, Cambridge, MA.

Engelbart, D. (1962) *Augmenting Human Intellect: A Conceptual Framework, Summary Report 3578,* Stanford Research Institute, Menlo Park, CA.

Engelbart, D. C. (1995) Toward augmenting the human intellect and boosting our collective IQ, *Communications of the ACM,* 38 (8), pp. 30-33.

Engeström, Y. (1999) Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on Activity Theory,* Cambridge University Press, Cambridge, UK, pp. 19-38.

Engeström, Y., Miettinen, R., & Punamaki, R.-L. (Eds.) (1999) *Perspectives on Activity Theory,* Cambridge University Press, New York, NY.

Fischer, G., Nakakoji, K., Ostwald, J., Stahl, G., & Sumner, T. (1993a) Embedding computer-based critics in the contexts of design, In: Proceedings of *Conference on Human Factors in Computing Systems (INTERChi '93)*, Amsterdam, Holland, pp. 157-164. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1990-1997/chi93/CHI93.html.

Fischer, G., Nakakoji, K., Ostwald, J., Stahl, G., & Sumner, T. (1993b) Embedding critics in design environments, *Knowledge Engineering Review,* 4 (8), pp. 285-307. Available at: http://www.cs.colorado.edu/~gerry/publications/journals/ker/index.html.

Frohlich, D. & Luff, P. (1990) Applying the technology of conversation to the technology for conversation. In P. Luff, N. Gilbert, & D. Frohlich (Eds.), *Computers and Conversation,* Academic Press, New York, NY.

Gadamer, H.-G. (1960/1988) *Truth and Method,* Crossroads, New York, NY.

Garfinkel, H. (1967) *Studies in Ethnomethodology,* Prentice-Hall, Englewood Cliffs, NJ.

Geertz, C. (1973) *The Interpretation of Cultures,* Basic Books, New York, NY.

Glenn, P., Koschmann, T., & Conlee, M. (1999) Theory sequences in a problem-based learning group: A case study, *Discourse Processes,* 27 , pp. 119-133.

Guzdial, M. & Turns, J. (2000) Sustaining discussion through a computer-mediated anchored discussion forum, *Journal of the Learning Sciences* .

Habermas, J. (1981/1984) *Reason and the Rationalization of Society, Volume One, The Theory of Communicative Action* (T. McCarthy, Trans.), Beacon Press, Boston, MA.

Hakkarainen, K. & Lipponen, L. (in prep) Epistemology of inquiry and computer-supported collaborative learning. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL2: Carrying Forward the Conversation,* Lawrence Erlbaum Associates, Mahwah, NJ.

Hall, R. (1996) Representation as shared activity: Situated cognition and Dewey's cartography of experience, *The Journal of the Learning Sciences,* 5 (3), pp. 209-238.

Hall, R. & Stevens, R. (1995) Making Space: A Comparison of Mathematical Work in School and Professional Design Practices. In S. L. Star (Ed.) *The Cultures of Computing,* Blackwell Publishers, Oxford, UK.

Hegel, G. W. F. (1807/1967) *Phenomenology of Spirit,* (J. B. Baillie, Trans.), Harper & Row, New York, NY.

Heidegger, M. (1927/1996) *Being and Time: A Translation of Sein und Zeit,* (J. Stambaugh, Trans.), SUNY Press, Albany, NY.

Hewitt, J., Scardamalia, M., & Webb, J. (1998) *Situative design issues for interactive learning environments,* at http://csile.oise.on.ca/abstracts/situ_design.

Hewitt, J. & Teplovs, C. (1999) An analysis of growth patterns in computer conferencing threads, In: Proceedings of *Computer Supported Collaborative Learning (CSCL '99)*, Palo Alto, CA, pp. 232-241.

Hollan, J., Hutchins, E., & Kirsh, D. (2000) Distributed cognition: Toward a new foundation of human-computer interaction research, *ACM Transactions on Computer-Human Interaction,* 7 (2), pp. 174-196.

Husserl, E. (1936/1989) The origin of geometry. (D. Carr, Trans.), In J. Derrida (Ed.) *Edmund Husserl's Origin of Geometry: An Introduction,* University of Nebraska Press, Lincoln, NE, pp. 157-180.

Hutchins, E. (1996) *Cognition in the Wild,* MIT Press, Cambridge, MA.

Hutchins, E. & Palen, L. (1998) Constructing meaning from space, gesture and speech. In L. B. Resnick, R. Saljo, C. Pontecorvo, & B. Burge (Eds.), *Discourse, Tools, and Reasoning: Situated Cognition and Technologically Supported Environments,* Springer Verlag, Heidelberg, Germany.

Jong, F. d., Diermanse, E., & Lutgens, G. (in prep) Computer supported collaborative learning in university and vocational education. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL2: Carrying Forward the Conversation,* Lawrence Erlbaum Associates, Mahwah, NJ.

Jordan, B. & Henderson, A. (1995) Interaction analysis: Foundations and practice, *Journal of the Learning Sciences,* 4 (1), pp. 39-103. Available at: http://lrs.ed.uiuc.edu/students/c-merkel/document4.HTM.

Keil-Slawik, R. (1992) Artifacts in software design. In C. Floyd, H. Züllighoven, R. Budde, & R. Keil-Slawik (Eds.), *Software Development and Reality Construction,* Springer Verlag, Berlin, Germany, pp. 168-188.

Kendon, A. (1990) *Conducting Interaction: Patterns of Behavior in Focused Encounters,* Cambridge University Press, Cambridge, UK.

Kintsch, E., Steinhart, D., Stahl, G., Matthews, C., Lamb, R., & the LSA Research Group (2000) Developing summarization skills through the use of LSA-backed feedback, *Interactive Learning Environments,* 8 (2), pp. 87-109.

Kling, R. (1999) What is social informatics and why does it matter? *D-Lib Magazine,* 5 (1).

Koschmann, T. (Ed.) (1996) *CSCL: Theory and Practice of an Emerging Paradigm,* Lawrence Erlbaum Associates, Hillsdale, NJ.

Koschmann, T. (1999) Toward a dialogic theory of learning: Bakhtin's contribution to learning in settings of collaboration, In: Proceedings of *Computer Supported Collaborative Learning (CSCL '99)*, Palo Alto, CA, pp. 308-313. Available at: http://kn.cilt.org/cscl99/A38/A38.HTM.

Koschmann, T. (in press) A third metaphor for learning: Toward a form of trans-actional inquiry into inquiry. In D. Klahr & S. Carver (Eds.), *Cognition and Instruction: 25 Years of Progress,* Lawrence Erlbaum, Mahwah, NJ.

Koschmann, T. & Glenn, P. (submitted) A tale of two theories: A sequential analysis of hypothesis generation, . Available at: http://edaff.siumed.edu/tk/articles/theories/.

Koschmann, T., Glenn, P., & Conlee, M. (1997) Analyzing the emergence of a learning issue in a problem-based learning meeting, *Medical Education Online,* 2 (1). Available at: http://www.utmb.edu/meo/res00003.pdf.

Koschmann, T., Glenn, P., & Conlee, M. (2000) When is a problem-based tutorial not tutorial? Analyzing the tutor's role in the emergence of a learning issue. In D. Evensen & C. Hmelo (Ed.) *Problem-Based Learning: A Research Paradigm on Learning Interactions,* Lawrence Erlbaum, Mahwah, NJ, pp. 53-74.

Koschmann, T. & LeBaron, C. (submitted) Learner articulation as interactional jointing: Studying gesture conversationally, . Available at: http://edaff.siumed.edu/tk/articles/gestures/.

Koschmann, T., Ostwald, J., & Stahl, G. (1998) Shouldn't we really be studying practice? [panel position paper], In: Proceedings of *International Conference on the Learning Sciences (ICLS '98)*, Atlanta, GA. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1998/icls98/ICLS Workshop.html.

Koschmann, T. & Stahl, G. (1998) Learning issues in problem-based learning: Situating collaborative information seeking. Workshop on Technologies for Collaborative Information Seeking [workshop position paper], In: Proceedings of *ACM Conference on Computer Supported Cooperative Work (CSCW 98)*, Seattle, WA.

Kraemer, K. & Pinsonneault, A. (1990) Technology and groups: Assessment of the empirical research. In J. Galegher, R. Kraut, & C. Egido (Eds.), *Intellectual Teamwork: Social and Technological Foundations of Cooperative Work,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 375-405.

Landauer, T. K. & Dumais, S. T. (1997) A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction and representation of knowledge, *Psychological Review,* 104 (2), pp. 211-240.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998) Introduction to latent semantic analysis, *Discourse Processes,* 25 (1), pp. 259-284.

Latour, B. & Woolgar, S. (1979) *Laboratory Life,* Sage Publications, Thousand Oaks, CA.

Lave, J. (1991) Situating learning in communities of practice. In L. Resnick, J. Levine, & S. Teasley (Eds.), *Perspectives on Socially Shared Cognition,* APA, Washington, DC, pp. 63-83.

Lave, J. & Wenger, E. (1991) *Situated Learning: Legitimate Peripheral Participation,* Cambridge University Press, Cambridge, UK.

LeBaron, C. (1998) *Building Communication: Architectural Gestures and the Embodiment of New Ideas*, Ph. D. Dissertation, Department of Communication Studies, University of Texas at Austin, Austin, TX.

LeBaron, C. & Hopper, R. (1997) Social learning during therapy for self: How a preoccupation with administrative matters may constitute putty for social practice, In: Proceedings of *Sixth International Conference on Language and Social Psychology*, Ottawa, Canada.

LeBaron, C. & Koschmann, T. (1999) The conversation of gestures: Interaction and learner articulation, In: Proceedings of *49th Annual Conference of the International Communication Association*, San Francisco, CA.

LeBaron, C. & Koschmann, T. (2001) Gesture and the transparency of understanding. In P. Glenn, C. LeBaron, & J. Mandelbaum (Eds.), *Excavating the Taken-for-Granted: Essays in Language and Social Interaction,* Lawrence Erlbaum, Mahwah, NJ.

LeBaron, C. & Streeck, J. (2000) Gesture, knowledge and the world. In D. McNeill (Ed.) *Language and Gesture,* Cambridge University Press, Cambridge, UK.

Marx, K. (1867/1976) *Capital, Volume I,* (B. Fowkes, Trans.), Vintage, New York, NY. Available at: http://www.karl-marx.org/archive/marx/works/1867-c1/index.htm.

McCall, R., Bennett, P., d'Oronzio, P., Ostwald, J., Shipman, F., & Wallace, N. (1990) PHIDIAS: Integrating CAD graphics into dynamic hypertext. In A. Rizk, N. Streitz, & J. Andre (Eds.), *Hypertext: Concepts, Systems and Applications. Proceedings of the European Conference on Hypertext (ECHT '90),* Cambridge University Press, Cambridge, UK, pp. 152-165.

McIlvenny, P. (1990) Communicative action and computers: Re-embodying conversation analysis? In P. Luff, N. Gilbert, & D. Frohlich (Eds.), *Computers and Conversation,* Academic Press, New York, NY.

Mittal, S., Bobrow, D., & Kahn, K. (1986) Virtual copies at the boundary between classes and instances, In: Proceedings of *Object-Oriented Programming Systems, Languages and Applications (OOPSLA '86)*, Portland, OR, pp. 159-166.

Nardi, B. (Ed.) (1996) *Context and Consciousness: Activity Theory and Human-Computer Interaction,* MIT Press, Cambridge, MA.

Nelson, T. (1981) *Literary Machines,* Mindful Press, New York, NY.

Nelson, T. H. (1995) The heart of connection: Hypermedia unified by transclusion, *Communications of the ACM,* 38 (8), pp. 3-33.

Norman, D. A. (1993) *Things That Make Us Smart,* Addison-Wesley Publishing Company, Reading, MA.

Nygaard, K. & Sørgaard, P. (1987) The perspective concept in informatics. In G. Bjerknes, P. Ehn, & M. Kyng (Eds.), *Computers and Democracy: A Scandinavian Challenge,* Avebury, Aldershot, UK, pp. 371-393.

Papert, S. (1980) *Mindstorms: Children, Computers and Powerful Ideas,* Basic Books, New York, NY.

Pea, R. (1985) Beyond amplification: Using the computer to reorganize mental functioning, *Educational Researcher,* 20 (4), pp. 167-182.

Pea, R. (1993) The collaborative visualization project, *Communications of the ACM,* 36 (5), pp. 60-63.

Roschelle, J. (1996) Learning by collaborating: Convergent conceptual change. In T. Koschmann (Ed.) *CSCL: Theory and Practice of an Emerging Paradigm,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 209-248.

Russell, T. (Ed.) (1999) *The No Significant Difference Phenomenon,* Mindspring Press. Available at: http://cuda.teleeducation.nb.ca/nosignificantdifference/.

Sacks, H. (1992) *Lectures on Conversation,* Blackwell, Oxford, UK.

Scardamalia, M. & Bereiter, C. (1996) Computer support for knowledge-building communities. In T. Koschmann (Ed.) *CSCL: Theory and Practice of an Emerging Paradigm,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 249-268.

Stahl, G. (1975) *Marxian Hermeneutics and Heideggerian Social Theory: Interpreting and Transforming Our World*, Ph.D. Dissertation, Department of Philosophy, Northwestern University, Evanston, IL. Available at: http://www.cs.colorado.edu/~gerry/publications/dissertations/philosophy/.

Stahl, G. (1993a) *Interpretation in Design: The Problem of Tacit and Explicit Understanding in Computer Support of Cooperative Design*, Ph.D. Dissertation, Department of Computer Science, University of Colorado, Boulder, CO. Available at: http://www.cs.colorado.edu/~gerry/publications/dissertations/computer.

Stahl, G. (1993b) Supporting situated interpretation, In: Proceedings of *Annual Meeting of the Cognitive Science Society (CogSci '93)*, Boulder, CO, pp. 965-970. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1990-1997/cogsci93/CogSci.html.

Stahl, G. (1998) Collaborative information environments for innovative communities of practice, In: Proceedings of *German Computer-Supported Cooperative Work Conference (D-CSCW '98): Groupware und organizatorische Innovation*, Dortmund, Germany, pp. 195-210. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1998/dcscw98/dcscw.html.

Stahl, G. (1999a) POW! Perspectives on the Web, In: Proceedings of *WebNet World Conference on the WWW and Internet (WebNet '99)*, Honolulu, HA. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/webnet99/webnet99.html.

Stahl, G. (1999b) Reflections on WebGuide: Seven issues for the next generation of collaborative knowledge-building environments, In: Proceedings of *Computer Supported Collaborative Learning (CSCL '99)*, Palo Alto, CA, pp. 600-610. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/cscl99/.

Stahl, G. (1999c) WebGuide: Guiding collaborative learning on the Web with perspectives, In: Proceedings of *Annual Conference of the American Educational Research Association (AERA '99)*, Montreal, Canada. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/aera99/.

Stahl, G. (2000a) book review: Professional Development for Cooperative Learning: Issues and Approaches, *Teaching and Learning in Medicine: An International Journal,* 12 (4). Available at: http://www.cs.colorado.edu/~gerry/publications/journals/medicine/coop_learn.html.

Stahl, G. (2000b) Collaborative information environments to support knowledge construction by communities, *AI & Society,* 14 , pp. 1-27. Available at: http://www.cs.colorado.edu/~gerry/publications/journals/ai&society/.

Stahl, G. (2000c) A model of collaborative knowledge-building, In: Proceedings of *Fourth International Conference of the Learning Sciences (ICLS 2000)*, Ann Arbor, MI, pp. 70-77. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/2000/icls/ -- and -- http://www.umich.edu/~icls/proceedings/abstracts/ab70.html.

Stahl, G. (2000d) WebGuide: Guiding collaborative learning on the Web with perspectives, *Journal of Interactive Media in Education (JIME)* . Available at: http://www-jime.open.ac.uk/00/stahl/.

Stahl, G. (in prep) Rediscovering CSCL. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL2: Carrying Forward the Conversation,* Lawrence Erlbaum, Mahway, NJ.

Stahl, G. & dePaula, R. (2001) Evolution of an interactive medium for learning to write summaries (in preparation). Available at: http://www.cs.colorado.edu/~gerry/publications/journals/ILE/ile.html.

Stahl, G. & Herrmann, T. (1999) Intertwining perspectives and negotiation, In: Proceedings of *International Conference on Supporting Group Work (Group '99)*, Phoenix, AZ. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/group99/.

Stahl, G. & Sanusi, A. (2001) It doesn't take a rocket scientist: Multi-layered perspectives on collaborative learning activities in a middle school rocket simulation project, In: Proceedings of *22nd Annual Ethnography in Education Research Forum*, Philadelphia, PA.

Stahl, G., Sumner, T., & Owen, R. (1995a) Share globally, adapt locally: Software to create and distribute student-centered curriculum, *Computers and Education. Special Issue on Education and the Internet,* 24 (3), pp. 237-246. Available at: http://www.cs.colorado.edu/~gerry/publications/journals/c&e/.

Stahl, G., Sumner, T., & Repenning, A. (1995b) Internet repositories for collaborative learning: Supporting both students and teachers, In: Proceedings of *Computer Support for Collaborative Learning (CSCL '95)*, Bloomington, Indiana, pp. 321-328. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1990-1997/cscl95/cscl.htm.

Steinhart, D. (2000) *Designing, Testing, and Evaluating Summary Street, an LSA-Based Summarization Tool*, Ph. D. Dissertation, Department of Psychology, University of Colorado, Boulder, CO.

Streeck, J. (1983) *Social Order in Child Communication: A Study in Microethnography,* Benjamins, Amsterdam, NL.

Streeck, J. (1993) Gesture as communication I: Its coordination with gaze and speech, *Communication Monographs,* 60 (Dec.), pp. 275-299.

Streeck, J. (1996) How to do things with things, *Human Studies,* 19 , pp. 365-384.

Suchman, L. (1987) *Plans and Situated Actions: The Problem of Human-Machine Communication,* Cambridge University Press, Cambridge, UK.

Suchman, L. & Trigg, R. (1991) Understanding practice: Video as a medium for reflection and design. In J. Greenbaum & M. Kyng (Eds.), *Design at Work: Cooperative Design of Computer Systems,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 65-90.

Vygotsky, L. (1930/1978) *Mind in Society,* Harvard University Press, Cambridge, MA.

Vygotsky, L. (1934/1986) *Thought and Language,* MIT Press, Cambridge, MA.

Wenger, E. (1987) *Artificial Intelligence and Tutoring Systems,* Morgan Kaufman, Los Altos, CA.

Wenger, E. (1998) *Communities of Practice,* Cambridge University Press, Boston, MA.

Winograd, T. & Flores, F. (1986) *Understanding Computers and Cognition: A New Foundation of Design,* Addison-Wesley, Reading, MA.

Biographical Sketch of Gerry Stahl, Principal Investigator

Center for LifeLong Learning and Design
Department of Computer Science, and
Institute of Cognitive Science
University of Colorado, Boulder, CO 80309-0430

(303) 492-3912 (phone)
(303) 492-2844 (fax)
Gerry.Stahl@Colorado.edu
www.cs.colorado.edu/~gerry

Professional Preparation

University of Colorado
1996-99 Postdoctoral Research Fellow
1993 Ph.D. in Computer Science
1990 M.S. in Computer Science
Northwestern University
1975 Ph.D. in Philosophy
1971 M.A. in Philosophy
University of Frankfurt
1973 Graduate study in critical social theory
University of Heidelberg
1968 Graduate study in continental philosophy
Massachusetts Institute of Technology (MIT)
1967 B.S. in Humanities & Science (math & philosophy)

Appointments and Professional Experience

Assistant Research Professor
1999-present Department of Computer Science and
Institute of Cognitive Science, Boulder, CO
Post Doctoral Research Fellow
1996-1999 Center for LifeLong Learning and Design, Boulder, CO
President
1995-1996 Personalizable Software, Niwot, CO
Director of Software R&D
1993-1996 Owen Research Inc., Boulder, CO
Graduate Research Assistant
1990-1993 College of Environmental Design, Boulder, CO
Intern Interface Developer
1990-1991 US West Advanced Technology, Denver & Boulder, CO
Computer Science Instructor & Teaching Assistant
1989-1990 University of Colorado, Boulder, CO
Executive Director
1984-1989 Community Computerization Project, Philadelphia, PA
Planning and Evaluation Specialist
1979-1984 Southwest Germantown Community Devel. Corp., Philadelphia, PA
Community Organizer & VISTA Supervisor
1978-1979 Philadelphia Council of Neighborhood Organizations, Philadelphia, PA
Systems Programmer
1974-1977 Temple University, Philadelphia, PA
1970-1971 Northwestern University, Evanston, IL
1969-1970 Temple University, Philadelphia, PA
Applications Programmer
Summer 1966 Brown Bovari Cie, Baden, Switzerland
Summer 1965 University of Pennsylvania, Philadelphia, PA

Related Publications:

Stahl, G. (1993) Supporting situated interpretation, In: *Proceedings of Annual Meeting of the Cognitive Science Society* (CogSci '93), Boulder, CO, pp. 965-970. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1990-1997/cogsci93/CogSci.html.

Stahl, G. (1999) POW! Perspectives on the Web, In: *Proceedings of WebNet World Conference on the WWW and Internet* (WebNet '99), Honolulu, HA. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/webnet99/webnet99.html.

Stahl, G. (1999) Reflections on WebGuide: Seven issues for the next generation of collaborative knowledge-building environments, In: *Proceedings of Computer Supported Collaborative Learning* (CSCL '99), Palo Alto, CA, pp. 600-610. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/cscl99/.

Stahl, G. (2000) A model of collaborative knowledge-building, In: *Proceedings of International Conference of the Learning Sciences* (ICLS '00), Ann Arbor, MI. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/2000/icls/.

Stahl, G. & Herrmann, T. (1999) Intertwining perspectives and negotiation, In: *Proceedings of International Conference on Supporting Group Work* (Group '99), Phoenix, AZ. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1999/group99/.

Significant Publications:

Stahl, G. (1996) Armchair missions to Mars: Using case-based reasoning and fuzzy logic to simulate a time series model of astronaut crews, *Knowledge-Based Systems*, 9, pp. 409-415. Also in: Pal, Dillon & Yeung (2000) *Soft Computing in Case Based Reasoning*, London, UK, Springer Verlag, pp. 321-334. Available at: http://www.cs.colorado.edu/~gerry/publications/journals/crew/index.html.

Stahl, G. (1998) Collaborative information environments for innovative communities of practice, *Proceedings of the German Computer-Supported Cooperative Work Conference* (DCSCW '98), Dortmund, Germany. Available at: http://www.cs.colorado.edu/~gerry/publications/conferences/1998/dcscw98/dcscw.html.

Stahl, G. (1999) WebGuide: Guiding collaborative learning on the Web with perspectives, *Annual Conference of the American Educational Research Association* (AERA '99), Montreal, Canada. Also in: *Journal of Interactive Media in Education (JIME)* (2000). Available at: http://www-jime.open.ac.uk/00/stahl/ and http://www.cs.colorado.edu/~gerry/publications/conferences/1999/aera99/.

Stahl, G. (2000) Collaborative information environments to support knowledge construction by communities, *AI & Society*, 14, pp. 1-27. Available at: http://www.cs.colorado.edu/~gerry/publications/journals/ai&society/.

Stahl, G., Sumner, T., & Owen, R. (1995) Share globally, adapt locally: Software to create and distribute student-centered curriculum, *Computers and Education*. Special Issue on Education and the Internet, 24 (3), pp. 237-246. Available at: http://www.cs.colorado.edu/~gerry/publications/journals/c&e/.

Major Recent Grants (last 3 Years)

- 2000-2001: "New Media to Support Collaborative Knowledge-Building: Beyond Consumption and Chat" (PI) $19,752; sponsor: Lab for New Media at CU and the Omnicom Corporation.
- 1997-2000: "Allowing Learners to be Articulate: Incorporating Automated Text Evaluation into Collaborative Software Environments" (primary author and primary software developer; PIs: Gerhard Fischer, Walter Kintsch and Thomas Landauer) $678,239; Sponsor: James S. McDonnell Foundation.
- 1997-2000: "Conceptual Frameworks and Computational Support for Organizational Memories and Organizational Learning" (co-PI with Gerhard Fischer and Jonathan Ostwald), $725,000; Sponsor: NSF.
- 1999-2000: "Interoperability among Knowledge Building Environments" (PI) $9,124; Sponsor: Center for Innovative Learning Technology / SRI.
- 1998-1999: "Collaborative Web-Based Tools for Learning to Integrate Scientific Results into Social Policy" (co-PI with Ray Habermann) $89,338; Sponsor: NSF.

Collaborators:

Thomas Herrmann (and the Informatics and Society research group at Dortmund), Timothy Koschmann (and the Problem-Based Learning research group at Southern Illinois), Chris Hoadley (SRI & Stanford), Alex Cuthbert (Berkeley), Charles Hendricksen (Washington), Geri Gay (Cornell), Simon Buckingham Shum (Open University).

BIOGRAPHICAL SKETCH OF CURTIS D. LEBARON, CO-PRINCIPAL INVESTIGATOR

Department of Communication
Campus Box 270
University of Colorado
Boulder, Colorado 80309-0270

(303) 492-7488 (phone)
(303) 492-8411 (fax)
Curtis.LeBaron@colorado.edu

Professional Preparation

B.A.	Department of English	Brigham Young University, 1979
M.A.	Department of Communication	University of Utah, 1983
Ph.D.	Department of Communication Studies	University of Texas at Austin, 1988

Appointments

Assistant Professor, Department of Communication, University of Colorado at Boulder (1996 to present).

Assistant Instructor, Department of Communication Studies, University of Texas at Austin (1992 to 1996).

Associate Instructor, Department of Communication, University of Utah (1991 to 1992).

Managing Editor, The National Center for Constitutional Studies, Salt Lake City, Utah (1990 to 1991).

Technical Writer, Clyde Digital Systems, Orem, Utah (1987 to 1989).

Teaching Assistant, Department of Philosophy, Brigham Young University (1986 to 1987).

Writing Instructor, Department of English, Brigham Young University (1986 to 1987).

Research Interests

LeBaron studies language and social interaction within institutional and organizational settings. He uses micro-analytic methods (e.g., Conversation Analysis, Micro-ethnography) to examine recordings of naturally-occurring human interaction. He explicates both the vocal and the visible behaviors whereby people interactively create their social identities and pursue their practical goals. Recent research topics include: the strategic use of physical space during a police interrogation; the detection of deception during group therapy sessions; the use of hand gestures to introduce and negotiate new ideas during meetings between professional architects and their clients. For many years, LeBaron's research and teaching has been influenced by emerging computer technologies, which facilitate micro-analysis of videotaped data and creation of multimedia presentations ("movies") to document research findings.

Related Publications:

LeBaron, C. (in press). Technology does not exist independent of its use. In R. Hall, T. Koschmann, & N. Miyake (Eds.), *CSCL2: Carrying Forward the Conversation*. Mahwah, NJ: Lawrence Erlbaum.

LeBaron, C. & Streeck, J. (2000). Gesture, knowledge, and the world. In McNeill, D., (Ed.), *Language and Gesture*. Cambridge: University Press.

Koschmann, T., & LeBaron, C. (1998, July). The complementarity of speech and gesticulation in learner articulation. Paper presented at *Eighth Annual Meeting of the Society for Text and Discourse*, Madison, WI.

Hopper, R. & LeBaron, C. (1998). How gender creeps into talk. *Research on Language and Social Interaction* **31** (1), 59-74.

LeBaron, C. & Streeck, J. (1997). Space, surveillance, and interactional framing of participants' experience during a police interrogation. *Human Studies* 20, 1-25.

Other Significant Publications

LeBaron, C., Mandelbaum, J., & Glenn, P. (Eds.) (in press). Excavating the taken-for-granted: An introduction. *Excavating the Taken-for granted: Studies in Language and Social Interaction*. Mahwah, NJ: Lawrence Erlbaum.

LeBaron, C., & Koschmann, T. (in press). Gesture and the transparency of understanding. In Glenn, P., LeBaron, C., & Mandelbaum, J. (Eds.), *Excavating the Taken-for Granted: Studies in Language and Social Interaction*. Mahwah, NJ: Lawrence Erlbaum.

LeBaron, C. (1996) "Looking for verbal deception in Clarence Thomas's testimony." Published in S.L. Ragan, et al., *The Lynching of Language: Gender, Politics, and Power in the Hill-Thomas Hearings*, Chicago: University of Illinois Press.

Glenn, P., LeBaron, C., & Mandelbaum, J. (Eds.) (in press). *Excavating the Taken-for Granted: Studies in Language and Social Interaction*. Mahwah, NJ: Lawrence Erlbaum.

BIOGRAPHICAL SKETCH OF THE PROJECT ADVISORY BOARD

The project team includes a number of Advisory Board members who bring important complementary skills and expertise from education, ethnography, human-computer interaction, and assessment. Science and math content expertise is provided by Kalmon, Nathan, and Otero, as well as the developer of VIRTUALBIOLOGYLAB (Klymkowski). Advisory board members attend monthly workshops to review project progress and to participate in data sessions. Individual members may take a more active role during specific project periods as needed. The breadth of the team is important to provide an interdisciplinary audience for the analysis of the data, as well as for the on-going design and assessment (esp. Barker, Garvin-Doxas, Palen) of the project.

Lecia Barker is Director of Evaluation and Assessment for ATLAS, the Alliance for Technology, Learning and Science. Her PhD dissertation in Communication was on the discursive construction of virtual community in LAMDAMOO, a computational artifact. She is currently Evaluator or co-PI in 7 grants, mostly from NSF.

Robert Craig is an Associate Professor of Communication who specializes in communication theory and discourse analysis. He has studied interactive discourse in college classrooms, especially critical thinking courses. He has written on theory of communication, grounded theory, and communication as a research field.

Kathy Garvin-Doxas conducts quantitative and qualitative assessment and evaluation of the SOLAR SYSTEM COLLABORATORY – a web-based freshman astronomy course for non-majors; for the past 3 years she has been evaluating the implementation of collaborative learning techniques at CU. Her PhD dissertation in Communication was a Bakhtinian analysis of collaboration in an organization becoming more participatory.

Stevan Kalmon is now a Regional Technology Consultant for the Colorado State Department of Education. Previously he was a high school teacher at New Vista H. S. in Boulder and educational advisor to L^3D. He will be a liaison for working with high schools in the later part of the project.

Michael Klymkowsky is the designer and developer of the VIRTUALBIOLOGYLAB. He is a Professor of Molecular, Cellular & Developmental Biology at CU. He has previously published textbooks and a CD-ROM (see his appended letter of support for details).

Timothy Koschmann is a Professor of Medical Education at the Southern Illinois University School of Medicine. He has conducted extensive research on Problem-Based Learning at the Medical School, often using micro-ethnography to analyze video data. A leader in the research area of Computer-Supported Collaborative Learning, he has published extensively there.

Mitchell Nathan is Assistant Professor in the CU School of Education. His specialty is learning and teaching in school settings, and educational technology. He conducts extensive field research in high school algebra classrooms. After earning his PhD in cognitive psychology, he did research at the Learning Research and Development Center at Pittsburgh and Vanderbilt University Learning Technology Center, where he worked on *Jasper* and *Scientists in Action*.

Valerie Otero joined the faculty of the CU School of Education in January 2001 as a science education specialist. She was a co-developer of curriculum materials and simulation visualization tools in a five-year NSF-funded project entitled: *Constructing Physics Understanding in a Computer Supported Learning Environment*. Her PhD dissertation was on the shifting role of visualization tools in the process of learning electrostatics in a collaborative environment.

Leysia Palen is an Assistant Research Professor in Computer Science and a member of L^3D. She specializes in the adoption and use of everyday artifacts like mobile phones and electronic and group-sharing calendars. She studied CSCW issues and ethnographic methods at UCSD and UC Irvine.

Tamara Sumner is Assistant Professor of Computer Science at CU and is a member of L^3D and ICS. She teachers HCI, AI, and the Internet. She is co-founder and co-editor of JIME. Her research includes digital libraries in geo-science and on-line scholarly publication. Previously she developed distance education courses at the Open University in England.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Colorado at Boulder

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Gerry Stahl

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Gerry Stahl - PI	4.00	0.00	0.00	$ 29,762	$
2. Curtis LeBaron - Co-PI	0.00	0.00	1.00	5,362	
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	4.00	0.00	1.00	35,124	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				14,352	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				49,476	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				9,373	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				58,849	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				1,000	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				4,477	
TOTAL OTHER DIRECT COSTS				7,477	
H. TOTAL DIRECT COSTS (A THROUGH G)				68,326	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) 47% of MTDC (Rate: 47.0000, Base: 10725) (Cont. on Comments Page)					
TOTAL INDIRECT COSTS (F&A)				30,459	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				98,785	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 98,785	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $		
PI / PD TYPED NAME & SIGNATURE* Gerry Stahl	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION	
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet / Initials - ORG

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** I- Indirect Costs**
47.4% of MTDC (Rate: 47.4000, Base 53624)

SUMMARY PROPOSAL BUDGET YEAR 2

ORGANIZATION: **University of Colorado at Boulder**				FOR NSF USE ONLY		
				PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Gerry Stahl**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. Gerry Stahl - PI	4.00	0.00	0.00	$ 31,101	$	
2. Curtis LeBaron - Co-PI	0.00	0.00	1.00	5,603		
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	4.00	0.00	1.00	36,704		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (1) GRADUATE STUDENTS				14,998		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				51,702		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				9,692		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				61,394		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				0		
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000		
2. FOREIGN				0		
F. PARTICIPANT SUPPORT COSTS						
1. STIPENDS $ 0						
2. TRAVEL 0						
3. SUBSISTENCE 0						
4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				2,000		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				1,000		
4. COMPUTER SERVICES				0		
5. SUBAWARDS				0		
6. OTHER				4,608		
TOTAL OTHER DIRECT COSTS				7,608		
H. TOTAL DIRECT COSTS (A THROUGH G)				71,002		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) 47% of MTDC (Rate: 47.0000, Base: 66894)						
TOTAL INDIRECT COSTS (F&A)				31,440		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				102,442		
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 102,442	$	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI / PD TYPED NAME & SIGNATURE* Gerry Stahl	DATE			FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE			Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION **University of Colorado at Boulder**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Gerry Stahl**				AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Gerry Stahl - PI	4.00	0.00	0.00	$ 32,501	$
2. Curtis LeBaron - Co-PI	0.00	0.00	1.00	5,855	
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	4.00	0.00	1.00	38,356	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				15,673	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				54,029	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				10,027	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				64,056	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				1,000	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				4,744	
TOTAL OTHER DIRECT COSTS				7,744	
H. TOTAL DIRECT COSTS (A THROUGH G)				73,800	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) 47% of MTDC (Rate: 47.0000, Base: 69556)					
TOTAL INDIRECT COSTS (F&A)				32,691	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				106,491	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 106,491	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $			
PI / PD TYPED NAME & SIGNATURE* **Gerry Stahl**	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY					
PROPOSAL NO.	DURATION (months) Proposed	Granted			
AWARD NO.					

ORGANIZATION
University of Colorado at Boulder

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Gerry Stahl

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Gerry Stahl - PI	12.00	0.00	0.00	$ 93,364	$
2. Curtis LeBaron - Co-PI	0.00	0.00	3.00	16,820	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	12.00	0.00	3.00	110,184	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (3) GRADUATE STUDENTS				45,023	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				155,207	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				29,092	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				184,299	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				6,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				3,000	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				13,829	
TOTAL OTHER DIRECT COSTS				22,829	
H. TOTAL DIRECT COSTS (A THROUGH G)				213,128	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				94,590	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				307,718	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 307,718	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY		
Gerry Stahl		INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

BUDGET JUSTIFICATION

Salaries

PI

The PI will work full-time on this project. He is a Research Professor with no teaching responsibilities. He will manage the project and supervise the project team. The current proposal requests 4 months per year of salary. A pending NSF ROLE proposal requests 9 months per year and would be re-allocated if both proposals are funded.

GRA

A doctoral student will be paid for half-time work on the project during the academic year (20 hours per week for 9 months). He or she will receive tuition reimbursement as well as GRA stipends.

Other Students

Other undergraduate and graduate students in Computer Science, Communication and Education will participate in the project through class group assignments associated with the project: e.g., interface design, interaction transcription, curriculum design.

Travel

Domestic

Travel expenses are budgeted for 2 trips per year to conferences.

Other Direct Costs

Materials and Supplies

Funds are budgeted for equipment needed to gather and analyze data, including video cameras, microphones, video digitization hardware and software, computer memory, etc.

Consultants

Some project Advisory Board members will be reimbursed as consultants to engage in project tasks as needed from time to time. They will be paid no more than $450 per day.

Indirect Costs

Per HHS agreement dated 8/16/99, indirect costs are calculated at 47.4% of M.T.D.C. for the period 7/1/99 - 6/30/02 and 47% of M.T.D.C for the period 7/1/02 - 6/30/04.

CURRENT AND PENDING SUPPORT

Investigator: **Gerry Stahl**	Other agencies (including NSF) to which this proposal has been/will be submitted. **None**

Support: Current Pending **X** Submission Planned in Near Future

Project/Proposal Title: **CSS: Perspectives on Collaboration: a Micro-ethnographic Study of Computational Perspectives in Computer Support for Collaborative Knowledge-Building at a Virtual Biology Laboratory** (this proposal)

Source of Support: **NSF - CSS**

Total Award Amount: **$307,718** Total Award Period Covered: **9/1/01 – 8/31/04**

Location of Project: **University of Colorado at Boulder**

Person-Months Per Year Committed to the Project. Cal: **4** Acad: Sumr:

Support: Current Pending **X** Submission Planned in Near Future

Project/Proposal Title: **ITR/PE (EHR): Information Technology for Distributed Collaborative Learning in a Virtual Biology Lab**

Source of Support: **NSF - ITR**

Total Award Amount: **$472,610** Total Award Period Covered: **9/1/01 – 8/31/04**

Location of Project: **University of Colorado at Boulder**

Person-Months Per Year Committed to the Project. Cal: **4** Acad: Sumr:

Support: Current Pending **X** Submission Planned in Near Future

Project/Proposal Title: **The Role of Computational Cognitive Artifacts in Collaborative Learning and Education**

Source of Support: **NSF - ROLE**

Total Award Amount: **$970,972** Total Award Period Covered: **5/1/01 – 4/30/04**

Location of Project: **University of Colorado at Boulder**

Person-Months Per Year Committed to the Project. Cal: **9** Acad: Sumr:

Support: Current **X** Pending Submission Planned in Near Future

Project/Proposal Title: **New Media to Support Collaborative Knowledge-Building: Beyond Consumption and Chat**

Source of Support: **Omnicom Corporation**

Total Award Amount: **$19,752** Total Award Period Covered: **11/1/00-4/30/01**

Location of Project: **University of Colorado at Boulder**

Person-Months Per Year Committed to the Project. Cal: **3** Acad: Sumr:

Investigator: **Curtis LeBaron**	Other agencies (including NSF) to which this proposal has been/will be submitted. **None**

Support: Current Pending **X** Submission Planned in Near Future

Project/Proposal Title: **CSS: Perspectives on Collaboration: a Micro-ethnographic Study of Computational Perspectives in Computer Support for Collaborative Knowledge-Building at a Virtual Biology Laboratory** (this proposal)

Source of Support: **NSF - CSS**

Total Award Amount: **$307,718** Total Award Period Covered: **9/1/01 – 8/31/04**

Location of Project: **University of Colorado at Boulder**

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: **1**

Support: Current Pending **X** Submission Planned in Near Future

Project/Proposal Title: **The Role of Computational Cognitive Artifacts in Collaborative Learning and Education**

Source of Support: **NSF - ROLE**

Total Award Amount: **$970,972** Total Award Period Covered: **5/1/01 – 4/30/04**

Location of Project: **University of Colorado at Boulder**

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: **2**

Facilities, Equipment and Other Resources

Computational Facilities

The Center for LifeLong Learning and Design, the Department of Computer Science, and the Institute of Cognitive Science at the University of Colorado, Boulder, have created a first-class computational environment for research in artificial intelligence, cognitive science, human-computer interaction, and social factors.

Over the last 15 years, the Department of Computer Science received a Coordinated Experimental Research (CER) grant and three Institutional Infrastructure grants from NSF. These grants have allowed the department to acquire some of the most modern machines and create a computationally rich research environment. In addition, these grants provided a basic level of networking infrastructure for the department.

The PI (Stahl) is a Senior Research Scientist on the new NSF/CISE Research Infrastructure grant. This grant will support the purchase of several laptop computers to facilitate project work and communication within the project.

The Communication Department maintains a lab for digital video analysis. This lab will be available to project staff.

Office Space

The College of Engineering and the Department of Computer Science provide faculty, staff, and Ph.D. students with office space. A unique Discovery Learning Center (DLC) is currently under construction as the next phase of the development of the College of Engineering complex. DLC will have the capacity to link to other sites, on campus, with our partners, in the community, and around the world, through state-of-the-art technology. Building completion is expected in August 2001, during the first phase of the project. L^3D is the major tenant in the DLC. The PI, some of the project staff, and proposed activities will be housed in the DLC. Most trials of educational artifacts will be conducted and videotaped in a specially designed area of the DLC. There will be space there for project workgroups and for the monthly Advisory Board meetings. The DLC is specifically designed to provide space for projects like the proposed one, which include students and faculty, which are interdisciplinary, and which take advantage of digital technologies.

UNIVERSITY OF COLORADO. BOULDER

COLORADO

Molecular, Cellular & Developmental Biology
Michael W. Klymkowsky, Professor
phone: 303-492-8508 / 7744 (fax)
e-mail klym@spot.colorado.edu

Tuesday, February 6, 2001

Professor Gerry Stahl
Computer Science
University of Colorado, Boulder
Boulder, Colorado 80309-0430

Dear Gerry,

I am pleased to give my enthusiastic support for your NSF CSS Program proposal: “Perspectives on Collaboration: A Micro-ethnographic Study of Computational Perspectives in Computer Support for Collaborative Knowledge-Building at a Virtual Biology Laboratory.”

I have been involved in a number of media and web-based educational projects, *e.g.* developing web-sites to support courses I have taught[1], writing and editing the “teachware” CD-ROM “The Dynamic Cell” published by Springer-Verlag[2], and authoring the “Working with the Literature” section of the web-site that accompanies W.H. Freeman’s best selling text “Molecular Cell Biology” by Lodish et al[3]. I have had first hand experience with laboratory courses, having completely redesigned the laboratory course (MCDB 3140) that accompanies our Cell Biology course (MCDB 3120).

I have read your NSF proposal and am happy to participate in the project. I believe that your work is likely to be useful to those developing web-delivered teaching applications in the natural sciences and other subjects. Over the past year Tom Lundy and I, working through our company virtuallaboratory.net, inc. (DUNS number: 001394381), have been developing web-based curricula and interactive FLASH 5-based web applications for high school “Advanced Placement”, introductory and advanced college-level biology (virtuallyBiology™) and genetics (virtuallyGenetics™) courses. We are in final contract negotiations with W.H. Freeman & Co to produce college level virtuallyBiology™ WebLabs; the first series of these labs are scheduled for release in January 2002 and have begun developing a similar series of virtuallyGenetics™ labs. Negotiations are on going with CogitoLearningMedia, Inc. to produce and distribute virtuallyBiology™ labs aimed at the high school AP audience. A number of our web-based labs are currently ready for student testing[4]. In the spring and fall of 2001, we will recruit students to test

---

[1] MCDB 4444: The Diseased Cell: http://spot.Colorado.edu/~klym/class4444.html; MCDB 3330: Evolution & Creationism: http://spot.Colorado.edu/~klym/class3330.html; MCDB 1150: Introduction to Molecular Biology: http://spot.Colorado.edu/~klym/class1150.html and MCDB 3120: Cell Biology: http://spot.Colorado.edu/klym/CellHome.htm

[2] http://www.springer.de/lifesci/dynamic-cell/

[3] http://www.whfreeman.com/lodish/con_index.htm?99ww1

[4] These labs can be viewed at our web site: http://www.virtuallaboratory.net

these labs. My department is supportive of the use of web-based labs and I am scheduled to teach a new course, MCDB 1111: Biofundamentals, in the spring of 2002. This introductory level course will use web labs as a substitute for conventional "wet" labs.

Wet labs are a cornerstone of the conventional biology curriculum. There are, however, many reasons to believe that interactive web-based labs will prove to be significantly more effective in teaching the basics concepts of experimental science. Web-based labs are not constrained by time, student technique, institutional facilities, or the availability of well-trained personnel and ancillary resources. Classic experiments, such as the studies of Luria & Delbruck which revealed the random nature of mutations or those of Monod and Jacob which established the regulatory organization of the gene, can be readily recreated using web-based applications. It is possible to create experiments in evolutionary and ecological biology that are impossible to perform in conventional lab courses. More to the point, conventional labs are subject to a very strong, and generally unacknowledged, selection pressure against exercises that are time consuming or that have a significant chance of "failure". This inevitably leads to a simplification of the experiments attempted, often at the expense of didactic substance.

In contrast, web-based laboratories enable (and truth to tell, force) students to discover for themselves how critical ideas were established in an experiential, "minds on" way. While conventional laboratory courses can often turn students off to science, web-based laboratories can inspire students - particularly in an age when more and more biology will be done using computers, both in "data mining" and the modeling of biologic systems.

There is a strong and quite sound argument that physical laboratories are essential to the training of practicing biologists. However, even here logic seems to favor web-based labs at the introductory and intermediate levels. Over the years, I have hosted over 30 independent study undergraduate students in my laboratory; I have consistently found the "training" they received in their laboratory experiences left them conceptually and technically unprepared for lab work. Web-based labs can provide a level of conceptual rigor that conventional labs do not approach, constrained as they are by the realities of biologic systems and educational economics. More importantly, large introductory laboratory courses are expensive (~$500-$600 per student here at the University of Colorado). They effectively drain scare resources away from smaller and more effective upper division laboratory courses and independent study experiences that are essential in the training of future biologists.

Finally, it is clear to us that in a project as revolutionary as our interactive WebLabs, student and instructor feedback, and responsive redesign and design modification are critical to the development of optimally effective teaching applications. Your project promises to provide the developers of web-based teaching applications critical insights into what works and what does not. As such it is fundamental to the successful development of new teaching technologies, and with them the promise of bringing high quality educational experiences to a much broader segment of the American and worldwide student population.

Sincerely,

Michael W. Klymkowsky
Professor