COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e., program, division, etc.)
Undergraduate Education/Inst.-Lab. Improvement

FOR NSF USE ONLY
NSF PROPOSAL NUMBER

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE
93-164 11/14/94

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	FILE LOCATION

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

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

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

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE:
University of Utah

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING ZIP CODE:
Office of Sponsored Projects
University of Utah
Salt Lake City, Utah 84112

AWARDEE ORGANIZATION CODE (IF KNOWN):

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING ZIP CODE:
Center for Integrated Science Education (CISE)
2480 MEB, University of Utah
Salt Lake City, Utah 84112

PERFORMING ORGANIZATION CODE (IF KNOWN):

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

TITLE OF PROPOSED PROJECT: Leonardo Laboratory: Project-Based Integrated Science for Non-Science Majors.

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE:
$ 22,365	12 months	8/1/94

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

☐ VERTEBRATE ANIMALS ☐ NATIONAL ENVIRONMENTAL POLICY ACT ☐ FACILITATION FOR SCIENTISTS/ENGINEERS WITH DISABILITIES
☐ HUMAN SUBJECTS ☐ PROPRIETARY AND PRIVILEGED INFORMATION ☐ RESEARCH OPPORTUNITY AWARD
☐ HISTORICAL PLACES ☐ DISCLOSURE OF LOBBYING ACTIVITIES ☐ INTERNATIONAL COOPERATIVE ACTIVITY:
☐ BEGINNING INVESTIGATOR (See GPG SECTION I) Country/countries
☐ GROUP PROPOSAL
☐ SMALL GRANT FOR EXPLORATORY RESEARCH (SGER) (SEE GPG SECTION II. C. 12)

PI/PD DEPARTMENT
Bioengineering/CISE

PI/PD POSTAL ADDRESS
University of Utah
2480 MEB
Salt Lake City, Utah

PI/PD FAX NUMBER
(801) 585-5361

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	Date
PI/PD J.D. Andrade	J.D. Andrade	11/9/94
Co-PI/PD		
Co-PI/PD		
Co-PI/PD		
Co-PI/PD		

Certification for Authorized Institutional 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 statue, debarment and suspension, drugfree workplace, and lobbying activities (see below), as set forth in the Grant Proposal Guide (GPG), NSF 94-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

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

The Leonardo Laboratory:
Experiment and Project-Based Integrated Science for Non-Science Majors

Summary:

The Leonardo Laboratory was established by the Center for Integrated Science Education (CISE) to provide a laboratory and working environment for non-science students involved in courses and projects which do not have access to conventional, major-based, undergraduate laboratories.

CISE is developing courses and mechanisms by which non-science majors and pre-service elementary teachers can become involved in the scientific method and process, learn the various concepts, themes, and principles of the basic sciences and participate in project-based science and technology activities (1,2).

Our courses and activities are based on two approaches:

1) Science Without Walls (sciences looked at as an integrated process and a way of looking at the world with common concepts, themes, and methods throughout all the sciences) (2), and

2) Science by Seduction (science viewed as a means by which to expand one's existing interests, hobbies, and activities, and through them to develop critical thinking and scientific process skills (1,2)).

The Leonardo Laboratory is established around common student interests and hobbies, including art, music, photography, health, sports, and gardening (Figure 1). Science "fearing", science-resistant students are urged to utilize their hobbies and interests in an open ended, extended way and, through the guidance of instructors, TAs, and undergraduate science students, see that their interests and hobbies are indeed connected to and a part of the larger scientific spectrum. Although the University has provided space for the Leonardo Laboratory, it has not provided any resources for equipping that space with the apparatus and instruments for science demonstrations, experiments, or projects. Such equipment is requested in this proposal.

Contents

Title Page 1
Certification Page 2
Project Data Form 3

Summary 4

Contents 5

1. Results from Prior NSF Support: no prior support related to undergraduate education 6

2. Narrative 6
   - A. Current Situation 6
   - B. Development Plan 8
   - C. Equipment 9
     - a. Requested 9
     - b. Equipment On Hand 10
     - c. Implementation & Maintenance 10
   - D. Faculty Expertise 10
   - E. Dissemination and Evaluation 11
   - F. Bibliography 12

3. Biosketch 12

4. Budget 15

5. Current and Pending Support 18

Appendices 19

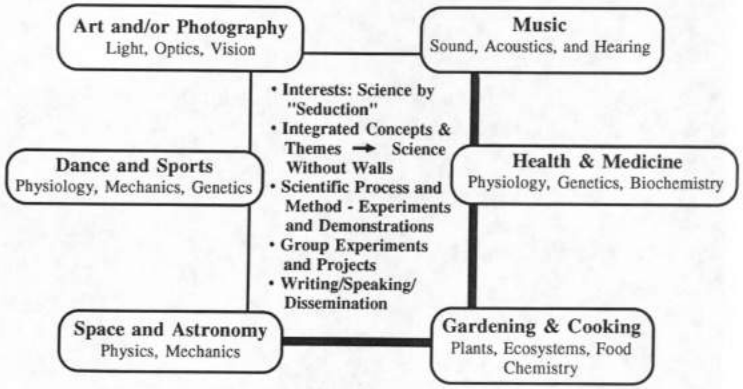

Figure 1. Science by "Seduction."

1. Results From Prior NSF Support:

The principle investigator and his co-investigators have had no prior NSF support pertaining to undergraduate education.

2. Narrative

A. The Current Situation:

The University of Utah has no hands-on, experiment-based, integrated science courses for non science majors. Although we offer a number of liberal and general education courses, some of which are in the sciences and permit non-science majors to fulfill science graduation credits, these courses are generally taught in a lecture format with little or no exposure to an experimental laboratory environment. Although demonstrations, simulations, and other activities are of course included, the real reality component in science education is missing, i.e., hands-on laboratory experience. The University does have laboratories for undergraduate science in the specific disciplines, generally designed for majors or as service courses for other majors. It is only recently that the University has shown a significant interest in the development of science courses for non-science majors by other than conventional didactic or computer-based means.

The Center for Integrated Science Education was established several years ago, initially focusing on the education of inservice teachers who have fears or anxieties towards science and mathematics. In the last several years over 400 teachers in the Utah area have taken a 10 hour inservice course titled Integrated Science Concepts and Themes, in which novel scientific phenomena were used as a means to motivate, stimulate, and interest them in the scientific process and in science experimentation and analysis. This has been quite successful. We now want to expand this into the undergraduate environment at the University with the establishment of a set of courses called Science Without Walls and Science by Seduction.

J. Andrade, PI, has offered several courses over the past year titled, Science Projects for the Utah Science Center. In this course a group of students, organized into an interest-based group, then work with faculty and technical staff in interactive, hands-on science exhibits/projects for an evolving new science center. These experiences have involved a limited number of students to date, largely because of limitations in space and resources. The establishment of the Leonardo Laboratory has now provided the space for expanded activities, and it is expected that this course component will grow. Andrade is encouraging faculty in other departments to offer comparable courses through their disciplines and their interests, which would likely involve significantly greater numbers of students for the next several years. The Utah Science/Art Center is scheduled to open Phase I in 1999, Phase II in 2002, and a Phase III possibly in 2006. The project is only now initiating fund raising and so resources from that source are not available at this time. However, it is anticipated that resources will be available in three years or so and will then provide a mechanism for continuing many of the activities initiated by this proposal.

The Leonardo Laboratory will be utilized for University of Utah undergraduate students in a variety of courses and projects designed for non science majors.

Science Without Walls is a two quarter, 20 week, Liberal Education course which will be offered starting January 2, 1995.

An assessment of the Science Without Walls course, to be conducted in June-July of 1995, is expected to lead to the recommendation that it be made a regular offering and that pre-service elementary teachers be encouraged to use the course to satisfy part of their science education requirement.

Assuming this proposal is funded, the Leonardo Laboratory will be equipped appropriately to permit the offering of non-major science related courses in multiple sections on a continual basis. The hope and expectation is that the Leonardo Lab would be in use at least 4-5 hours per day as a part of a regular course schedules, and in use an additional 6-8 hours per day for independent use by students working on their experiments and projects. It is anticipated that over the next 2-3 years the Laboratory would handle 150-200 students per year, plus an additional number of in-service teachers involved in short courses and workshops during the summer months.

B. Development Plan:

The Science Without Walls course is diagrammed in Figure 2. A group of students are organized into various interest-based groups. We use their interests or hobbies (Figure 1) to involve them in the scientific process, the scientific method, and a variety of experiments and projects. By going through their window of interest or aptitude, reminiscent of Howard Gardner's *Frames of Mind* (1), the students are "seduced" into probing and learning areas which they normally considered to be of little interest to them. We have used this in our inservice courses with practicing teachers now for three years with considerable success

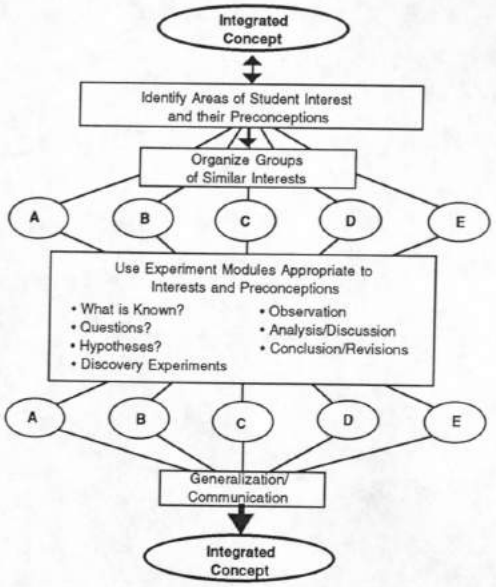

Figure 2. The Development of a Typical Concept Module.

The Leonardo Laboratory was established by the Center for Integrated Science Education within the past year to provide an environment for the students in these courses to learn to use scientific apparatus and tools to experiment, to develop science demonstrations and activities for their classmates, and otherwise to be involved in group projects. Unfortunately, that space is space only. There is no equipment, apparatus, or other facilities with which to conduct the experiments; that is the basis of this request.

The University has committed to the project by establishing the Center for Integrated Science Education and by providing released time for a number of faculty members to work on Center projects. It has also provided the space, about 900 sq/ft in four small laboratories, in which to establish the Leonardo Laboratory. This proposal requests the equipment required to make this a functioning and effective undergraduate science laboratory for non-science majors and for inservice elementary teacher candidates.

C. Equipment:

a. Requested

At this time we have selected 6 general interest or aptitude areas with which to initiate the laboratory and the courses (Figure 1).

Art and Photography are of interest to most fine arts students. Basically, the visual arts and photography involve light, optics, perspective, color, texture, and of course the sense of vision and sight (3-5). All of this includes many topics of physics, chemistry, biology, physiology, and mathematics -- including many principles and concepts which can be easily developed and experienced through art and photography (3-5).

Music is another topic of major interest to students with aptitudes in the arts. Music is especially straightforward to connect to science and particularly to various areas of physics that deal with sound, acoustics, pressure waves and changes, the sense of hearing and perception of sound (5-7). The structure of music lends itself to a variety of mathematical analyses. The nature of musical instruments and their sound generation characteristics all can play a role.

The interest area of Space and Astronomy can involve many of the very basic concepts of physics, mechanics, and even chemistry, including the creation of the elements and the existence and properties of molecules in space. It also allows topics such as planets, geosphere, and biosphere to be developed.

In the area of Dance and Sports, those students with a particular interest in the performing arts or sports have a particular interest. Typical scientific disciplinary topics of physiology, mechanics, genetics are easily connected and developed.

Health and Medicine are, of course, related to Dance and Sports and allow the development of experiences in physiology, genetics, biochemistry and related topics. Most students don't realize that many of the very basic concepts in the physical sciences were discovered by early investigators in the life and medical sciences. The Leonardo connection is particularly relevant here because of Leonardo da Vinci's strong interest in anatomy and physiology, as well as in mechanics, sculpture, architecture, and art.

Gardening and Cooking are topics of particular interest to many, and particularly older, students. Topics include much of basic biology, particularly plants and ecosystems, as well as chemistry and physics of food, energy collection and transfer, i.e., solar energy and photosynthesis, and related topics (8, 9).

Emphasis in the first year course and in the development of the Leonardo Laboratory will be on Art and Photography, Sound and Music, and Health and Medicine. Students in the course will be encouraged to develop interests and conduct projects in those three areas.

In the second year of the course we will add Space and Astronomy, Dance and Sports, and Gardening and Cooking. There may be some additional topics incorporated, and perhaps one of these topics would be eliminated in the second year, based on student interest and success in the first year of these offerings.

b. Equipment on Hand

Equipment presently on hand is extremely limited. J. Andrade has budgeted $2,000 with which to buy supplies and limited equipment for the initial offering of Science Without Walls, beginning January, 1995. Nearly $2,000, some provided by the Utah Science/Art Center project, have been spent to equip the Leonardo Laboratory in a very minimal way. At this point it is mainly configured with tools for the design and prototyping of exhibits and apparatus. We have managed to borrow a number of pieces of research equipment on very short term loan, which can be called back with little no notice.

c. Implementation and Maintenance

Mr. James Biggs, a graduate student in Bioengineering, has been assigned to manage and maintain the Leonardo Laboratory. He has been working with J. Andrade for the past 6 months in establishing the facility, and will continue to work on the project for at least the next two years. We are committed to maintaining a half time graduate student manager/TA for the laboratory. This individual will generally have adequate skills for the maintenance, calibration, and upgrading of the various instruments requested.

In addition, technical staff from the Departments of Bioengineering, Biology, Chemistry, and Physics are all involved with the establishment of the laboratory and have agreed to lend their services on a limited basis to its implementation, maintenance, and operation. These individuals are primarily responsible for the large undergraduate disciplinary-based lab in their specific departments, and therefore have considerable experience with undergraduate laboratories.

D. Faculty Expertise:

J. Andrade, Co-Director for the Center for Integrated Science Education, has made the Leonardo Laboratory -- and integrated science experiences for non-science major undergraduates a major personal objective and priority. He is devoting over one third of his time and effort to undergraduate science education. In the 1994-'95 year that effort is nearly full time as a result of a University Professorship appointment. Several years ago he significantly decreased the size of his research group to permit active involvement in undergraduate and public science education activities.

The experience of managing a large research group over the years is useful in the implementation, operation, and maintenance of the new Leonardo Laboratory. In addition, Joe's graduate students in Bioengineering and Materials Science serve as resource people and mentors for the undergraduate students. They are all involved to various extents in the undergraduate education activities. One such students, currently Mr. James Biggs (noted above), is a formal TA for the Leonardo Laboratory.

The Executive Committee of the Center for Integrated Science Education, consisting of faculty representing the Departments of Chemistry, Biology, Physics, Mathematics, Geology and Geophysics, and several other technical areas, are also all deeply committed to undergraduate science education for non-majors. These CISE faculty will serve as guest lecturers, guest demonstrators, advisors, and general resource people for the students involved in the Leonardo Laboratory. The CISE faculty all have access to the laboratory, meet there on a regular basis, and are readily accessible and available. In addition, the technical staff in the research groups of the CISE faculty, and the technical staff in their respective departments responsible for the departmental undergraduate laboratories, are also all available and accessible.

There is indeed a university-wide commitment to the establishment of effective, non-major undergraduate science education. The effort is enthusiastically supported by the Dean of the College of Science, Dr. B. Rushing, the Dean of the Graduate School of Education, Dr. C. Kennedy, and the Dean of the College of Engineering, Dr. D. Pershing, all three of whom also serve on the Executive Committee of CISE. In addition, the Dean of Undergraduate Studies, Dr. R. Keele, is committed to enhanced undergraduate science education, hence, the courses described above, the Leonardo Laboratory, and this proposal.

E. Dissemination and Evaluation:

J. Andrade and the other faculty involved in the project all participate regularly in national meetings and workshops related to undergraduate science education and informal science education, especially the National Science Teachers Association, American Association of Physics Teachers, American Chemical Society, and National Association of Biology Teachers.

The major dissemination mechanism will be through scholarly articles published in journals related to science education and undergraduate studies. However, there is another unique dissemination mechanism which is indicated briefly in the center of Figure 1, and that is the students themselves. The University has a very strong writing program -- we are committed to incorporating writing and communication skills in all components of the undergraduate experience. Student groups present the results of their projects as interactive, hands-on lecture demonstrations to the class and to the campus community. We are developing a mechanism through which they will also be presented to the general public and be incorporated in hands-on workshops and demonstrations in appropriate national venues. Student writing activities, however, will lead to coverage in local and hopefully national print media, and possibly in television and radio as well. We are working closely with our local educational FM and television stations on a project along these lines. We are committed to extensive dissemination and evaluation of this and related projects.

We are firmly committed to having outstanding undergraduates participate in such conferences and meetings. As an example, three undergraduates who have been involved with the program to date are giving a workshop at the Las Vegas National Science Teachers Association Meeting in December titled "Guess, Test, and Guess Again: Science Fairs in the Elementary Environment." Only one of these three students is a science (actually engineering) student. The other is a music major. The third a major in interdisciplinary studies. Another workshop, "Megamolecules: Polymers in the Chemistry Curriculum," is given by a former graduate student in the Department of Materials Science, Dr. Rob Scheer, who has been involved with these activities. The third workshop at the same meeting, "Photons, Bioluminescence, and the Ozone Hole," is by J. Andrade and is a direct result of CISE activities in the enhancement of integrated science education. Students involved in these projects normally attend major national meetings related to science education, as well as local conferences and workshops.

Evaluation and assessment are being conducted by our colleagues in the Graduate School of Education with expertise in these areas, largely based on an interview process with students before and after their experience in the courses and laboratories. The results of these evaluations and assessment activities will likely result in one or more scholarly publications initiated by the assessment/evaluation professionals.

F. Bibliography:

1. Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences*, Basic Books.
2. F.J. Rutherford and A. Ahlgren, *Science for All Americans*, Oxford University Press, 1990.
3. S.J. Williamson and H.Z. Cummins, *Light and Color in Nature and Art*, Wiley, 1983.
4. D. Falk, et al., *Seeing the Light: Optics in Nature, Photography...*Wiley, 1986.
5. L. Schlain, *Art and Physics*, Quill, 1991.
6. C. Taylor, *Exploring Music: Science & Technology of Tones & Tunes*, Institute of Physics, 1992.
7. F. Winckel, *Music, Sound and Sensation*, Dover, 1967.
8. D. Walker, *Energy, Plants, and Man*, Oxygraphics, Ltd. (Sussex, UK), 1992.
9. C. Snyder, *The Extraordinary Chemistry of Ordinary Things*, Wiley, 1992.

3. Biosketch:

J. D. Andrade (next sheet).

4. Budget Justification:

The equipment requested falls into several generic categories:

- *General science laboratory equipment,* such as the two balances, refrigerator, the Ph meter, vacuum dessicator and pump, the spectrophotometer, water bath, stirrers, and optical microscopes.

- *Equipment focused towards Art, Optics and Vision*, which includes the camcorder monitor system, the art/paint software, the PowerMac suitable for running such graphics-based software, view camera, densitometer/scanner (although the later is, of course, used for a wide range of projects).

- *Equipment related to sound, music, acoustics, and the physical principles derived therefrom,* which includes the oscilloscope, one of the computers, a signal generator, audio amplifier, and audio sound music software.

- *Equipment related to sports, dance, and physiology,* including the physiology monitoring system, some of the camera video equipment, equipment related to biology, biochemistry, and general chemistry, including the liquid and thin layer chromatography, again the spectrophotometer, the radiometer system for light intensity measurements, freezer, centrifuge, and other pieces noted above.

Other areas, listed in Figure 1, all utilize components of the equipment previously described.

The budgets provided are estimates based on current catalog prices and discounts. In some cases we were unable to negotiate discounts in time. It is estimated that some of the prices will increase, but that some of the discounts will be negotiated more effectively by the time funds are available for the shipping purpose.

Shipping costs are included in the budget estimates. Assembly and installation of the equipment will be accomplished by existing staff. Appropriate safety and first aid equipment and resources are provided in the laboratory.

Appendices

A. Major Undergraduate Equipment

There is at present no major undergraduate equipment for science education for non-science majors. Most of the existing courses and offerings are offered in a non-laboratory format. In a few cases demonstrations and related experiences are performed in existing discipline-focused undergraduate laboratories. The establishment of the Leonardo Laboratory was intended to provide a facility and the resources for integrated, project-based science education for non-science majors.

B. Course Descriptions:

Liberal Education 144-145, Science Without Walls: A two quarter concept- and inquiry-based course primarily for non-science majors. "Science Without Walls" focuses on major science concepts, applicable to all science "disciplines." It is intentionally multi- and inter-disciplinary. Science Without Walls considers science as an integrated set of concepts and phenomena. With such concepts and understanding in hand, students will have a firm foundation and "literacy" in science. Concepts and topics are derived from national reports and curricular reform movements which have evolved in the last several years. Selection and development of materials and modules for sensing and discovery of key integrated concepts will be developed through students' understanding their own conceptions, "fears," and needs of the themes to be covered. Experiences during the second term will also involve means of extending the students' senses, i.e., instrumentation and tools for observation and measurement.

Bioengineering 596, Special Project: Science Projects for the Utah Science Center:

C. Subject Area Majors:

Not applicable.

D. Student Research:

Not applicable.

E. Research on Humans and Animals:

Not applicable.