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. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPRISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Brian M Slator

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 tasks, 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 is not a precondition of 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-represendted 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. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPRISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Phillip E McClean

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 tasks, 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 is not a precondition of 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-represendted 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. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPRISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Bernhardt Saini-Eidukat

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 tasks, 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 is not a precondition of 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-represendted 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. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPRISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Donald P Schwert

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 tasks, 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 is not a precondition of 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-represendted 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. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPRISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Alan R White

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 tasks, 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 is not a precondition of 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-represendted 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).

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:

Dr. Benjamin Bell, Columbia University, benjamin.bell@columbia.edu
Dr. Jeff Berger, Northwestern University, berger@ils.nwu.edu
Dr. Eli Blevis, Illinois Institute of Technology , eli@id.iit.edu
Dr. Robin Burke, University of Chicago, burke@cs.uchicago.edu
Dr. Danny Edelson, Northwestern University, edelson@ils.nwu.edu
Dr. Andrew Gordon, IBM TJ Watson research center, asgordon@us.ibm.com
Dr. Steve McGee, NASA Center for Ed. Tech., mcgee@cet.edu
Dr. Nicole Pinkard, U. of Michigan, pinkard@umich.edu
Dr. Brian Smith, MIT Media Laboratory, bsmith@media.mit.edu
Dr. Stanley Supinski, USAF Academy, supinskisb.dff@usafa.af.mil
Dr. Susan Williams, Vanderbilt University, Susan.Williams@Vanderbilt.Edu

REVIEWERS NOT TO INCLUDE:

Not Listed

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 00-2

NSF 99-167 **04/17/00**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

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

INFORMATION TECHNOLOGY RESEARC, INFORMATION TECHNOLOGY RESEARC

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				803882299	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

456002439

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

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

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

North Dakota State University Fargo

AWARDEE ORGANIZATION CODE (IF KNOWN)

0029975000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

Post Office Box 5405
University Station
Fargo, ND. 581055405

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

PERFORMING ORGANIZATION CODE (IF KNOWN)

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

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

TITLE OF PROPOSED PROJECT **ITR/SOC: Systems for Learning Science and Assessing Student Learning**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PREPROPOSAL NO., IF APPLICABLE
$ **2,503,190**	**60** months	**09/01/00**	

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

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

PI/PD DEPARTMENT
Department of Computer Science

PI/PD POSTAL ADDRESS
IACC Building, Room #258

Fargo, ND 58105
United States

PI/PD FAX NUMBER
701-231-8255

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME **Brian M Slator**	**Ph.D.**	**1988**	**701-231-6124**	**slator@badlands.nodak.edu**
CO-PI/PD **Phillip E McClean**	**Ph.D.**	**1982**	**701-231-8443**	**mcclean@plains.nodak.edu**
CO-PI/PD **Bernhardt Saini-Eidukat**	**Ph.D.**	**1991**	**701-231-8785**	**sainieid@badlands.nodak.edu**
CO-PI/PD **Donald P Schwert**	**Ph.D.**	**1978**	**701-231-7496**	**schwert@plains.nodak.edu**
CO-PI/PD **Alan R White**	**PH.D.**	**1981**	**701-231-8380**	**alwhite@plains.nodak.edu**

CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators:

I certify to the best of my knowledge that:

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

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

Name (Typed)	Signature	Social Security No.*	Date
PI/PD **Brian M Slator**		**SSN's are confidential and are not displayed *ON FASTLANE SUBMISSIONS***	
Co-PI/PD **Phillip E McClean**			
Co-PI/PD **Bernhardt Saini-Eidukat**			
Co-PI/PD **Donald P Schwert**			
Co-PI/PD **Alan R White**			

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 Federal debt status, debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 00-2. 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.

Debt and Debarment Certifications

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

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

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

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan 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) **Dr. Edna T. Holm, Interim Dean/Research**		**04/09/00**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
701-231-8045	**ndsu-research@plains.nodak.edu**	**701-231-8098**

*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.

Project Summary

We propose a 5-year project to study science learning in authentic, immersive, virtual environments. To do this, we propose a four-part plan of work that includes:

1) the design and implementation of a range of simulated environments for teaching science topics such as geology, biology, and computer science, each framed according to our theoretical approach: role-based learning;
2) the design and development of an innovative, integrated, distributed software platform for developing and hosting virtual environments of any type;
3) the design and implementation of empirical studies using an innovative protocol, scenario-based assessment, for measuring student learning in our virtual worlds;
4) design and management of a graduate level summer school course for in-service teachers who will be trained, beginning in year three of the project, to use our virtual environments in their classrooms.

The success of this project depends on implementing this 4-part plan, which in turn depends on fundamental Computer Science research in the areas of distributed systems, software agents and intelligent tutoring, and virtual environments.

This document describes our approach, which stresses the ideas of authentic instruction and authentic assessment. We describe our theory of role-based learning and outline our plans for instantiating this framework in parallel virtual worlds for education. The inter-disciplinary nature of the project team is complemented by a common, theoretically motivated approach, and shared responsibilities as regards design and management.

We describe our empirical methods, based on a protocol called scenario-based assessment, and give an account of a large controlled study showing our methods have a statistically significant positive effect on student learning.

We describe our plans for regional outreach and national impact, in part through a dissemination scheme involving K-12 teachers, and in part through public access to our systems via the internet.

This is a multi-disciplinary project spanning information technology and scientific applications, involving a team of faculty and student researchers from an EPSCoR state, North Dakota. This is a long term and high risk project, employing innovative technology and methods, but with potential for high payoff in terms of changing and improving the way science is taught in our schools.

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 (including 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	3	
E	Biographical Sketches (Not to exceed 2 pages each)	12	
F	Budget (NSF Form 1030, including up to 3 pages of budget justification)	4	
G	Current and Pending Support (NSF Form 1239)	10	
H	Facilities, Equipment and Other Resources (NSF Form 1363)	1	
I	Special Information/Supplementary Documentation	0	
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, however, the entire proposal must be paginated. Complete both columns only if the proposal is numbered consecutively.

ITR/SOC: Systems for Learning Science and Assessing Student Learning

The study of computer-based instruction requires two fundamental elements: 1) software designed to teach; and 2) rigorous experiments designed to measure learning. This proposal contains those two fundamental elements. We propose to develop a theory for the design of teaching software called "role-based environments", and we propose a rigorous experimental procedure for measuring student learning called "scenario-based assessment" (Slator et al., 1999). Both of these are non-standard approaches and therefore high-risk. Or they would seem so, except we have conducted a large, rigorous, controlled study showing that our approach actually works. We seek funding to expand and continue this work.

We are planning a 5-year project that concentrates, in the first two years, on developing and testing role-based environments. In the summer, before the third year, we plan to conduct a month-long summer training course with K-12 teachers. We plan to pay these teachers to attend, in addition to offering them graduate credit. The teachers will learn about our courseware, how to administer it at their own site, and how to develop custom modules tailored to their own schools. In the third and fourth years, we will continue developing and testing our role-based environments, but with priority given to providing the K-12 teachers with courseware support, custom programming, and gathering data on student performance. We plan to repeat the summer training course before years four and five as well. In the fifth year we anticipate continued development along the same lines, as well as an initiative formalizing our approach, either by founding a Center for role-based environment research and development, or forming a company to market our courseware.

Authentic Instruction and Authentic Assessment

Every field of science has a set of correlative beliefs that constitute the science. Recent work in the philosophy of science has given us a deeper understanding of what a science really is; that scientific facts are given coherence by their context of other facts and practices (e.g., Thagard, 1989). Simply put, current views of science hold that a field is an interconnected set of things we know and things we do.

Rather than say that a science is some body of knowledge, we now say that a particular science is defined by practicing scientists. These scientists are seen as a community or culture whose members share a set of beliefs and practices. Science, in this view, is seen as a “community of practice” (e.g., Pea, 1993). Typically, the practices — for example, the methods used in the laboratory or field — determine which beliefs are accepted by community members. The knowledge and acceptance of these practices gives meaning to the beliefs. In this view, the practices of scientists are fundamental to a science.

The focus on embedding science facts in a context of scientific practice is reflected in much current educational practice. This move is often billed as teaching science in an “authentic” context. Authenticity requires that the context in which students learn a set of facts

is an analog of the context in which scientists do their work. Therefore, many have moved from a focus on teaching a broad set of specific facts to a focus on embedding a more limited set of facts in a richer context of scientific practice (Edelson, Pea, and Gomez, 1996). This is seen as a way to teach students how to think like a scientist.

Scientific thought, then, is a type of "situated cognition" (Lave and Wegner, 1991). The "situations" of what is called situated cognition are the contexts in which scientists do their work. These situations describe how scientists discover knowledge (Brown, Collins, and Duguid, 1989). To understand science is to understand the tools of scientists. Tools embody the practice of a community (Lave and Wegner, 1991).

Meanwhile, the economics of assessment drives teachers to teach disconnected facts and assess student learning through recognition of sets of individual facts. The easiest assessment we can do is the multiple choice test. With these tests, we can ask each student to look over a set of questions. These questions are "facts" that have been presented. Often the questions can be seen as a virtual mad-lib where we take an incomplete sentence and offer various words to complete the sentence. To select the correct answer from the list of potential completions, the student must recognize the fact as presented in the course materials. If the student can complete a number of these sentences, we assume this is a good heuristic for understanding the field of study.

Authentic assessment is often used in discussions of assessment but is rarely defined (AAAS, 1993; PCAST, 1997). Given the preceding discussion, it stands to reason that authentic assessment requires that the student be asked to use knowledge about a scientific domain (both in tools and practices) and to perform tasks that make sense within that domain. Students should be able to demonstrate that they not only "know what" but also "know how". Furthermore, authentic assessment means that students must be judged by the criteria with which scientists are judged: their ability to use the tools of their field to answer questions of relevance within their field. An authentic assessment in science is when scientists judge another scientist's work to be acceptable within the domain of that field, e.g., using the tools and practices of the field the scientist was able to determine some fact within that field.

Authentic instruction (Brown, Collins, and Duguid, 1989) would allow the student to participate in the practices of the working scientist. Students would be a part of laboratory research or field work. Students would have access to the tools of the working scientist and would, in every case, be shepherded through the scientific process. New concepts — the beliefs of the scientist — would be introduced in this naturalistic context. As noted above, the economics of assessment have determined, to a large extent, the practice of inauthentic assessment. What may be less obvious is that the economics of instruction have likewise determined the practice of inauthentic instruction. In the past, when we taught a student some domain of science, an instructor often had to lecture the student rather than require the student to adopt the practices and tools of the working scientist.

The Theory of Role-based Environments

An apprentice watches their master, learning techniques and practicing their craft; they observe the master's actions and internalize them. When confronted with a problem, the apprentice asks, "what would the master do in this situation?" And then the apprentice models the expertise of the master in the pursuit of their goals. This is a common experience shared by silversmiths, doctors, Ph.D. candidates, and anyone else learning to become what they want to be. When John Houseman says, in the Paper Chase that "We are not teaching you the law, we are teaching you to think like a lawyer," this is what he means.

This proposal contains two essential elements in the service of studying how students can learn science: 1) the implementation of theoretically motivated, immersive, virtual environments to teach science; and 2) assessment of student learning in these environments. The other major component of this project involves dissemination and outreach, where we propose to distribute our systems to in-service teachers after a period of development followed by a period of teacher training and support.

Below we describe our implemented systems, provide results of a rigorous study showing they actually work, and outline our plans for moving these systems into the public schools. This combination of development and outreach towards a sustained, long-term commitment motivates this as a five-year project.

Implementing Role-based Environments to Teach

The theory of role-based environments is both simple to explain and complex to implement. The idea is to put students into authentic situations that will challenge them to think through problems and act like scientists. In practice this means implementing authentic simulated environments where students can learn-by-doing. This entails implementing a vast range of interacting locations, artifacts, and instruments to support 1) authentic problem solving situations, 2) research questions and content-relevant goals, and 3) online help and tutorial advice in context.

Development of such systems is difficult, expensive, and inherently collaborative, and requires three components: 1) content expertise by subject matter experts and the associated (non-standard) pedagogical design; 2) software design, development, and project management; and 3) fundamental Computer Science research in the areas of distributed systems, software agents and intelligent tutoring, virtual environments, and scientific visualization.

Experience of the Project Team

The NDSU World Wide Web Instructional Committee (WWWIC; McClean et al., 1999) is engaged in several virtual/visual research and development projects: three are NSF-supported, the Geology Explorer (Schwert et al., 1999), the Virtual Cell (White et al., 1999) the Visual Computer Program (Juell, 1999) and the ProgrammingLand MOOseum of Computer Science (Slator and Hill, 1999). These have shared and individual goals. Shared goals include the mission to teach

science structure and process: the scientific method, scientific problem solving, diagnosis, hypothesis formation and testing, and experimental design. The individual goals are to teach the content of specific scientific disciplines: Geology, Cell Biology, Computer Science.

In addition, WWWIC is applying what has been learned in Science education to new domains: history, microeconomics, and anthropology. Further, WWWIC has active research projects in three highly related areas: 1) qualitative assessment of student learning, 2) tools for building virtual educational environments, and 3) intelligent software tutoring agents (Slator, 1999).

The WWWIC program for designing and developing educational media implements a coherent strategy for all its efforts. This strategy is to deploy teaching systems that share critical assumptions and technologies (e.g. LambdaMOO; Curtis, 1998), in order to leverage from each other's efforts. In particular, systems are designed to employ consistent elements across disciplines and, as a consequence, foster the potential for intersecting development plans and common tools for that development. Our simulations are implemented by building objects and interfaces onto a MOO ("MUD, Object-Oriented", where MUD stands for "Multi-User Domain"). MUDs are typically text-based electronic meeting places where players build societies and fantasy environments, and interact with each other. Technically, a MUD is a networked multi-user database and messaging system. The basic components are "rooms" with "exits", "containers" and "players". MUDs support the object management and inter-player messaging that is required for multi-player games, and at the same time provide a programming language for writing the simulations and customizing the environements.

Major WWWIC Team Efforts

Space does not permit full description of the WWWIC projects listed above. However, since palpable concentration is placed on shared design and development, a brief description of two projects will provide a representative picture of the effort.

Example: the Geology Explorer

The Geology Explorer project implements a virtual world where learners assume the role of a geologist on an expedition to explore the geology of a mythical planet. Learners participate in field-oriented expedition planning, sample collection, and "hands on" scientific problem solving. The Geology Explorer world, Planet Oit, is simulated on an Object Oriented Multi-user Domain, the Xerox PARC LambdaMOO. A text-based version of Geology Explorer was tested in an introductory geology class during the Summer 1998. Results of that test were used to prepare for a larger test in the same geology class during Fall 1998 and Fall 1999. A graphical user interface to the Geology Explorer is under development.

To play the game, students are transported to the planet's surface and acquire a standard set of field instruments. Students are issued an "electronic log book" to record their findings and, most importantly, are assigned a sequence of exploratory goals. These goals are intended to

motivate the students to view their surroundings with a critical eye, as a geologist would. Goals are assigned from a principled set, in order to leverage the role-based elements of the game. The students make their field observations, conduct small experiments, take note of the environment, and generally act like geologists as they work towards their goal of, say, locating a kimberlite or a graphite deposit. A scoring system has been developed, so students can compete with each other and with themselves. The Geology Explorer prototype can be visited at http:/ /oit.cs.ndsu.nodak.edu/

Example: the Virtual Cell

The Virtual Cell (VCell) is an interactive, 3-dimensional visualization of a bio-environment. VCell has been prototyped using the Virtual Reality Modeling Language (VRML), and is available via the Internet. To the student, the Virtual Cell looks like an enormous navigable space populated with 3D organelles. In this environment, experimental goals in the form of question-based assignments promote diagnostic reasoning and problem-solving in an authentic visualized context.

The initial point of entry for the Virtual Cell is a VRML-based laboratory. Here the learner encounters a scientific mentor and receives a specific assignment. In this laboratory, the student performs simple experiments and learns the basic physical and chemical features of the cell and its components. More notably, our laboratory procedures are crafted such that they necessitate a voyage into the Virtual Cell where experimental Science meets virtual reality. As the project progresses, students revisit the laboratory to receive more assignments. Periodically, the student will bring cellular samples back to the virtual lab for experimentation. The Virtual Cell prototype can be visited at http://www.ndsu.nodak.edu/instruct/mcclean/vc/

Technology aside — the virtual world simulations are implemented on an object-oriented database (LambdaMOO; Curtis, 1998), running on a Unix server. Client software is written in Java and delivered by an HTTP server on the same machine. The Java applets are, among other things, a wrapper on a Telnet client, which connects back to the LambdaMOO server through a non-Unix port (i.e. not port 23). As a consequence, connections to the various simulations, some of which have been publicly available since 1998, and visited by hundreds of players from sites all over the United States and around the world, IS NOT ACCESSIBLE FROM WITHIN THE WALLS OF NSF due to their firewalled system security. Anyone can visit the sites listed above, but those behind the NSF firewall, or other similarly secured sites, cannot log on and join the simulations.

Software Tutors

A key feature of WWWIC educational environments is the ability to tutor students, which is done through unintrusive but proactive software agents. Agents monitor student actions and "visit" a student when the need arises. Tutors give advice, but they do not mandate or insist on student actions, nor do they block or prevent student actions. Tutors are extremely important in providing timely advice to students having problems. They are also extremely important in providing a round-the-clock presence which affords a self-paced, anytime-anywhere experience for the students.

The present cast of tutors provides intelligent help by matching a representation of the goal-based tasks assigned in the environment with a record of student action, including movements and experiments. When a student commits a diagnostic error by, say, mis-identifying an outcrop, the tutors are able to ask questions, suggest experiments, and perform certain other scripted interventions. These scripts and tutoring interactions are likewise designed to be authentic, modeled on the experience of a geologist leading a field camp.

WWWIC projects, most notably the Geology Explorer, currently implement diagnostic tutoring agents. Tutoring is done through unintrusive but proactive software agents that monitor student actions and “visit” a student as the need arises. Tutors give advice, but they neither mandate or insist on student actions nor block or prevent student actions. Tutors are extremely important in providing timely advice to students having problems. They are also extremely important in providing a round-the-clock presence which affords a self-paced, anytime-anywhere experience for the students.

The present cast of tutors provides intelligent help by matching a representation of the goal-based tasks assigned in the environment with a record of student action, including movements and experiments. When a student commits a diagnostic error by, say, mis-identifying an outcrop, the tutors are able to ask questions, suggest experiments, and perform certain other scripted interventions. These scripts and tutoring interactions are designed to be authentic, modeled on the experience of a geologist leading a field camp. Three opportunities for diagnostic tutoring are:

- an equipment tutor that detects when a student has failed to "buy" equipment necessary to achieving their goals
- an exploration tutor that detects when a student has overlooked a goal in their travels
- a science tutor that detects when a student makes an incorrect diagnosis and why (i.e. what evidence they are lacking); or when a student makes a correct report with insufficient evidence (i.e. a lucky guess)
  The science tutor is called by the report verb (described in

http://oit.cs.ndsu.nodak.edu/oit/usercard.html). For example, suppose the student is given the goal of locating and identifying graphite used in the production of steel and other materials. To confirm that a mineral deposit is indeed graphite the student must test the deposit with the "streak plate" and observe a black streak, and scratch the deposit to determine its hardness is less than 2.0 on the standard (Mohs) scale, and report that the sample as graphite

The tutor checks the player's history and determines which case pertains:

- (wrong tests) the player has "guessed" incorrectly and the player's history property indicates they have not conducted the necessary tests to identify the rock/mineral in question
- (wrong answer) the player has "guessed" incorrectly and the player's history property indicates they have conducted the necessary tests to identify the rock/mineral in question
- (lucky guess) the player has "guessed" correctly but the player's history property indicates they have not conducted the necessary tests to identify the rock/mineral in question
- (good work) the player has "guessed" correctly and the player's history property indicates they have conducted the necessary tests to identify the rock/mineral in question

The system encodes the necessary and sufficient experiments for each rock and mineral, as well as their expected results. The tutors check these facts against the student's history property whenever the student "guesses" a deposit's identity. Tutors remediate, as appropriate, according to the four cases listed above.

Context: Previous Experience with Case-based Reasoning

The PI has considerable research experience in the area of case-based reasoning. As a member of the research faculty at Northwestern University, he designed, managed and/or played a leading role in the implementation of the following research and development projects.

ORCA - (the ORganizational Change Advisor) was a job aid and creativity tool to assist consultants whose task is process redesign and managing organizational change. Using ORCA, the consultant systematically and iteratively analyzes the situation of a client in order to recognize potential business or organizational problems. The system assists the consultant in thinking and problem solving by retrieving historical cases that are judged relevant to understanding the client's situation. The retrieval and examination of past cases provides general perspective and contextual advice which helps the consultant plan for change and avoid past failures (Bareiss and Slator, 1993).

The Risk/Audit Coach was a performance support system designed to assist internal auditors in planning and executing their audit engagements. By modeling the auditor's task, and further modeling the processes being audited, the Coach was able to provide structured task-oriented support and context-sensitive help and advice at every stage of the auditing process. In addition, by tracking an auditor's progress and the categorization of their audit, the Risk/Audit Coach was able to retrieve relevant similar audit reports and audit stories from its case library (Slator, 1996).

In addition, the FoodStation project was designed to allow the user to explore a wide variety of options in food preparation and consumption, including recipes and recipe guides, on-line shopping capabilities and recommendations for different classifications of consumers (Slator and MacQuarrie, 1995). The TAXOPS tax opportunity advisor helps tax professionals to uncover possible consulting opportunities (Slator and Riesbeck, 1992; Slator and Fidel, 1994). The QED project focused on the development of a story-based learning system to provide Total Quality Management (TQM) teams (Slator et al., 1994).

Context: Mining for Cases on Planet Oit

During Fall 1998 and 1999, the entire NDSU Physical Geology class (400+ students) were given the opportunity to participate in an experiment to evaluate the effectiveness of Planet Oit on conceptual learning and problem-solving: the role-based skills. Students were divided into three experimental groups: two groups were matched to ensure equal distributions of technological ability and were asked to experience Planet Oit or an alternate internet-based activity equal in estimated time-on-task; the third group did no additional activity. Then, after the

players experienced an extended exploration of Planet Oit (or alternative exercise), they were given a similar post-test survey with different but analogous problem solving scenarios, and asked again to record their questions and impressions.

Through the course of the experiment, and by interacting with students both off- and online, we came to believe that identifiable learning and problem-solving styles were being employed by the students. Some students appeared to take an analytical approach: frequently referencing the online help, conducting sequences of experiments, and making diagnoses and scoring points in a deliberate fashion. Other students seemed to take a pattern-matching approach: exploring far and wide in search of outcrops that seemed to match the description of what they were looking for, and then scoring points with relatively few experiments. There was also a small but noticeable group taking a straight brute force approach, simply visiting location after location and identifying everything there, one after another, as their goal, eventually succeeding after many tries. One monument to this approach was the student who in 1998 made 1,244 guesses on the way toward obtaining 5 correct answers.

To investigate the nature of the trends we believed we were seeing, an analysis was conducted using logging data to count the number of "reports" (i.e. guesses), the number of locations visited, and the number of experiments conducted (e.g. hit, scratch, streak, etc.), for the 81 students who had completed the game and an evaluation survey. These data from the 1999 study are summarized in Figure 1.

	Reports	**Moves**	**Experiments**
average	**42.6**	**139.2**	**73.8**
st. dev	**38.2**	**83.1**	**63.2**
min	**5**	**19**	**0**
max	**238**	**518**	**301**

Figure 1: Student reports, moves, and experiments

Using these values for average and standard deviation, we developed a classification of behaviors by looking for combinations of either much higher or much lower than average activity in terms of reports, moves, or experiments, or combinations of these. These data are summarized in Figure 2. There are a total of 24 clusters, each marked with a code, which represent 3 interesting categories.

Key: R = many reports; r = few reports;
M = many moves; m = few moves;
E = many experiments; e = few experiments.

Example: "-M-" means normal reporting, many moves, normal experiments (where normal is within one-half standard deviation from the mean).

The values in Figure 2 indicate that a wide range of approaches are supported by the Geology Explorer, a testament to the user-centered and user-controlled nature of the simulation. Further, almost half of the students can be classified as consistently efficient, not only economizing on their problem-solving effort, but doing so across all three dimensions.

Meanwhile, over half were above normal in one or more dimension, with 17 making excessive reports (code "R", the brute force approach); 19 making excessive movements around the planet (code "M", the pattern matching approach), and 22 making more than the normal number of experiments (code "E"). Note that 3 students were excessive on all 3 dimensions, and only 2 students were within 1/2 standard deviation on all 3 (marked with a “*”).

Consistently normal or below normal activity		Consistently normal or above normal activity		Mixed problem-solving activity	
rme	10	-ME	5	-Me	4
r-e	8	--E	4	rM-	2
r--	5	R-E	4	r-E	2
-m-	5	R--	3	RmE	2
-me	4	RME	3*	---	2*
--e	4	RM-	3	Rm-	1
rm-	4	-M-	2	-mE	1
				rmE	1
				R-e	1
				Rme	1
Total 40 (49.4%)		Total 24 (29.6%)		Total 17 (21.0%)	

Figure 2: Learning/problem-solving styles

Building Case-based Tutors

Experience has shown that case-based reasoning research begins with 1) knowledge acquisition of conceptual structure and 2) of cases of prototypical problem solving; followed by 3) knowledge analysis and knowledge representation design; followed by 4) an iterative procedure of a) knowledge structure building, b) retrieval engine implementation and testing; followed by 5) interface design, implementation, testing, and evaluation. However, please note this is not simply a software development project which can be marched through "by the numbers. There are unknowns in the knowledge acquisition and analysis process, and experience has shown it is common in exploratory development of this type to uncover unexpected factors in later stages that require backtracking.

The result of this project will be a set of case-based tutoring agents whose user interface will be similar to the diagnostic tutors described above in terms of visiting and advising. However, the content of the case-based tutors remediation will be a case of success or failure retrieved as relevant from the case library, and presented to the student as an example to adapt to their own problem solving adventures.

We propose a project that operates under the following plan of work.

1) Knowledge acquisition of conceptual structure. This is achieved by interviewing experts and browsing standard documents. WWWIC committee members (McClean et al., 1999) will provide the necessary expertise and reference material. Note that one structure will be developed but partitioned to contain domain features from each discipline, as well as common problem solving features from both the domains of geology and biology.
2) Knowledge acquisition of cases of prototypical problem solving. This is achieved by data mining the historical records of student use, as described above, for the Geology Explorer

project (Schwert et al., 1999). We have already identified what appear to be three major categories of student problem solving style, with a total of 24 minor classifications within these three. Further exploration is required. In particular, we have an analogous data set, as yet unanalyzed, collected during Fall 1999 while conducting a similar study with 500+ students using the Virtual Cell (White et al., 1999).

3) Knowledge analysis and knowledge representation design. This is an exercise in knowledge engineering (sometimes known as indexing), where the data are iteratively organized into taxonomies of conceptual and procedural knowledge. The resulting structures, sometimes referred to as a "theory" of the domain, are used to represent cases.
4) An iterative procedure of
    a) Knowledge structure building. The domain theory and prototypical cases are translated into objects (sometimes called Memory Organization Packets (MOPs); Riesbeck and Schank, 1989), which are further imbued with problem-solving advice, and sometimes conversational networks, resulting in a case-library.
    b) Retrieval engine implementation and testing. This is a matter of implementing the ORCA retrieval algorithm (Bareiss and Slator, 1993), which has the unique benefit of enlarging its case library as a consequence of use (Slator and Bareiss, 1992). Normal software testing procedures will be employed.
5) Interface design, implementation, testing, and evaluation. The user interface to the case-based tutors will modeled on the diagnostic tutors described above, in terms of questions, suggestions, and scripted interactions, with tutors visiting and remediating on the basis of retrieved cases. In the second year of the project, a sequence of studies of student use will be conducted, to evaluate and refine the design and implementation.

Assessment Results

While all WWWIC projects are based on the idea of authentic assessment within authentic contexts, and all projects have studies underway, the results shown below are from our first major study, which is representative of the others. Briefly, the assessment goal is to determine the benefit to students derived from their "learn by doing" experience using the Geology Explorer. Our scenario-based assessment protocol is a qualitative one that seeks to measure how student thinking has improved. During Fall 1998 and 1999, the entire NDSU Physical Geology class (400+ students) were given the opportunity to participate in an experiment to evaluate the effectiveness of Planet Oit on conceptual learning and problem-solving: the role-based skills.

When learners join the synthetic environment they are assigned goals, selected by content matter experts to be appropriate to the learner's experience. Goals are assigned point values, and learners accumulate objectively measured scores as they achieve their goals. The goals are taken from a principled set, where easier goals are followed by more advanced ones. Similarly, certain goals in a set are required while others are optional. In this way, designers can insure that highly important concepts are thoroughly covered while allowing the maximum flexibility to the learner. Subject matter experts identify teaching objectives in more-or-less traditional ways, while learner outcomes are assessed in terms of the performance of specific and authentic tasks. This is the particular strength of learn-by-doing immersive environments, that a learner's success in achieving their goals provides an automatic assessment of their progress.

All students were asked to answer open-ended scenario-based questions before and after the experiment. These scenario questions were word problems that presented the student with a situation that a field geologist might be confronted with. Students responded to the question with a narrative answer, which was evaluated according to an established protocol.

Lately you and your best friend have been experimenting with “new age” forms of relaxation and health improvement. One day your friend tells you that there is going to be a Crystal Power Retreat at a nearby national park and you can’t resist.

It's a beautiful summer night, and you spread out your sleeping bag after a fun day of looking at exhibits and demonstrations. Your souvenir of the day is a beautiful quartz crystal you purchased from a vendor. You are tired from the days activities, but are unable to sleep as something hard is digging into your back.

You grope around and dislodge a hard, clear, thumbnail-sized crystal.

Your friend says, "Cool! I'll give you five bucks for that."

What do you do?

List the things you would consider in your decision.

List the questions you would ask yourself, and reasons behind those questions.

Figure 1: A sample scenario

Students were divided into three experimental groups: two groups were matched to ensure equal distributions of technological ability and were asked to experience Planet Oit or an alternate internet-based activity equal in estimated time-on-task; the third group did no additional activity. Then, after the players have experienced an extended exploration of Planet Oit (or alternative exercise), they were given a similar post-test survey with different but analogous problem solving scenarios, and asked again to record their questions and impressions. These documents are then compared with the pre-test versions, looking for evidence of improved performance. If players score better on the problem solving scenarios, this creates the clear implication that they have learned from the experience. Analysis of the data shows that students who participated in the Planet Oit experience performed significantly better on scenario questions compared to those that participated in the alternative exercise or those who did no additional activity. This demonstrates the effectiveness of our methods.

Scores were evaluated using a one-way analysis of variance and the Duncan’s means separation test (Table 1). No significant difference (P = 0.393) was detected among Pre-experience group means. In contrast, Post-experience group means demonstrated a significant difference (P = 0.002). Among these means the Post-experience mean of the Geology Explorer group was significantly higher mean test score than the other two groups.

Table 1. Performance results of Geology Explorer experiment.

Group	Group size	Pre-experience mean score	Post-experience mean score
Control	161	9.3a	25.6a
Alternate	95	8.5a	24.4a
Geology Explorer	78	6.8a	35.9b
		F = 0.094	F = 6.320
		P = 0.393	P = 0.002

Please note this is the first ever result of its kind, and its importance cannot be over-stressed. We have discovered an effect. While a few others have shown significance in controlled studies over the years (e.g. Huppert et al., 1998; Mestre et al., 1992; Van Haneghan et al., 1992),

this is the first where significant improvement in student learning provably resulted as a direct consequence of student use of an immersive (and self-paced) virtual environment, without direct intervention from a teacher or indeed any additional classroom experience at all. These results unequivocally support our methods and justify the approach.

Problems with software development on a MOO

LambdaMOO is a dynamic, continuous, simulation environment with an interpreted object-oriented programming language. The LambdaMOO platform has many fine qualities, including this elegant language, also called LambdaMOO, and the ability to replace and compile individual verbs (aka methods) on objects, without recompiling any other parts of the application. LambdaMOO also features a fail-safe mechanism for cancelling runaway processes that depends on monitoring verbs for their 'tick count' and killing those that exceed a quota. Of course, in a continuous simulation, some routines are intended to run perpetually, and this is orchestrated with a 'suspend' mechanism which also monitors tick counts, but pauses and refreshes at appropriate moments so that it's possible for routines to have essentially unlimited ticks. Similarly, and not foreseen by the designers, it is necessary for some routines processing large datasets to also pause and get a new allocation of ticks, even though they are not intended to be running forever. Because the MOO was designed to be an open environment, the tick counting was essential to the operation of the MOO. But the overhead involved in monitoring all these executions, and refreshing tick quotas, is considerable and creates obvious inefficiencies.

Source code control is also a serious problem in development environments of this type. There is no facility for checking code in and out, beyond a cumbersome and somewhat baroque system of ownerships and permissions. And there is no facility for version control either. In fact, LambdaMOO provides no built-in support for file handling of any sort. The only way to write and replace code is to enter it at the command line, or 'send' code with one of the freely available editing clients (like MacMOOSE or tkmoo-lite), which essentially do the same thing.

Therefore, all code in LambdaMOO is equivalent to the 'stored procedures' implemented in distributed database, where the 'state of the art' is to fashion updates that are tested in an offline 'mirror' of the database, and then uploaded 'live' to the server while other operations are ongoing. In this mode of operation, source code and version control are relegated to external offline processes. However, software tools of this sort are absent from the LambdaMOO environment, and are sorely needed if virtual environments are to even approach production-level development.

In addition to the above, there is no facility for synchronizing mirrored MOOs, and so no way to fully protect against network outage. There is currently no way to support a distributed approach where code and data are protected against all-too-common server crashes and network "accidents".

Similarly, there are no facilities in LambdaMOO for the type of development support that modern software developers expect: clickable reference to inspectable objects, visual interfaces

for managing classes and methods, even editing applications with convenient indicators for bracket matching and variable references. These common elements are increasingly necessary as applications grow and evolve, and none are available at this time.

Further, and most serious from the code development point of view, the LambdaMOO execution environment is single threaded and purely interpreted. This has profound effects on run-time efficiencies, and will eventually dominate the capacity of servers and bandwidth to provide acceptable service. Even though we have implemented an innovative. low-bandwidth protocol for graphical manipulations, there is a limit which will quickly be reached as virtual environments approach production-level traffic.

Problems with tool and interface development on a MOO

In order to facilitate the rapid development of virtual environments for education in a range of disciplines, there is a need for customizable tools that can be placed in the hands of both software professionals and content experts. While these two professions are normally kept separate, we find there is a significant overlap in responsibilities when the object under construction is a virtual world. Content experts, in particular, need to create and customize objects in the environment in order to design the pedagogy that rests on top of the simulation environment.

It should be possible, for example, for a biologist to specify the appearance of a constituent, say a cellular organelle, and provide it's coordinates for placement in the virtual world, and define the behavior of the constituent in terms of a pre-defined range of virtual scientific instruments employed by biologists; for example, an autoclave or a spectroscopic microprobe. Not coincidentally, these are exactly the operations necessary for a geologist to perform in the construction of a parallel environment for geology. Not necessarily in terms of specific artifacts and instruments, although some overlap is anticipated, but in the general terms of scientific exploration and experimentation.

The need is for tools and interfaces that are portable across any sort of virtual environment. These should be easy to use, and should present a view of the environment that can be switched back and forth from a expert's view to a student's view. It should be the job of software developer to provide customizable widgets, and the job of the content expert to select and modify these appropriate to the lesson being constructed.

Problems with instructor maintenance and management on a MOO

An instructor who has integrated a virtual environment into their lesson planning needs to track student progress in several dimensions. Besides the usual reporting of student accomplishments, this instructor will want to track time-on-task, goals assigned and achieved, interactions with other students and software tutors, use of navigation and instrumentation, and so forth. Unfortunately, there is no simple facility for this provided by LambdaMOO, and instructors must learn to develop software for themselves if they are to customize their reporting functions.

As virtual worlds become more ubiquitous in the classroom there will be a need for an array of tracking and book-keeping support not currently existing. These will be expected and necessary if virtual environments are to make significant inroads into classroom pedagogy, and will be demanded by the K-12 teachers we propose to induct during year three of this project.

Integrating Virtual Environment Development and Customization

We propose a long-range design and development project that will provide an integrated solution to the several problems just listed. This project will culminate in a customizable environment geared towards providing the development tools needed for creating and maintaining virtual environments of any kind, with support for content developers and end-users (both instructors and students), in the form of consistent and portable interfaces to code and content.

We propose a project that operates under the following plan of work.

1. Implement a new MOO in Java; this will address many of the efficiency concerns, and support threaded processes, which are necessary in the long term
2. Implement a file I/O capability so that source code control, can be effected through a back-end database
3. Building on #2, implement a set of reporting tools and interfaces
4. Implement an integrated environment for code and content development based on server-side parameters; this innovation will provide standard, customizable interfaces based on server-side specifications. In this way, interface development, including limited artifact function, can be provided for any sort of virtual environment, and data management will support code development for those best equipped.
5. Implement a mirroring protocol so that servers can be load balanced, and protected from network failure, while preserving the dynamic elements necessary for an authentic pedagogical experience. This will be designed so that servers can by added as load increases, and so that servers can be located both locally and remotely, to guard against various forms of outage.

What's New Here

The successful completion of this project depends on several innovations. First, we will design and build a series of unique educational modules in geology, biology, and computer science. Our immersive, multi-user, role-based, approach to authentic instruction is unlike most other such systems, and our new modules will be consistently different in the same manner. Second, our approach to assessment is new in that it proposes to examine students on the same sort of authentic tasks they train on. This approach is also notably different in that if provably works. Third, our immersive environments are designed to support anywhere-anytime participation through software tutoring that focuses students efforts on, and remediates over, authentic tasks. We do not propose to model students, but rather tasks and performance outcomes. The thrust towards building case-based models of tutoring, is new and forms an innovative complement to the diagnostic tutoring also being developed. Fourth, we propose to synthesize all the best of traditional software practice into an integrated and customizable development environment that is dynamic and distributed. This is innovative in that we tackle a problem not usually faced: software and content solutions in a dynamically changing virtual

world. Lastly, we propose to spread our pedagogy and technology into the K-12 arena by training in-service teachers to use our integrated tools to customize their own curriculum. Teachers will not be mere clients of our wares, they will be participants in shaping their instruction.

Conclusion

Our project is about studying learning, which we do by building virtual environments and conducting studies aimed at helping us more fully understand the immersive role-based effect we have discovered. The project addresses social (educational) issues and extends undergraduate education, both in terms of training students to design and build educational modules of this sort, thereby integrating research and education, and in terms of its impact on educational methods resulting in better science education disseminated broadly to society via the internet. By the same token, our game-like approach promises to "infuse education with the excitement of discovery". Further, in the middle of this project our vision broadens to include K-12 education by enlisting in-service teachers to integrate our systems into their lesson planning through the NSF ND-STEP Science Teacher Enhancement Project and the NSF COMSTEP Collaborative for Mathematics and Science Teacher Preparation (see http://www.ndsu.nodak.edu/ science_ed/ for further information about these programs).

This research approach is inherently multi-disciplinary. Our central mission draws different educational modules in different subject areas together under a single framework, which motivates the scope and length (5 years) of the project. Our project is long term and high risk, employing innovative technology and methods, but with potential for high payoff, in terms of both regional (North Dakota is an EPSCoR state), and national impact on computer-based education and in terms of improving the way science is taught in our schools.

References Cited

AAAS, (1993). Benchmarks for Science Literacy. American Association for the Advancement of Science. http://project2061.aaas.org/ tools/ benchol/ bolframe.html

Bareiss, E. Ray, and Brian M. Slator (1993). The Evolution of a Case-based Approach to Knowledge Representation, Categorization, and Learning, In Categorization by Humans and Machines. (The Psychology of Learning and Motivation, Vol. 29, Chapter 6, pp. 157-186, edited by Nakamura, Taraban, and Medin). San Diego: Academic Press.

Brown, John Seely, A. Collins, and P. Duguid. (1989). Situated Cognition and the Culture of Learning, Educational Researcher, 18(1), pp. 32-42.

Curtis, Pavel (1998). Not Just a Game. High Wired: on the Design, Use, and Theory of Educational MOOs. University of Michigan Press. pp. 25-42.

Edelson, D., Pea, R., & Gomez, L. (1996). Constructivism in the Collaboratory. In B. G. Wilson (Ed.), Constructivist learning environments: Case studies in instructional design, (pp. 151-164). Englewood Cliffs, NJ: Educational Technology Publications.

Huppert, Jehuda; Yaakobi, Judith; and Lazarowitz, Reuven (1998), Learning microbiology with computer simulations: Students' academic achievement by method and gender: Research in Science & Technological Education, p.231-245.

Juell, Paul (1999). Educational Opportunities Using VRML in the AI Classroom. Intl. Conf. on Mathematics/ Science Education & Technology (M/SET-99), March 1-4, 1999, San Antonio, TX, pp. 119-123.

Lave, Jean, & Wenger, Etienne. (1991). Situated Learning. Cambridge: Cambridge University Press. (see http:// hale.pepperdine.edu/ ~rsaldric/ situated.html)

McClean, Phillip E. , Donald P. Schwert, Paul Juell, Bernhardt Saini-Eidukat, Brian M. Slator, Alan R. White. (1999). Cooperative Development of Visually-Oriented, Problem-Solving Science Courseware. Intl. Conf. on Mathematics/ Science Education & Technology (M/SET-99), March 1-4, 1999, San Antonio, TX, pp. 486-491.

Mestre, Jose P., Dufresne, Robert J., Gerace, William J., Hardiman, Pamela T., and Tougher, Jerold S. (1992), Enhancing higher-order thinking skills in physics, in Halpern, Diane F., ed., Enhancing thinking skills in the sciences and mathematics: Hillsdale, NJ, Lawrence Erlbaum Associates, Publishers, p.77-94.

Pea, R. (1993). Practices of distributed intelligence and design for education. In G. Salomon (Ed) Distributed cognition: Psychological and educational considerations, 47-87. Cambridge, Mass: Cambridge University Press.

PCAST (1997). Report to the President on the Use of Technology to Strengthen K-12 Education in the United States. President's Committee of Advisors on Science and Technology. Panel on Educational Technology. March. http:// www.whitehouse.gov/ WH/ EOP/ OSTP/ NSTC/ PCAST/ k-12ed.html

Riesbeck, C. & Schank, R.C. (1989). Inside Case-based Reasoning. Hillsdale, NJ: Lawrence Erlbaum Assoc.

Schwert, Donald P., Brian M. Slator, Bernhardt Saini-Eidukat, (1999). A Virtual World For Earth Science Education In Secondary And Post-Secondary Environments: The Geology Explorer. Intl. Conf. on Mathematics/ Science Education & Technology (M/SET-99), March 1-4, 1999, San Antonio, TX, pp. 519-525.

Slator, Brian M. and E. Ray Bareiss (1992). Incremental Reminding: the case-based elaboration and interpretation of complex problem situations. Proceedings of the 14th Annual Conference of the Cognitive Science Society. Bloomington, IN, pp. 1122-1127.

Slator, Brian M. and Christopher K. Riesbeck (1992). TaxOps: a Case-based Advisor. International Journal of Expert Systems, Vol. 4, No. 2, pp. 117-140 (Special issue on Case-based Reasoning, edited by Evangelous Simoudis), JAI Press: Greenwich, CT.

Slator, Brian M. and Kerim C. Fidel (1994). Topical Indexing and Questions to Represent Text for Retrieval and Browsing. Integrated Computer-Aided Engineering , Vol. 6, No. 4, pp. 495-510. (Special Issue on Knowledge Extraction from Text, edited by Steven Leo Lytinen). Wiley and Sons: New York.

Slator, Brian M., Harold "Cliff" Chaput, Kerim C. Fidel, Ken Greenlee, Debra Jenkins, Scott MacQuarrie, Colette Marine, Leena Nanda, Lee Pavlock, and Diane Schwartz (1994). Problem Solving and Case-based Reasoning. Annual Review of Communications. National Engineering Consortium: Chicago, IL. pp. 435-444.

Slator, Brian M. and Scott D. MacQuarrie (1995) Case-based Reasoning, Multi-media Learning Environments and Tools for AI. International Journal of Microcomputer Applications (IJMA). Vol. 14, No. 3. Edited by L. Miller.

Slator, Brian M. (1996) Educational Technologies Utilized in the Audit Coach Project. *Internal Auditor*. Journal of the Institute of Internal Auditors. June. p. 37.

Slator, Brian M. (1999). Intelligent Tutors in Virtual Worlds. Proc. of the 8th Intl. Conf. on Intelligent Systems (ICIS-99). June 24-26. Denver, CO, pp. 124-127.

Slator, Brian M. and Curt Hill (1999). Mixing Media For Distance Learning: Using IVN And Moo In Comp372. World Conf. on Educational Media, Hypermedia and Telecommunications (ED-MEDIA 99), June 19-24, Seattle, WA, pp. 881-886.

Slator, Brian M., Paul Juell, Phillip E. McClean, Bernhardt Saini-Eidukat, Donald P. Schwert, Alan R. White, Curt Hill (1999). Virtual Environments for Education at NDSU. World Conf. on Educational Media, Hypermedia and Telecommunications (ED-MEDIA 99), June 19-24, Seattle, WA, pp. 875-880. *Top Paper Award*

Thagard, P. (1989). Explanatory coherence, Behavioral and Brain Sciences 12 : 435-467.

Van Haneghan, J.P., Barron, L., Young, M.F., Williams, S.M., Vye, N.J., & Bransford, J.D. (1992). The Jasper series: An experiment with new ways to enhance mathematical thinking. In D. F. Halpern (Ed.), Enhancing thinking skills in the sciences and mathematics (pp. 15-38). Hillsdale, NJ: Erlbaum.

White, Alan R., Phillip McClean, and Brian M. Slator (1999). The Virtual Cell: A Virtual Environment for Learning Cell Biology. Proc. of the Tenth Intl. Conf. on College Teaching and Learning: Innovation in a Global Learning Community. April 14-17. Jacksonville, Florida.

Brian Michael Slator
Associate Professor
Computer Science Dept, North Dakota State University,
IACC Bldg, Rm. 258-A6, Fargo, ND 58105
slator@badlands.nodak.edu http://www.cs.ndsu.nodak.edu/~slator/
(office) 701-231-6124 (home) 701-271-8875

Education

Ph.D. 1988 Computer Science (Related Area: Linguistics), New Mexico State University, Las Cruces, NM; Dissertation: Lexical Semantics and Preference Semantics Analysis; Advisor: Dr. Yorick A. Wilks.

M.S. 1985 Computer Science (Minor: Linguistics), New Mexico State University, Las Cruces, NM; Thesis: Natural Language Interface: An Algorithm for Design.

B.S. 1983 Computer Science (with Honors; second major in English), University of Wisconsin - La Crosse.

Employment

1996-present Associate Professor, Computer Science Dept., North Dakota State University.

1992-1996 Assistant Professor (Research), The Institute for the Learning Sciences, Northwestern University.

1990-1992 Research Associate, The Institute for the Learning Sciences, Northwestern University.

1989-1992 Research Specialist, Natural Language Group, (Summer position), Computing Research Laboratory, New Mexico State University.

1988-1990 Assistant Professor, Department of Computer Science, North Dakota State University.

1985-1988 Graduate Research Fellow, Natural Language Group, Computing Research Laboratory, New Mexico State University.

Up to 5 Publications Most Closely Related

1. Slator, Brian M. (1999). Intelligent Tutors in Virtual Worlds. *8th International Conference on Intelligent Systems*. Denver, CO. June 24-26.
2. Slator, B.M., P. Juell, P.E. McClean, B. Saini-Eidukat, D.P. Schwert, A. White, C. Hill (1999). Virtual Environments for Education at NDSU. *World Conference on Educational Media, Hypermedia and Telecommunications (ED-MEDIA 99)*, June 19-24, Seattle, WA. (Outstanding Paper Award)
3. Schwert, D.P., B.M. Slator, B. Saini-Eidukat, (1999). A Virtual World For Earth Science Education In Secondary And Post-Secondary Environments: The Geology Explorer. *International Conference on Mathematics/Science Education &Technology (MSET-99)*, March 1-4, San Antonio, TX.
4. Slator, Brian M., Donald Schwert, Bernhardt Saini-Eidukat (1999). Phased Development of a Multi-Modal Virtual Educational World. *Proceedings of the International Conference on Computers and Advanced Technology in Education (CATE'99)*, Cherry Hill, NJ, May 6-8
5. Slator, Brian M. and Golam Farooque (1998). The Agents in an Agent-based Economic Simulation Model. *11th International Conference on Computer Applications in Industry And Engineering (CAINE-98)* November 11-13, 1998, Las Vegas, Nevada USA, pp. 175-179. (International Society for Computers and Their Applications (ISCA)).

Up to 5 Other Significant Publications

1. Slator, Brian M. and Harold "Cliff" Chaput (1996). Learning by Learning Roles: a virtual role-playing environment for tutoring.*Third International Conference on Intelligent Tutoring Systems (ITS'96)*. Montreal: Springer-Verlag, June 12-14, pp. 668-676. (Lecture Notes in Computer Science, edited by C. Frasson, G. Gauthier, A. Lesgold).
2. Manaris, Bill and Brian M. Slator (1996). Interactive Natural Language Processing: Building on Success. *IEEE Computer*. (Special Edition on Interactive Natural Language Processing, Edited by Manaris and Slator). July. pp. 28-32.
3. Guthrie, Louise, James Pustejovsky, Yorick A. Wilks and Brian M. Slator (1996). The Role of Lexicons in Natural Language Processing. *Communications of the ACM*. (Special Edition on Natural Language Processing, edited by Yorick A. Wilks), Vol. 39, No. 1, pp. 63-72.
4. Slator, Brian M. and Kerim C. Fidel (1994). Topical Indexing and Questions to Represent Text for Retrieval and Browsing. *Integrated Computer-Aided Engineering*, Vol. 6, No. 4. (Special Issue on Knowledge Extraction from Text, edited by Steven Leo Lytinen). Wiley and Sons: New York.
5. Slator, Brian M. and Christopher K. Riesbeck (1992). TaxOps: a case-based advisor. *International Journal of Expert Systems*, Vol. 4, No. 2, pp. 117-140 (Special issue on Case-based Reasoning, edited by Evangelous Simoudis), JAI Press: Greenwich, CT.

List of collaborators during the last 48 months

Roger Schank, Chris Riesbeck, Ray Bareiss, Alex Kass, Gregg Collins, Tom Hinrichs, Cliff Chaput, Bob Hooker, Scott MacQuarrie, Kerim Fidel: Institute for the Learning Sciences at Northwestern University

Kendall Nygard, Mark Pavicic, Ken Magel, Paul Juell, Bill Perrizo: Computer Science Dept. at NDSU

Phil McClean, Alan White, Don Schwert, Bernhardt Saini-Eidukat Joseph Latimer, Jeffrey Clark, Plant Science, Botany/Biology, Geosciences, Business, and Sociology/Anthropology Departments at NDSU

Richard Beckwith, Intel Corporation

Yorick Wilks: Sheffield University

Louise Guthrie: University of Texas, El Paso

Bill Manaris: University of Southwest Louisiana

Graduate and Postdoctoral Advisors

Dr. Yorick A. Wilks, Department of Computer Science, University of Sheffield, Regent Court, 211 Portobello Street, Sheffield, UK, S14DP (ph: 011-44/742-825-571; email: yorick@dcs.sheffield.ac.uk)

Other Relevant Information

Dr. Brian M. Slator is Associate Professor of Computer Science at North Dakota State University. Dr. Slator has in-depth experience with the design, development and implementation of a number of MUD and MOO environments for learning. Although involved in related projects at New Mexico State University and elsewhere, the expertise of highest direct relevance to this project was gained while employed as a research scientist at the Institute for the Learning Sciences (ILS) where he designed and managed the development of a number of multi-media applications in educational technology and case-based reasoning for intelligent tutoring and job-aid style performance support. In addition, he was the architect of an interactive, multi-user retailing game, its economic simulation and software agent-based tutoring, and manager of the GAMES project.

BIOGRAPHICAL SKETCH

PHILLIP E. McCLEAN
Associate Professor of Plant Sciences
Department of Plant Sciences, North Dakota State University
Loftsgard Hall Rm. 270B, Fargo, ND 58105

mcclean@plains.nodak.edu
(office) (701) 231-8443 (office fax) (701) 231-8474 (home) (701) 293-9796

Education

Ph.D. - **1982** Genetics, Colorado State University
M.S. - **1980** Genetics, Colorado State University
B.S. - **1977** Biology, Metropolitan State College

Employment

1998-present Professor, Department of Plant Sciences, North Dakota State University
1995-1988 Director, Cellular and Molecular Biology Program, North Dakota State University
1991-1998 Associate Professor, Department of Plant Sciences, North Dakota State University
1985-1991 Assistant Professor, Department of Plant Sciences, North Dakota State University
1984-1985 Postdoctoral Fellow - University of Missouri, Division of Biological Sciences
1982-1984 Postdoctoral Fellow - University of Virginia, Department of Biology

Relevant and Significant Publications

Software Development Papers

1. Juell, P., J. Grosen, C. Balachandran, P. McClean, R. Collins, B. Saini-Eidukat V. Tareski, F. Dooley, N. Lilleberg, J. Ross and T. Colville. 1997. Year two of NDSU's Instructional Web project. pp 205-209. Small College Computing Symposium (SCCS 97).
2. McClean, P.E. From Mendel to DNA: teaching genetics on the web. 1999. Proceedings of the International Conference on College Teaching and Learning. p. 27.
3. Slator, B.M., P. Juell, P.E. McClean, B. Saini-Eidukat, D.P. Schwert, A. White, C. Hill. 1999. Virtual environments for education at NDSU. World Conference on Educational Media, Hypermedia and Telecommunications (ED-MEDIA 99). June 19-24, Seattle, WA.
4. White, A.R., P.E. McClean, and B.M Slator. 1999. The Virtual Cell: An interactive, virtual environment for cell biology. World Conference on Educational Media, Hypermedia and Telecommunications (ED-MEDIA 99). June 19-24, Seattle, WA.
5. McClean, P.E. , D.P. Schwert, P. Juell, B. Saini-Eidukat, B.M. Slator, A. White. 1999. Cooperative Development of Visually-Oriented, Problem-Solving Science Courseware. International Conference on Mathematics/Science Education &Technology, March 1-4, 1999, San Antonio, TX.
6. McClean, P, S Islam. 1997. WWW-based display of plant pedigrees. Abstracts of Plant and Animal Genome V meeting, San Diego, Jan 1997. Proceedings of Small College Computing Symposium (SCCS 98).

Molecular Genetics Papers

7. Bassett, M.J., L. Brady, and P.E. McClean. A new allele, t^{cf}, at the *T* locus for partly colored seedcoats in common bean. J. Amer. Soc. Hort. Sci. (in press)
8. Strausbaugh, C.A., J.R. Myers, R.L. Foster, P. McClean. *bc-1* and *bc-u,* two genes controlling bean common mosaic virus resistance in common bean are linked. J. Amer. Soc. Hort. Sci. (in press)
9. Rivkin, M.I., C.E. Vallejos, P.E.. McClean. 1999. Disease-resistance related sequences in common bean. Genome 42:41-47.

10. Brady, L, M.J. Bassett, P.E. McClean. 1998. Molecular mapping in common bean: RAPD markers for *T* and *Z*, two genes controlling partly colored seed coat patterns in common bean. Crop Sci. 38:1073-1075.

Collaborators During the Last 5 Years

Ken Grafton, Jack Rasmussen, Gary Secor, Brian Steffanson, North Dakota State Unversity; Mark Bassett, Eduardo Vallejos, University of Florida; Robert Forester, Carl Strausbaugh, University of Idaho, Jim Myers, Oregon State University; Randy Shoemaker, USDA/ARS, Alex Borovkov, Monsanto Comp.;

Graduate Students and Post-Doctoral Scholars

Alex Borovkov, Irina Borovkov, John Ewing, Mark Rivkin, Venugopal Kalavacharla, Ron Sayler, Gary Vallad, Cheng Wang Guo; 8 graduate students, 3 postdoctoral scholars

Graduate and Post-Doctoral Advisors

Maureen Hanson, Donald Miles, Donald Wood

Other Relevant Information

Dr. McClean has been committed to the use of information technology to improve student learning for several years. He initially converted his course materials to a multimedia format using Toolbook. With the advent of browsers for the WWW, he then converted both his undergraduate ("http://www.ndsu.nodak.edu/instruct/mcclean/plsc431") and graduate ("http://www.ndsu.nodak.edu/instruct/mcclean/plsc731") genetic courses into WWW format. These efforts were cited when he received the College Agriculture Early Career Award of Excellence in Teaching in 1995. In 1998, Dr. McClean's efforts in technology applications to teach were recognized when he received the inaugural Peltier Award for Innovation in Teaching (at NDSU. Most recently, Dr. McClean was awarded a Innovative Excellence in Teaching, and Learning Award at the the 10th International Conference on College Teaching, Learning and technology (Jacksonville, FL; April 14-17, 1999).

Bernhardt Saini-Eidukat
Assistant Professor of Geology
Department of Geosciences, Stevens Hall
North Dakota State University, Fargo, ND 58105-5517

sainieid@badlands.nodak.edu http://www.ndsu.nodak.edu/geosci/
office: 701-231-8785 office fax: 701-231-7149 home: 701-235-4953

Education

Ph.D. 1991. Geology. University of Minnesota.
B.S. 1984. Geology. University of Minnesota.
B.S. 1984. Geophysics. University of Minnesota.

Employment

1997–present:	Assistant Professor, Dept. of Geosciences, North Dakota State University
1993–1997:	Instructor, Dept. of Geosciences, North Dakota State University
1991–1993:	Research Scientist, Inst. of Geol. Sci., Mining University of Leoben, Austria.
1990–1991:	Fulbright Grantee, Inst. of Geol. Sci., Mining University of Leoben, Austria.
1989–1990:	Geologist, U.S. Bureau of Mines, Twin Cities Research Center, Mpls., Minnesota.
1987–1989:	Research Assistant, Dr. P. Weiblen, Dr. Gust Bitsianes, University of Minnesota.
1988:	Electron Microscopist, The 3M Company, Corporate Research Lab, St. Paul, MN.
	Consulting Geologist, CNA Consulting Engineers, Mpls., Minnesota.
1984–87:	Teaching Assistant, Department of Geology, University of Minnesota.
	Field Assistant, Island Mountain, California.
	Geologist, Minnesota Geological Survey, Silver Bay, Minnesota.
	Research Assistant, Dr. E. Ito, Oxygen Isotope Lab, University of Minnesota.
	Consulting Geologist, Guyana, South America.

5 Relevant Publications

McClean, P.E., Schwert, D.P., Juell, P., Saini-Eidukat, B., Slator, B.M., and White, A.R. 1999. Cooperative Development of Visually-Oriented, Problem-Solving Science Courseware.Proceedings, International Conference on Mathematics/Science Education and Technology, March 1-4, San Antonio, Texas.

Saini-Eidukat, B., Schwert, D.P., and Slator, B.M., 1999. Designing, Building, and Assessing a Virtual World for Science Education. Proceedings, International Conference on Computers and Their Applications, April 7-9, Cancun, Mexico.

Saini-Eidukat, B. and Yahin, A. 1999. Web-phreeq: An Instructional Tool for Modeling the Distribution of Chemical Species in Water. Computers & Geosciences, v. 25, no.4, pp. 347-353. (invited)

Saini-Eidukat, B. 1998. A WWW and spreadsheet based exercise in river flood frequency analysis. Journal of Geoscience Education v. 46, p. 154-156.

Saini-Eidukat, Bernhardt, Don Schwert and Brian M. Slator. 1998. Text-Based Implementation of the Geology Explorer, a Multi-User Role-Playing Virtual World to Enhance Learning of Geological Problem-Solving. Geological Society of America Abstracts with Programs, Vol. 30, No. 7, October, 29. Toronto.

Up to 5 Other Significant Publications

Saini-Eidukat, B., Rudashevsky, N.S. and Polozov, A.G. (1998) Evidence for hibbingite-kempite solid solution. Mineralogical Magazine, v. 62(2), pp. 251-255.

B. Saini-Eidukat, O.A.R. Thalhammer, M.J. Iljina and T.T. Alapieti (1997) Siliceous, high-magnesian parental magma compositions of the PGE-rich Early Paleoproterozoic layered intrusion belt of northern Finland. Proceedings, 30th International Geological Congress, v. 9, pp. 177-197.

Saini-Eidukat, B., and Weiblen, P.W. (1996) A new method of fossil preparation, using high-voltage electric pulses. Curator, 39: 139-144.

Melcher, F., Raith, J., Prochaska, W., and Saini-Eidukat, B. (1996) The metamorphosed molybdenum-vein type deposit of the Alpeinerscharte, Tyrol (Austria) and its relation to Variscan granitoids. Mineralium Deposita, 31: 277-289.

Rudashevsky, N.S., Burakov, B.E., Lupal, S.D., Thalhammer, O.A.R., and Saini-Eidukat, B., 1995, Liberation of accessory minerals from various rock types by electric pulse disintegration — method and application: Trans. Inst. Mining Metall., v. 104, p. C25-C29.

Collaborators Not Listed Above

Ernesto Bjerg, Universidad Nacional del Sur, Bahia Blanca, Argentina
Daniel Gregori, Universidad Nacional del Sur, Bahia Blanca, Argentina

Graduate Students and Post-Doctoral Scholars

The Department of Geosciences at NDSU does not have a graduate program.

Graduate and Post-Doctoral Advisors

Paul. W. Weiblen, University of Minnesota; Eugen F. Stumpfl, Mining University of Leoben, Austria.

Other Relevant Information

Dr. Bernhardt Saini-Eidukat is Assistant Professor of Geology at North Dakota State University. Saini-Eidukat is a petrologist, mineralogist, and economic geologist who has researched platinum group element (PGE) geochemistry of igneous rocks as related to problems of magma evolution, tectonic setting and hydrothermal transport. He has also investigated manganiferous iron formation from the perspective of applying the *in situ* leaching method for extracting manganese, and has evaluated pulsed power technology as a rock disaggregation method. Current research involves ore genesis of a volcanogenic massive sulfide deposit in Ontario, tectono-magmatic evolution of Northern Patagonia, and the development of interactive computer modeling and teaching software.

DONALD P. SCHWERT
Professor of Geology
Department of Geosciences, North Dakota State University
Stevens Hall Rm. 131, Fargo, ND 58105-5517

schwert@plains.nodak.edu *http://www.ndsu.nodak.edu/instruct/schwert*
(office) (701) 231-7496 (office fax) (701) 231-7149 (home) (701) 232-1257

Education:

Ph.D. 1978. Earth Science. University of Waterloo (Canada).
M.S. 1975. Zoology. SUNY CES&F at Syracuse University
B.S. 1972. Chemistry / Biology. Allegheny College

Employment:

1992-present Professor of Geology, Department of Geosciences, North Dakota State University
1986-1992 Associate Professor, Department of Geology, North Dakota State University
1982-1986 Assistant Professor, Department of Geology, North Dakota State University
1978 -1982 Visiting Assistant Professor, Department of Geology, North Dakota State University
1978 Postdoctoral Fellow, Department of Earth Sciences, University of Waterloo, Canada

Relevant Publications:

McClean, P.E., D.P. Schwert, P. Juell, B. Saini-Eidukat, B.M. Slator, and A.R. White. 1999. Cooperative development of visually-oriented, problem-solving science coursewrare. Proceedings of the International Conference on Mathematics/Science Education & Technology, San Antonio. *(in press).*

Saini-Eidukat, B., D.P. Schwert, and B. Slator. 1999. Designing, building, and assessing a virtual world for science education. Proceedings of the 14th International Conference on Computers and their Applications (CATA-99), Cancun, Mexico. *(in press).*

Schwert, D.P., B.M. Slator, and B. Saini-Eidukat. 1999. A virtual world for earth science education in secondary and post-secondary environments: the Geology Explorer. Proceedings of the International Conference on Mathematics/Science Education & Technology, San Antonio. *(in press).*

Slator, B.M., D.P. Schwert and B. Saini-Eidukat. 1999. Phase development of a multi-modal virtual educational world. Proceedings of the IASTED International Conference on Computers and Advanced Technology in Education (CAT'99), Cherry Hill, N.J. *(in press).*

Slator, B.M., D.P. Schwert, B. Saini-Eidukat, J. Abel, J. Bauer, B. Gietzen, N. Green, T. Kavli, L. Koehntop, B. Marthi, V. Nagareddy, A. Olson, Y. Jia, K. Peravali, D. Turany, V. Bender, and J. Walsh. 1998. Planet Oit: a virtual environment and educational role-playing game to teach the geosciences. Proceedings of the Small College Computing Symposium, pp. 378-392.

Up to 5 Other Significant Publications:

Reiss, R., A.C.Ashworth, and D.P. Schwert. *in press.* Molecular genetic evidence for the post-Pleistocene divergence of populations of the arctic-alpine ground beetle Amara alpina (Paykull) (Coleoptera: Carabidae). *Journal of Biogeography*.

Schwert, D.P., H.J. Torpen, and E.R. Hajic. 1997. Characterization of the late-Wisconsin tundra/forest transition in midcontinental North America using assemblages of beetle fossils. *Quaternary Proceedings* 5: 237-243..

Schwert, D.P. 1996. Effect of Euro-American settlement on an insect fauna: a paleontological analysis of the recent chitin record of beetles (Coleoptera) from northeastern Iowa. *Annals of the Entomological Society of America*, 89(1): 53-63.

Cong, S., A.C. Ashworth, D.P. Schwert, and S.M. Totten. 1996. Fossil beetle evidence for a short, interval near 40,000 yr B.P. at Titusville, Pennsylvania. *Quaternary Research*, 45:216-225

Reiss, R.A., D.P. Schwert, and A.C. Ashworth. 1995. Field preservation of Coleoptera for molecular genetic analyses. *Environmental Entomology*, 24(3):716-719.

List of Collaborators During the Last 48 Months

Richard Baker, University of Iowa; E.A. Bettis, Iowa Geological Survey; Clarke Garry, University of Wisconsin-River Falls; Ed Murphy and John Hoganson, North Dakota Geological Survey; Allan Ashworth, Alan White, Paul Juell, Bernhardt Saini-Eidukat, Phillip McClean, and Brian Slator, North Dakota State University;.

Graduate Students and Post-Doctoral Students

The Department of Geosciences does not have a graduate program.

Graduate and Postgraduate Advisors

Dr. Daniel L. Dindal, SUNYCES&F at Syracuse University; Dr. Alan V. Morgan and Dr. Paul F. Karrow, University of Waterloo.

Other Relevant Information

Dr. Schwert teaches courses in physical geology, geomorphology, structural geology, and glacial geology. He also coordinates North Dakota's major www geologic information site, with access being particularly aimed toward the K-12 community. Schwert is active in the campus-wide www development effort at NDSU and is currently working on developing an outreach training course for North Dakota earth science teachers. Schwert is North Dakota coordinator for the Upper Midwest Aerospace Consortium's EdParc project, which introduces ArcView software/databases into the K-12 curriculum. Schwert has been PI on ten Eisenhower grants for K-12 teacher training, including one awarded for 1999.

Dr. Schwert's research interests have been in the application of insect remains in paleoclimatic and paleoenvironmental modeling. His studies have been primarily supported through NSF, NSF-EPSCoR, and EPA-EPSCoR. In 1991, the North Dakota Science Teachers Association awarded Schwert its "Friend of Science Award," in 1992 he was recipient of NDSU's top award for teaching,, in 1997 he was recipient of his college's top award for teaching, and in 1998 he was co-recipient of his college's top award for service.

ALAN ROBERT WHITE
Associate Professor and Chair of Botany
Department of Botany, North Dakota State University
Fargo, ND 58105-5517 USA
(701) 231-8380 Fax (701) 231-7149 alwhite@plains.nodak.edu

Education

Ph.D.	**1981**	Botany	University of North Carolina, Chapel Hill
B.S.	**1977**	Biology	University of North Carolina, Chapel Hill

Employment

North Dakota State University, Fargo, ND

1997 - present	Chair, Department of Botany
1996 - 1997	Visiting Res. Scientist, Dept. of Cell Biology, John Innes Centre, Norwich, UK
1994 - present	Associate Professor of Botany, Department of Botany
1992 - 1995	Director, Cellular and Molecular Biology Ph.D. Program
1988 - 1994	Assistant Professor of Botany, Department of Botany

Marshall University, Huntington, WV.

1988 - 1988	Assistant Professor of Pharmacology, School of Medicine
1984 - 1988	Assistant Professor of Biological Sciences, Department of Biological Sciences
1982 - 1984	NIH Postdoctoral Fellow - Department of Chemistry, University of Colorado.
1981 - 1982	Postdoctoral Fellow - Research Triangle Institute, Research Triangle Park, NC.

Relevant and Significant Publications

Mazz Marry, Maureen C. McCann, Frank Kolpak, **Alan R. White**, Nicola J. Stacey, and Keith Roberts. 1999 Heterogeneity in the ferulic acid content of pectic polysaccharides from sugar-beet cell walls. *Journal of the Science of Food and Agriculture* (In Press)

Slator, B.M., P. Juell, P.E. McClean, B. Saini-Eidukat, D.P. Schwert, **A.R. White**, C. Hill. 1999 Virtual Environments for Education. Journal of Network and Computer Applications, Academic Press (In Press).

P.E. McClean, D.P. Schwert, P. Juell, B. Saini-Eidukat, B.M. Slator, **A.R. White**. 1999 Cooperative development of visually-oriented, problem-solving science courseware. M/SET 99, The International Conference on Mathematics/Science Education and Technology. San Antonio, TX.

Alan R White, Phillip E. McClean, and Brian M. Slator. 1999 The Virtual Cell: A virtual environment for learning cell biology . The 10th Internat. Conf. on College Teaching and Learning. Jacksonville, FL.

Alan R White, Phillip E. McClean and Brian M. Slator. 1999 The Virtual Cell: An interactive, virtual environment for cell biology. World Conf. on Educational Media, Hypermedia and Telecommun. (ED-MEDIA 99). Seattle, WA.

B.M. Slator, P. Juell, P.E. McClean, B. Saini-Eidukat, D.P. Schwert, **A.R. White**, C. Hill. 1999 Virtual environments for education at NDSU. World Conference on Educational Media, Hypermedia and Telecommunications (ED-MEDIA 99). Seattle, WA. **Outstanding Paper Prize**

Debra Baer, **Alan R. White**, and Neil C. Gudmestad. 1998 Partial characterization of an extracellular _-fructofuranase from *Clavibacter michiganensis* ssp *sepedonicus*. *Can. J Microbiology* **44:**852-865.

Ann G. Matthysse, Darby L. Thomas, and **Alan R. White**. 1995 Mechanism of Cellulose Synthesis in *Agrobacterium tumefaciens*. *J. Bacteriol.* **177:**1076-1081.

Mary L. Pollitz, Judy A. Timpa, **Alan R. White**, and Bruce P. Wasserman. 1994 Non-aqueous gel permeation chromatography of wheat starch in dimethylacetamide (DMAC) and LiCl: Extrusion induced fragmentation. *Carbohydrate Polymer* **24:**91-99.

Alan R. White, Yi Xin, and Vida Pezeshk. 1993 Xyloglucan glucosyltransferase in Golgi membranes from *Pisum sativum* (pea). *The Biochemical Journal* **294:**231-238.

S.C. Fry, W.S. York, P. Albersheim, A.G. Darvill, T. Hayashi, J.-P. Joseleau, Y. Kato, E.P. Lorences, G.A. Maclachlan, M. McNeil, A.J. Mort, J.S.G. Reid, H.-U. Seitz, R.R. Selvendran, A.G.J. Voragen, and **A.R. White**. 1993 An unambiguous nomenclature for xyloglucan-derived oligosaccharides. *Physiologia Plantarum* **89**:1-3.

Alan R. White, Yi Xin, and Vida Pezeshk. 1993 Separation of membranes from semiprotoplasts of suspension-cultured sycamore maple cells. *Physiologia Plantarum* **87**:31-38.

Mark B. Watson, **Alan R. White**, and H. Wayne Elmore. 1990 Extracellular polysaccharides from *Pteridium aquilinum* suspension cultures. *Phytochemistry* **29**:3815-3818.

Roger A. O'Neill, **Alan R. White**, William S. York, Alan G. Darvill and Peter Albersheim. 1988 A gas chromatographic / mass spectrometric assay for glycosylases. *Phytochemistry* **27**:329-333.

Relevant and Significant Publications (Cont)

Alan R. White, Alan G. Darvill, William S. York, and Peter Albersheim. 1984 High-performance gel permeation chromatography assay for endoglycanase activities. *J Chromatography* **298**:525-530.

Candace H. Haigler, **Alan R. White**, R. Malcolm Brown, Jr., and Kay M. Cooper. 1982 Alteration of *in vivo* cellulose ribbon assembly by CM-cellulose and other polysaccharides. *J Cell Biol* **94**:64-69.

Alan R. White. 1982 Visualization of cellulases and cellulose degradation. In: *Cellulose and Other Natural Polymer Systems*. R. Malcolm Brown, Jr. (Ed) Plenum Publ Corp, New York. p. 489-509.

Moshe Benziman, Candace H. Haigler, R. Malcolm Brown, Jr., **Alan R. White**, and Kay M. Cooper. 1980 Cellulose biogenesis: Polymerization and crystallization are coupled processes in *Acetobacter xylinum*. *Proc Nat Acad Sci USA* **77**:6678-6682.

Selected Grants from Past 10 Years

National Science Foundation, EPSCoR, Advancing Science Excellence in North Dakota (ASEND) Program: *Biosynthesis of xyloglucan by Golgi membranes of sycamore cells.* Oct 1989 - Oct 1990. $ 15,000. (Complete)

National Science Foundation, Division of Cellular Biosciences: *Biosynthesis of xyloglucan by plant Golgi membranes.* Sep 1990 - Jun 1994. $ 262,555 NSF funding + $ 20,000 NDSU match. (Complete)

American Society for Cell Biology, Cell Biology Teacher Research Fellowship: Summer research stipend for Mr. Cy C. Kotaska, Sawyer Public School, Sawyer, ND. Jun - Aug 1991. $5,500. (Complete)

National Science Foundation, Research Experience for Undergraduates Program, Supplement to NSF funding. Apr 1992 - Feb 1993. $10,000. (Complete)

U.S. Department of Agriculture, Cooperative State Research Service, Alternative Crops Program: *Alkaline-hydrogen peroxide treated wheat bran fiber.* Jul 1992 - Jun 1993. $ 25,000. (Complete)

National Science Foundation, Research Experience for Undergraduates Program, Supplement to NSF funding. Apr 1993 - Feb 1994. $10,000. (Complete)

National Science Foundation, EPSCoR, Advancing Science Excellence in North Dakota (ASEND) Program: *Establishment of a Regulatory Biosciences Center.* Sep 1992 - Jun 1995. $206,250. (Complete)

U.S. Department of Agriculture, Competitive Research Grants Program: *Purification and Characterization of Xyloglucan Xylosyl Transferase.* Sep 1993 - Aug 1996. $100,000. (Complete)

National Science Foundation, Research Experience for Undergraduates Program, Supplement to NSF funding. Apr 1995 - Feb 1996. $8,000. (Complete)

National Science Foundation, Division of Molecular and Cellular Biosciences: *Xyloglucan glucosyltransferase in plant Golgi membranes.* May 1995 - Sep 1999. $300,000. (Active)

National Science Foundation, Research Experience for Undergraduates Program, Supplement to NSF funding. Oct 1997 - Sep 1998. $5,000. (Active)

National Science Foundation, Directorate for Education and Human Resources: *A shared development environment for science-based courseware.* Oct 1997 - Sept 2000. $ 155,000. Co-PI (Active)

National Science Foundation, Division of Undergraduate Education: *The NDSU Collaborative for Mathematics and Science Teacher Preparation (NDSU-CoMSTeP).* Mar 1999 - Feb 2002. $604,905. Co-PI (Active)

North Dakota EPSCoR, New Faculty Start-Up Funding : *Two plant physiology positions for the Department of Botany/Biology.* July 1999 - June 2001. $134,600. (Active)

National Science Foundation, EPSCoR: *The Virtual Center for Plant Genomics: A MultiInstitutional EPSCoR Proposal.* July 1999 - June 2001. $ 403,475. Co-PI (Active)

Collaborators During the Last 5 Years

Kent Chapman, University of North Texas; Candace H. Haigler, Texas Tech University; Ann G. Matthysse, University of North Carolina; Keith Roberts & Maureen McCann, John Innes Centre, Norwich, UK.

PI's Graduate and Postdoctoral Advisors

R. Malcolm Brown, Jr., Professor of Botany, Johnson & Johnson Centennial Chair in Plant Cell Biology, Department of Botany, University of Texas, Austin, TX 78713-7640.

Peter Ingram, Senior Physicist, Camille Dreyfus Laboratory, Research Triangle Institute, PO Box 12194, Research Triangle Park, NC 27709.

Peter Albersheim and Alan G. Darvill, Co-directors, University of Georgia, Complex Carbohydrate Research Center, 220 Riverbend Rd, Athens, GA 30602.

Graduate Student Advising (Major Professor)

Mark B. Watson, Anne M. Hoylman, Douglas L. Pittman, Marshall University. Xin Yi, Jason Netland, Zhiyong Yang, David Cavalier, North Dakota State University.

Richard Timothy Beckwith

Intel Corporation
JF3-379, 2111 N.E. 25th Ave.
Hillsboro, OR 97214-5961
richard.beckwith@intel.com

Home: (503) 230-7025 Work: (503) 264-4760

Education

Teachers College, Columbia University
Ph.D., January 1988, Developmental and Educational Psychology

University of Massachusetts/Boston
BA in Psychology, June 1981, Summa cum Laude
Honors in Psychology and Linguistics

Work Experience

Intel Corporation, Intel Architecture Laboratory
Research Psychologist 1996-present

Work with social scientists and technologists to provide Intel engineers with a vision of computing five years out. Responsibilities include doing ethnographic fieldwork to support the development and evaluation of prototype hardware and software products, integration of qualitative field data with extant quantitative data, analysis of these data, and evangelizing research to internal and external customers.

Northwestern University, The Institute for the Learning Sciences
Research Scientist -- Assistant Professor 1991-1995
Associate Professor 1995-1996

Worked with various teams to support the development of training and educational software. Responsibilities included the design and supervision of all research involving human subjects. Activities included both data gathering for software design and evaluating software for training efficacy and usability. Methodologies included: user observations, structured interviews, surveys, focus groups, and history analysis.

Princeton University, Cognitive Science Laboratory
Research Associate 1988-1991

Worked with George Miller's team on the development of a lexical database organized on psycholinguistic principles. Responsibilities included surveying psycholinguistic and neuropsychological data and working with programmers to ensure that the structure of the database and the procedures involved in data access reflected salient properties as determined by these data.

Teachers College, Columbia University
Research Assistant 1981-1991

Worked with Lois Bloom's team of researchers looking at language acquisition in the first two years of life. Oversaw the development and maintenance of a computer/video

laboratory. Methodologies included quasi-naturalistic observations of mother-infant dyads, microanalysis of data, development of coding schemes and a suite of lag-sequential analysis tools, and the implementation of a language acquisition simulation.

Selected Publication

Miller, George, Richard Beckwith, N. Fellbaum, M. Gross, and D. Miller (1991). Introduction to WordNet: An On-Line Lexical Database. International Journal of Lexicography, 3, 1-12.

Beckwith, Richard and George Miller (1991). Implementing a Lexical Network. International Journal of Lexicography, 3, 303-312.

Bell, Benjamin L., Ray Bareiss, and Richard Beckwith (1994). "Sickle Cell Counselor: A Prototype Goal-Based Scenario for Instruction in a Museum Environment". The Journal of the Learning Sciences, 3(4), 347-386..

Beckwith, Richard (1995) Strategies for Supporting the Design of Educational Software: A Look at Authoring Environments Put into Practice. Chaired at the American Educational Research Association, Spring 1995 meeting.

Beckwith, Richard and D. Teibel (1998) The Creative PC in the Classroom. Presented at the International Conference on Technology and Education, Spring 1998 meeting.

SUMMARY PROPOSAL BUDGET — YEAR 1

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

ORGANIZATION: **North Dakota State University Fargo**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Brian M Slator**

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. **Brian M Slator - Associate**	**0.00**	**0.00**	**10.00**	$ **70,728**	$
2. **Paul Juell - Associate**	**0.00**	**0.00**	**5.00**	**33,154**	
3. **Phillip E McClean - Professor**	**0.00**	**0.00**	**5.00**	**33,154**	
4. **Bernhardt Saini-Eidukat - Assistant**	**0.00**	**0.00**	**5.00**	**33,154**	
5. **Donald P Schwert - Professor**	**0.00**	**0.00**	**5.00**	**33,154**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**5.00**	**33,154**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	**0.00**	**0.00**	**35.00**	**236,498**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**120.00**	**0.00**	**0.00**	**530,461**	
3. (**4**) GRADUATE STUDENTS				**241,920**	
4. (**6**) UNDERGRADUATE STUDENTS				**302,400**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**1,311,279**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**235,530**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,546,809**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
laptops $ **32,000**					
servers **16,000**					
workstations **50,000**					
TOTAL EQUIPMENT				**98,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**36,000**	
2. FOREIGN				**15,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
(**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**10,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**48,000**	
3. CONSULTANT SERVICES				**50,000**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**108,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,803,809**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Overhead (Rate: 41.0000, Base: 1705808)**					
TOTAL INDIRECT COSTS (F&A)				**699,381**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,503,190**	
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)				$ **2,503,190**	$

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

PI / PD TYPED NAME & SIGNATURE*: **Brian M Slator** DATE

ORG. REP. TYPED NAME & SIGNATURE* DATE

FOR NSF USE ONLY

INDIRECT COST RATE VERIFICATION

Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
White, Alan R - Professor	**0.00**	**0.00**	**5.00**	**33154**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION: **North Dakota State University Fargo**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Brian M Slator**

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. **Brian M Slator - Associate**	**0.00**	**0.00**	**10.00**	$ **70,728**	$
2. **Paul Juell - Associate**	**0.00**	**0.00**	**5.00**	**33,154**	
3. **Phillip E McClean - Professor**	**0.00**	**0.00**	**5.00**	**33,154**	
4. **Bernhardt Saini-Eidukat - Assistant**	**0.00**	**0.00**	**5.00**	**33,154**	
5. **Donald P Schwert - Professor**	**0.00**	**0.00**	**5.00**	**33,154**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**5.00**	**33,154**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	**0.00**	**0.00**	**35.00**	**236,498**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**120.00**	**0.00**	**0.00**	**530,461**	
3. (**4**) GRADUATE STUDENTS				**241,920**	
4. (**6**) UNDERGRADUATE STUDENTS				**302,400**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**1,311,279**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**235,530**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,546,809**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **$ 98,000**					
TOTAL EQUIPMENT				**98,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**36,000**	
2. FOREIGN				**15,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
(**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**10,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**48,000**	
3. CONSULTANT SERVICES				**50,000**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**108,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,803,809**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**699,381**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,503,190**	
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)				$ **2,503,190**	$

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

PI / PD TYPED NAME & SIGNATURE*: **Brian M Slator** DATE

ORG. REP. TYPED NAME & SIGNATURE* DATE

FOR NSF USE ONLY

INDIRECT COST RATE VERIFICATION

Date Checked	Date Of Rate Sheet	Initials - ORG

NSF Form 1030 (10/98) Supersedes all previous editions

C***SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.B)**

Budget Justification

Budget is requested for a five-year project.

Salary is requested for the PI for two months per summer and for content area faculty (in Geoscience, Biology, etc.), for one month per summer.

Salary is requested for two full-time professional software developers.

Salary is requested for four full time (20 hour/week) graduate research assistants each year.

Salary is requested for six full time (20 hour/week) undergraduate employees.

Equipment funds are requested for 10 client workstations in year one, for software development; four laptops in year two for providing on-site demonstrations during travel; and 4 server machines in year three. In year four, 10 more workstations are requested (on a standard three-year replacement cycle). Four more laptops are requested in year five, for long-term loan to K-12 teachers involved in the project.

Funds are requested for consultant expenses, primarily for assistance with evaluation studies and analysis of data.

Funds are requested, under the heading of “G2. DISSEMINATION”, to conduct K-12 teacher training, starting with the summer of year three.

Travel funds are requested to send faculty and students to national and international meetings.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Brian Slator**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Shared Development Environment for Science-based Courseware**

Source of Support: **NSF/DUE**
Total Award Amount: $ **155,000** Total Award Period Covered: **02/01/98 - 01/31/01**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Learning by Doing Physical Geology in a Virtual Laboratory/Virtual Field Trip Computer Environment**

Source of Support: **NSF/GEO**
Total Award Amount: $ **49,981** Total Award Period Covered: **10/01/99 - 09/30/01**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **The Virtual Center for Plant Genomics**

Source of Support: **NSF-EPSCoR**
Total Award Amount: $ **403,475** Total Award Period Covered: **07/01/99 - 06/30/01**
Location of Project: **Montana State University, subaward to North Dakota State**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.50** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **New Directions in Virtual Geoscience Education**

Source of Support: **NSF-CCLI**
Total Award Amount: $ **74,192** Total Award Period Covered: **05/01/00 - 04/30/01**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Intelligent Tutoring Using Case-based Reasoning**

Source of Support: **North Dakota EPSCoR**
Total Award Amount: $ **38,273** Total Award Period Covered: **05/01/00 - 04/30/02**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Brian Slator**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Learning Computer Science in Virtual Worlds**

Source of Support: **NSF-ITR**
Total Award Amount: $ **332,903** Total Award Period Covered: **08/01/00 - 07/31/03**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Real World Geology on a Virtual Planet**

Source of Support: **NSF-ITR**
Total Award Amount: $ **466,122** Total Award Period Covered: **09/01/00 - 08/31/03**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Learning in a Virtual, Interactive World**

Source of Support: **NSF-ITR**
Total Award Amount: $ **497,463** Total Award Period Covered: **08/01/00 - 07/31/03**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Training Future Scientists with a Virtual Cell**

Source of Support: **Dept. of Education - FIPSE Comprehensive Program**
Total Award Amount: $ **202,000** Total Award Period Covered: **10/01/00 - 09/30/03**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Systems for Learning Science and Assessing Student Learning**

Source of Support: **NSF-ITR**
Total Award Amount: $ **2,324,544** Total Award Period Covered: **09/01/00 - 08/31/05**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **2.00**

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Phillip E. McClean

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: X Current Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: A Shared Developmental Environment for Science-based Courseware

Source of Support: NSF

Total Award Amount: $155,000 Total Award Period Covered: 24 months (2/98 - 1/00)

Location of Project: North Dakota State University

Person-Months Per Year Committed to the Project. Cal: 3 Acad: 2 Sumr: 1

Support: xCurrent ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Biotechnology Improvement of Dry Bean

Source of Support: North Dakota Agricultural Experiment Station

Total Award Amount: $1,200 Total Award Period Covered: 12 months (7/98 - 6/99)

Location of Project: North Dakota State University

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

Support: X Current Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: The Virtual Center for Plant Genomics: A Multi-institutional Infrastructure Proposal
(NOTE: Award amount is subcontract amount to NDSU.)

Source of Support:

Total Award Amount: $403,475 Total Award Period Covered: 7/99 - 6/01

Location of Project: North Dakota State University

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

Support: ☐ Current XPending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Training Future Scientists with a Virtual Cell

Source of Support: Department of Education: FIPSE Comprehensive Program

Total Award Amount: $202,000 Total Award Period Covered: 10/00 - 9/03

Location of Project: North Dakota State University

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

Support: ☐ Current XPending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: ITR/SOC: Learning in a Virtual, Interactive World

Source of Support: NSF/ITR

Total Award Amount: $497,463 Total Award Period Covered: 8/00 - 7/03

Location of Project: North Dakota State University

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

---

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Other agencies (including NSF) to which this proposal has been/will be submitted.

Investigator: **Bernhardt Saini-Eidukat**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Silicic Magmatism in Northern Patagonia: Constraints from the Somoncura Massif, Argentina**

Source of Support: **NSF**

Total Award Amount: $ **57,302** Total Award Period Covered: **07/01/00 - 06/30/02**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **1.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Shared Developmental Environment for Science-Based Courseware**

Source of Support: **NSF Division of Undergraduate Education**

Total Award Amount: $ **155,000** Total Award Period Covered: **02/01/98 - 01/31/01**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Learning by Doing Physical Geology in a Virtual Laboratory/Virtual Field Trip Computer Environment**

Source of Support: **NSF-GEO**

Total Award Amount: $ **49,981** Total Award Period Covered: **10/01/99 - 09/30/01**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Science-Based Virtual Teaching Environments for the Classroom**

Source of Support: **U.S. Department of Education - FIPSE**

Total Award Amount: $ **443,232** Total Award Period Covered: **09/01/99 - 08/31/02**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Science-Based Virtual Teaching Environments for the Classroom**

Source of Support: **U.S. Department of Education - Implementation Grant**

Total Award Amount: $ **335,956** Total Award Period Covered: **10/01/99 - 09/30/02**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal: Acad: **1.00** Sumr: **1.00**

---

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Donald Schwert**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Shared Developmental Environment for Science-Based Courseware**

Source of Support: **NSF Division of Undergraduate Education**

Total Award Amount: $ **155,000** Total Award Period Covered: **02/01/98 - 01/31/00**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal: Acad: **1.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **New Directions in Virtual Geoscience Education**

Source of Support: **NSF-DUE-CCLI**

Total Award Amount: $ **74,192** Total Award Period Covered: **01/01/00 - 12/31/02**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **1.00** Sumr: **1.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Learning by Doing Physical Geology in a Virtual Laboratory/Virtual Field Trip Computer Environment**

Source of Support: **NSF-GEO**

Total Award Amount: $ **50,000** Total Award Period Covered: **09/01/98 - 08/30/99**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal: Acad: **1.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Real World Geology on a Virtual Planet**

Source of Support: **NSF-ITR**

Total Award Amount: $ **466,122** Total Award Period Covered: **09/01/00 - 08/31/03**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **1.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Natural History of the Dakotas Field Course**

Source of Support: **Dwight D. Eisenhower Act**

Total Award Amount: $ **19,495** Total Award Period Covered: **02/01/00 - 06/30/01**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **0.25**

---

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Donald Schwert**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ND Master Science Teacher Project**

Source of Support: **Dwight D. Eisenhower Act**

Total Award Amount: $ **29,360** Total Award Period Covered: **02/01/00 - 06/30/01**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Systems for Learning Science and Assessing Student Learning**

Source of Support: **NSF-ITR**

Total Award Amount: $ **2,324,544** Total Award Period Covered: **09/01/00 - 08/31/05**

Location of Project: **North Dakota State University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **2.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

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

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

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

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

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

---

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this

Investigator: Alan R. White

Other agencies (including NSF) to which this proposal has been/will be

Support: xCurrent G Pending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: Xyloglucan Glucosyltransferase in Plant Golgi Membranes

Source of Support: NSF - MCB

Total Award Amount: $300,000 Total Award Period Covered: 12 months (5/95 – 10/00)

Location of Project: North Dakota State University

Person-Months Per Year Committed to the Project. Cal: 3 Acad: 1 Sumr: 2

Support: xCurrent G Pending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: **The NDSU Collaborative for Mathematics and Science Teacher Preparation (NDSU-CoMSTeP)**

Source of Support: **NSF - DUE**

Total Award Amount: $ 604,905 Total Award Period Covered: **36 months** (3/99 – 2/02)

Location of Project: North Dakota State University

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

Support: xCurrent G Pending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: **Two Plant Physiology Positions for the Department of Botany/Biology**

Source of Support: **ND-EPSCoR, New Faculty Start-Up Grants**

Total Award Amount: $ 68,600 Total Award Period Covered: 24 months (7/99 – 6/01)

Location of Project: North Dakota State University

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

Support: X Current Pending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: A Shared Developmental Environment for Science-based Courseware

Source of Support: NSF-DUE

Total Award Amount: $155,000 Total Award Period Covered: 24 months (2/98 - 1/01)

Location of Project: North Dakota State University

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

Support: X Current Pending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: The Virtual Center for Plant Genomics: A Multi-institutional Infrastructure Proposal
(NOTE: Award amount is subcontract amount to NDSU.)

Source of Support:

Total Award Amount: $403,475 Total Award Period Covered: 7/99 - 6/01

Location of Project: North Dakota State University

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

Support: G Current XPending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: Training Future Scientists with a Virtual Cell

Source of Support: Department of Education: FIPSE Comprehensive Program

Total Award Amount: $202,000 Total Award Period Covered: **10/00 - 9/03**

Location of Project: North Dakota State University

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

Support: G Current XPending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: ITR/SOC: Learning in a Virtual, Interactive World

Source of Support: NSF/ITR

Total Award Amount: $497,463 Total Award Period Covered: 8/00 - 7/03

Location of Project: North Dakota State University

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

Support: G Current XPending G Submission Planned in Near Future G *Transfer of Support

Project/Proposal Title: **Systems for Learning Science and Assessing Student Learning**

Source of Support: **NSF/ITR**

Total Award Amount: **$2,232,544** Total Award Period Covered: **9/00 - 8/05**

Location of Project: North Dakota State University

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

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Richard Beckwith**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Real World Geology on a Virtual Planet**

Source of Support: **NSF-ITR**
Total Award Amount: $ **466,122** Total Award Period Covered: **09/01/00 - 08/31/03**
Location of Project: **North Dakota State University**
Person-Months Per Year Committed to the Project. Cal: **0.50** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory:

Clinical:

Animal:

Computer: **Each PI has a desktop computer. In addition, Dr. Slator has a laboratory room with four workstations, and three unix servers running FreeBSD, one of which hosts the Planet Oit simulation. This lab space is served by a 100 MBit switch.**

Office:

Other: _____

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

The NDSU Multimedia Center is located in the IACC Building at NDSU. Computer equipment includes three Dell PCs, two Macintosh PowerPCs, and one iMac. The Center licenses a wide variety of multimedia development software. The IACC building is also home to a set of student clusters where upwards of 200 workstations, both PC and Mac, are available 24 hours per day.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.