THE UNIVERSITY OF UTAH

February 20, 1991

Dr. Gerhardt Salinger
National Science Foundation
Materials Development, Research
and Informal Science Education
Room 635
1800 G. Street, N.W.
Washington, D.C. 20050

Dear Dr. Salinger:

We are pleased to submit a pre-proposal, Night-Life: Enhancement of Science Education Via Bioluminescence, to the Materials Development Program of the Directorate for Science and Engineering Education.

This proposal has been under development for approximately one year as a joint collaboration between the Department of Educational Studies and the Department of Bioengineering at the University of Utah. We are working closely with the Salt Lake City School District and the State Office of Education, as well as with local industry.

We hope that you, your colleagues, and your advisors find this project responsive and appropriate to the Materials Development Program. We look forward to your critique and to the possibility of submitting a more formal proposal for your May 15 deadline.

Please let us know if you need any further information.

Sincerely,

Trish Stoddart

T. Stoddart, Assistant Professor
Educational Studies

J.D. Andrade, Professor
Bioengineering

mm/f17

cc: C. Blankenship, Dean, Graduate School of Education
D. Pershing, Dean, College of Engineering

Department of Bioengineering
2480 Merrill Engineering Building
Salt Lake City, Utah 84112
(801) 581-8528
FAX: 801-581-8692

Preliminary Proposal

NIGHT-LIFE:
Enhancement of Science Education Via Bioluminescence

We propose to develop, test, and disseminate NIGHT-LIFE, integrated science "discovery" materials based on bioluminescence -- light generated by living systems.

Nearly everyone who discovers and observes bioluminescence is impressed and motivated to see and learn more. In these times where children have their senses constantly stimulated to near exhaustion, bioluminescence is a relatively unknown, unexperienced phenomenon which can readily compete for a student's attention and interest.

The project will develop science materials which will be used for student-centered and parallel teacher education activities.

This curriculum will allow teachers to develop new scientific concepts, enhance their experience with the scientific method, and help provide a practical understanding of science via the observation of bioluminescence.*

Bioluminescence is a phenomenon which is largely unknown to students and teachers and almost totally excluded from all science curricula and textbooks, from kindergarten to undergraduate college.

The basic idea is to have the students *discover* something completely new -- and then participate in discussions that lead to the development of scientific reasoning and the formulation of questions, hypotheses, and experiments. Observation of living light leads immediately to a set of questions:

- Where does the light come from? (no batteries, bulbs, or wires),
- Why is the light blue? Can it be green? red?
- Why do you have to wet it?
- Why does the light go out? Can you make it come back?
- Why does it smell fishy?

Depending on the students' ages and backgrounds, they will discover their own answers and be led into various areas and aspects of science.The teacher and the materials serve as resources to *aid* their discoveries and education.

Depending on the observations and the questions, students and teachers can probe into biology, chemistry, physics, mathematics, geology, and environmental sciences (Figure 1). The approach is to teach by discovery and observation -- and let the students go where their interests take them. As long as the student remains motivated and in a discovery mood, he/she will learn science. Our goal is simply to help guide -- to help them discover that science is integrated -- is a

* The attached packet will illustrate. Take the little packet with the brown fishy powder (the blue/red material is a drying agent) with you into a dark room. A bathroom or closet with the door closed and lights out will suffice. Wait a few seconds for your eyes to adapt to the dark. Then wet your finger with a little tap water -- touch your wet finger to the powder. Observe, play, and discover!

(1) NSF - NIGHT LIFE 5/91

CEP 91-...

No. of Proposal Copies to:
AGENCY 15 + 3 cover p.
OSP 2

P.I.D. No.: ______ (For OSP use only)

OFFICIAL DOCUMENT SUMMARY SHEET

FOR PROCESSING OF PROPOSALS TO OFFICE OF SPONSORED PROJECTS

SECTION I *(To be completed by the Principal Investigator or Originating Department/Office)* (SEE REVERSE SIDE).

PROJECT DETAILS (Check one)	(Check one)	(Check one)	Name of AGENCY where Proposal is to be submitted:
[X] Grant [ ] Contract [ ] Clinical Test [ ] Other Agreement	[X] Research Fed [ ] Research Non-Fed [ ] Inst. Serv Fed [ ] Inst. Serv Non-Fed [ ] Public Serv Fed [ ] Public Serv Non-Fed [ ] Other	[X] New [ ] Renewal [ ] Continuation [ ] Revised [ ] Supplemental	National Science Foundation Street Address (Bldg., Name/no. & Room No. required when hand delivered): Data Support Services, Room 223 1800 G Street, N.W. Washington, D.C. 20550 City / State / Zip Code / Phone No.
Deadline Date ► 5/15/91 [ ] Postmark [X] Due at Agency [ ] Special Courier	Account no. to be charged		Attention: Person to whom addressed: (Room 635) G. Salinger, Science & Engineering Educ.

TITLE AND NARRATIVE DESCRIPTION *(Indicate how project will aid academic program of University)*

NIGHT-LIFE: Integrated Science Education Materials Based on Bioluminescence.
This is a multidisciplinary activity involving faculty in the Dept. of Educ. Studies (Coll. of Educ.) and the Dept. of Bioengineering (Coll. of Engr.). The program will support much needed activities in the enhancement of science education in the public schools. Faculty, staff, and student support are budgeted. A company in which the University has an equity holding, Protein Solutions, Inc., is also directly involved.

Principal Investigator [ ] Will [X] Will not be on extended leave of absence during the project.
[X] Has [ ] Has no potential conflict of interest with private company or investment group. J. Andrade is pres. of Protein Solutions, Inc. (PSI)

Health and/or Safety reviews required? (See reverse side) [ ] Yes [X] No Committee/Board Approval This grant is covered by

Indirect Cost Waiver requested? (See reverse side) [ ] Yes [X] No Waiver Approved: V.P. for research or designee the Technology Transfer agreement betwe the U. of Utah Protein Solutic Inc.

AGENCY FUNDS (fill in dates and amounts)	Immediate Period	Total Period
DATES	From 9/1/91 to 8/30/91	From 9/1/91 to 8/30/94
Direct Costs	70,220	214,184
Indirect Costs	32,117	100,970
Total Costs	102,337	315,154

UNIVERSITY FUNDS
[ ] Institutional Cost Sharing Agreement
[ ] Mandatory Cost Sharing/Matching
[X] Other type matching or contribution
[ ] Indirect cost subsidy
[ ] Cost Sharing shown for proposal review only.
If other than institutional cost-sharing attach cost-sharing data sheet

DEPARTMENT AND COLLEGE APPROVALS	We certify that staff, space, equipment, computer time, etc., are available and/or budgeted herein. If not, attach statement of additional requirements. Principal Investigator will submit the final technical report as required.	ORIGINATING DEPARTMENT/OFFICE Bioengineering	PHONE NO. (801)581-8528
		PRINCIPAL INVESTIGATOR J.D. Andrade	DIRECTOR of Technology Xfr Transmittal R. Brown
		DEPARTMENT CHAIRPERSON R. Normann	DEAN D. Pershing/ C. Blankenship

Dir: Center for Integrated Science Educ. (CISE)
J. Andrade

SECTION II *(To be completed by the Office of Sponsored Projects)*

ADDITIONAL REQUIREMENTS BY THE UNIVERSITY

Items of special or unusual significance (Remodeling, etc.)

Full Proposal

PROPOSAL OR APPLICATION REVIEW AND ROUTING

Reviewed by Sponsored Projects			

SECTION III *(To be completed when final contract or agreement is processed)*

Date contract received	Contract period of Performance	Contract Number	Amount
	19___ to ___ 19___		

I have reviewed this contract and recommend that it be accepted. To the best of my knowledge the requirements and terms set forth therein can be fulfilled in the time and under the conditions specified. I am aware of the Utah State laws governing the employment of relatives on such contracts.

coherent whole -- and that they can discover, appreciate, and understand it.

Our long range aim is simply to put together a fully integrated science teaching system based on bioluminescence. Students know that the physical and biological world are indeed interrelated. If we can build on their innate creativity and their natural observations and help them see how all phenomena are interrelated and coupled, then we think they will find their school experience, their teachers, and their studies far more credible and interesting.

We propose to develop, test, produce,apply, and disseminate science education materials using bioluminescence for grades 4-6.

We propose a 3 year collaborative interdisciplinary project involving the Department of Educational Studies in the Graduate School of Education, the Department of Bioengineering, the Salt Lake City School District, and Protein Solutions, Inc., a local company specializing in materials for science education.

The materials will aid in the observation, discovery, and in the learning of basic concepts in various science fields (Figure 1). Teachers and their students will develop new and expanded understandings of science concepts in a completely new domain -- bioluminescence. The concepts and understanding derived from bioluminescence are general and applicable to the full range of scientific and technical subjects.

We will develop and produce 3 different bioluminescent systems (each based on a different organism), develop preliminary materials and experiments, use these to assess student preconceptions and interest levels, and use them to assess teacher preconceptions and interest levels; we will then develop modified and enhanced materials.

An assessment plan will be included -- as well as a comprehensive plan for publication and dissemination.

Bioluminescence is a nearly ideal phenomenon with which to study the effectiveness of curricula on teacher motivation and education, as well as on student motivation and education.

Bioluminescence is not a completely understood phenomenon; much science in the field remains to be done. It is a living, breathing, developing field of science and not an old, established subject. Old, established subject areas tend to be treated didactically; bioluminescence cannot. Educationally and scientifically it must be treated in an observational and experimental manner.

Project Schedule (Figure 2):

In <u>year one</u> we will develop the assessment and interview methods, perform research and development on the various types and classes of bioluminescence and select and implement at least three basic discovery experiments. Given the assessment and interview methods and the discovery experiments, we will then initiate the student and teacher demonstrations and the interview and assessment process. All of this is to be completed in year one.

In <u>year two</u> the development of bioluminescence will continue in order to have available a more complete and appropriate understanding and a wider range of experiments and observations. Given the bioluminescent materials available at that point, and the responses from the interviews, we will then develop a preliminary curriculum model, and the materials to accompany it. This will be done in close collaboration with the Salt Lake and Davis School Districts. This would require much of the first part of year two. The curriculum model and materials will be available towards the latter part of year two, and will then be field tested in classrooms by expert science teachers and selected other members of the faculty and of the participating schools.

Given the results of the field testing and the initial model curriculum and materials, we will then initiate appropriate in service training for a selected group of interested teachers. This will be completed at the end of year two, or early in year three. The group of educated teachers will then introduce the bioluminescence materials to their particular classrooms.

Meanwhile, bioluminescence research and development will continue with better and more enhanced bioluminescent materials and modules being produced.

Towards the middle of <u>year three</u> there will then be a critical assessment of the model curriculum, of the materials, and of the results; and we will then modify and enhance the experiments and the materials.

The overall goal is, by the conclusion of year three, that a well tested, integrated science curriculum, based on bioluminescence, will be available. In addition, we will have learned a great deal about the fundamentals of teacher and student discovery and education in science.

We will publish and disseminate information about this project during the entire three year period. At the end of year three extensive publication and dissemination activities are planned.

Monitoring and Evaluation:

Two different Advisory Committees for this project are being formulated:.

A set of experts on bioluminescence will be asked to review and critique all of the materials produced to minimize any scientific inaccuracies or misinterpretations. They will be individually invited to campus to give seminars and lectures on their bioluminescence work and to observe and to assess the activities and developments in this project. We expect them to be active partners throughout the entire project.

A second group of experts, recognized and accomplished science educators, is also being assembled. These individuals will provide criticism and advice regarding the implementation and application of the bioluminescence modules to the student and teacher populations. They will also participate in critical assessment of the curriculum later in the project. At that point they will be augmented by another group, which has had no previous exposure to the project, to provide an objective critique and assessment.

Organization and Management:

This project is a cooperation between the Department of Bioengineering and the Department of Educational Studies at the University of Utah. Bioengineering is an inherently inter and multi disciplinary program, which merges all areas of science, engineering, and medicine. J. Andrade, Professor and Chairman of the Department of Bioengineering, will serve as co-principle investigator and will be largely responsible for the scientific and technical side of the project (the right side of Figure 2). He will directly supervise all of the bioluminescence research and development activities, the preparation of materials and experiments, and the scientific and technical evaluation of all written materials.

Dr. Tricia Stoddart, Assistant Professor of Educational Studies, is co-principle investigator and will be responsible for the educational studies aspect of the project (left side of Figure 2). She will supervise Dr. Rene Stofflet, a postdoctoral fellow with a strong science and science teaching background. Drs Stoddart and Stofflet will be responsible for all of the direct education and teaching aspects of the project.

Both groups will work closely together and will be responsible for the selection of topics and the design and development of experiments and materials (the central portion of Figure 2).

Utilization & Dissemination/Cooperative Relationships:

Presentations and progress reports on the NIGHT-LIFE bioluminescence curriculum will be presented at regular intervals to the annual conferences of the Utah Education Association, the Utah Science Teachers' Association, the National Science Teachers' Association, the International Conference on Bioluminescence and Chemiluminescence, and to other appropriate national and international meetings. We will strive to obtain input and advice from both the education and science communities.

During the first three years of this project the materials will be produced on campus. The scientific and technical materials will be produced in Dr. Andrade's laboratories. The curriculum will be made available to participating teachers in schools in Utah on a gratis basis with the costs covered by project budgets and resources.

In year three a small set of curricular materials will also be available to others who inquire and appear to have a strong interest in implementing the curriculum.

The bioluminescence concept for science education is being developed by Protein Solutions, Inc. (PSI), a small Utah company whose goal is to develop bioluminescence-based education products for children. PSI has provided the funding and motivation which led to the existing bioluminescence expertise in Dr. Andrade's laboratory.

The University of Utah and PSI have mutually agreed that PSI will produce, market and distribute the curriculum. At the conclusion of this NSF sponsored project, the company would subcontract with the

University to maintain, enhance, and expand the bioluminescence integrated science curriculum, NIGHT-LIFE.

We, therefore, have in place a mechanism to develop outstanding materials for science education and a means to distribute and disseminate the curriculum to the widest possible audience, thereby insuring its wide acceptance and implementation.

Budget:

We anticipate requesting a budget of about $250,000/year for three years. Direct costs would average about $175,000/year. About half of the total would be expended for bioluminescence technology and materials development. The other half would be used for curriculum development, testing, evaluation, teacher compensation, and dissemination costs. No other funds are available for this project.

Further Information, contact:

J.D. Andrade (801) 581-4379 office
(801) 277-1259 home

T. Stoddart (801) 581-7158 office
(801) 484-0768 home

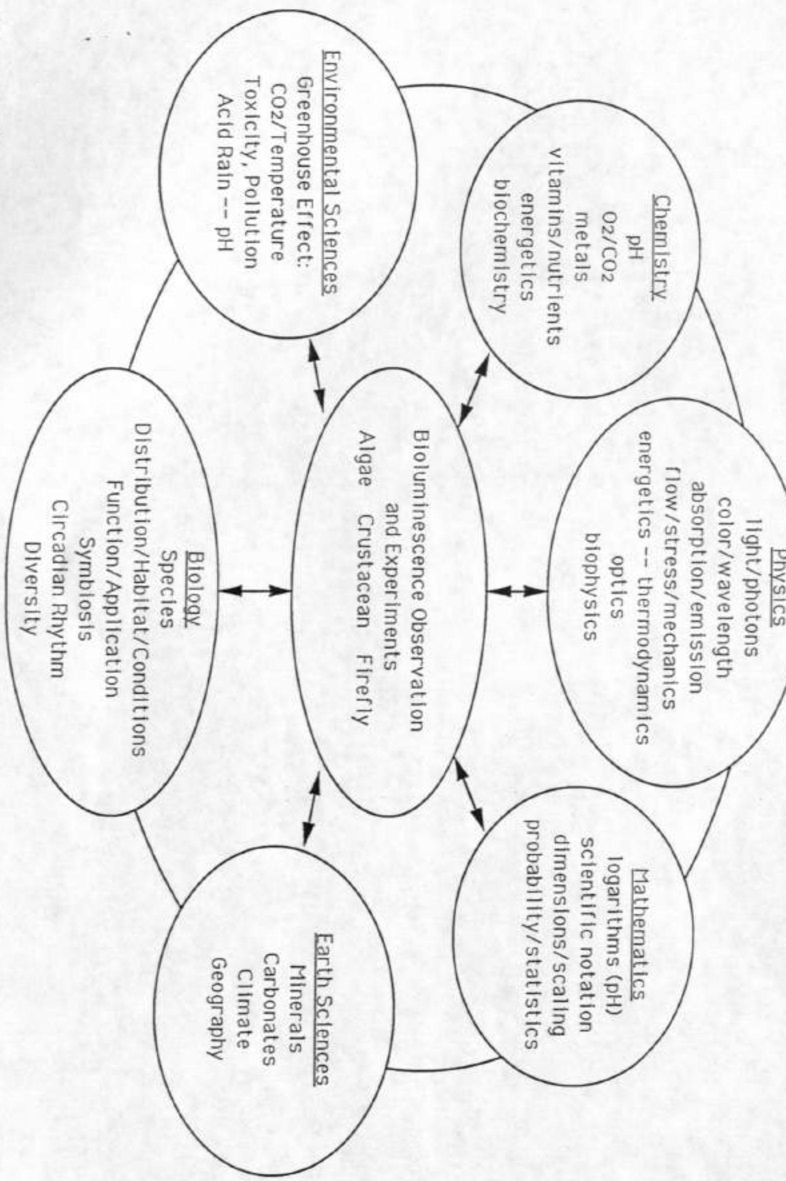


Figure 1: Bioluminescent organisms and their observation are shown as the center of an integrated science "wheel". Each of the classical specialties or disciplines are indicated with selected subject examples. These subjects and topics can all be directly observed and experimentally studied via bioluminescence.

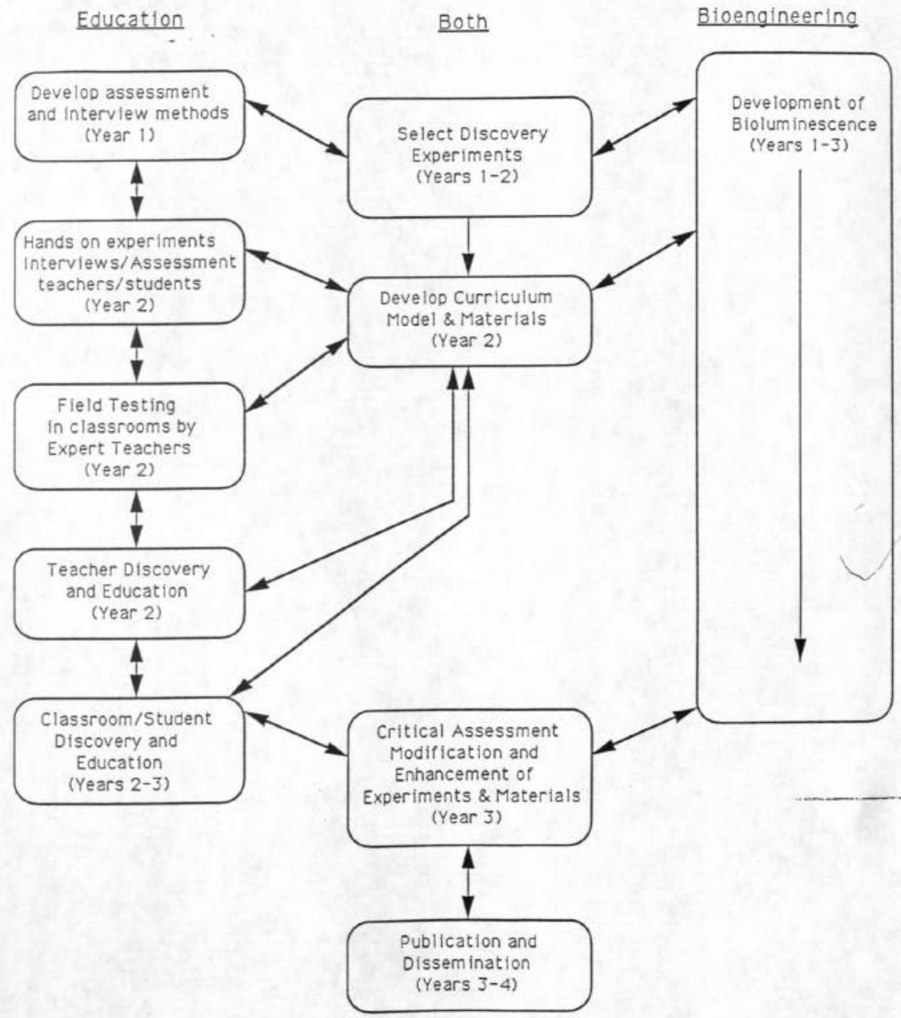


Figure 2. The major subprojects in this proposal.
The right side refers to the research and development aspects (headed by Andrade); the left side refers to student and teacher assessment and education (headed by Stoddart); both groups will be closely involved in the selection and development of experiments and materials (center). The double arrows (⟷) refer to the continual improvement of each subproject based on experience and input from the other. The duration of each subproject is indicated.

NATIONAL SCIENCE FOUNDATION

PROJECT SUMMARY

NSF AWARD NO.

FOR NSF USE ONLY

DIRECTORATE/DIVISION	PROGRAM OR SECTION	PROPOSAL NO.	F.Y.

NAME OF INSTITUTION (INCLUDE BRANCH/CAMPUS AND SCHOOL OR DIVISION)

University of Utah
Colleges of Engineering and Education
Depts. of Bioengineering and Educational Studies
2480 MEB
Salt Lake City, Utah 84112

ADDRESS (INCLUDE DEPARTMENT)

Department of Bioengineering
2480 MEB
University of Utah
Salt Lake City, Utah 84112

PRINCIPAL INVESTIGATOR(S)

J.D. Andrade/T. Stoddart

TITLE OF PROJECT

NIGHT-LIFE: Integrated Science Education Materials Based on Bioluminescence

TECHNICAL ABSTRACT (LIMIT TO 22 PICA OR 18 ELITE TYPEWRITTEN LINES)

We propose to develop, test, and disseminate NIGHT-LIFE, integrated science "discovery" materials based on bioluminescence -- light generated by living systems.

This project will develop integrated science materials which involve student-centered and parallel teacher education activities, allowing teachers to develop new scientific concepts, and a practical understanding of science via the observation of bioluminescence.

The project involves science and teacher education professionals and interdisciplinary scientists knowledgeable in bioluminescence. The project includes the developmnet of novel materials and curriculum aids for grades 4-6 and means for teacher motivation and education. There is also a cooperation with a local company which will scale up the production and dissemination of the materials. Teacher and student participants will be from local school districts and from Northern Illinois via a cooperation with R. Stoflett at Northern Illinois University.

Scientific discipline(s) involved: Biology/Chemistry/Physics/Life Science/Physical Science/ Environmental Science

Program(s) to which submitting: Materials Development

Instructional grade levels (within K-12) 4-6

Budget Justification:

Senior Personnel. The amount of work proposed is relatively large in comparison to the personnel cost budgeted. This is in part because the University's new Center for Integrated Science Education (CISE) will provide some resources to assist with the work needed on this project. Dr. Andrade is Director of CISE and Drs. Stoddart, Gess-Newsome, and Winters are all involved. There is a brief discussion of CISE on the next page.

In addition, Dr. Andrade will be on sabbatical leave for the 1991-'92 academic year and will be in residence at the University of Utah during most of that period, directing most of his activities to integrated science education, the conduct of this project, and the establishment of CISE (see letter on page after next).

A half-time technician is budgeted, whose activities will be mainly focused on the development of the bioluminescent materials, and part-time graduate and undergraduate students will work both on the technical aspects as well as the teacher and student assessment parts of the project.

We have estimated a 5% annual increase in salaries in the budgets for years two and three.

Equipment costs in the first year are for a CamCorder VCR to facilitate the teacher and student interview and assessment process. Incubators are to permit the large scale culture of the bioluminescent microalgae. The office computer will be used for all project related activities, including data storage, analysis, correspondence and related word processing, and the preparation of the educational materials and modules. As virtually all of the materials required for the teacher and student assessment and discovery parts of the project for the first three years will be provided by project funds, it is imperative that a highly efficient and productive mechanism of producing the organisms, related materials, and documents be in place.

The University of Utah is cost sharing on a one for two basis for the equipment items.

The $2,500 budgeted for travel in the first year, and increasing in years 2-3, are in large part for the information acquisition and dissemination activities, some of which are summarized in Table 3 in the proposal.

We feel it is imperative that the project professional staff be involved with most major professional meetings in which elementary and integrated science education topics are discussed and presented. The funds used for project related travel will actually be significantly greater than listed in the proposal as Dr. Gess-Newsome will use some faculty start-up funds; Drs. Andrade and Stoddart will also use funds available through CISE and Departmental and College sources.

Participant support costs are for teacher consultants. Local costs for such activities are $35 per teacher per half day. We expect to involve 10-15 teachers, and have at least five half day sessions per year.

Materials and supplies are budgeted at $7,500. Most of these funds are for the technical materials.

Publication page charges are budgeted to facilitate the dissemination process not only through professional meetings and visits, but through the normal professional journal literature.

Consultant services are budgeted; one third of that for Dr. Rene Stofflett, one of our collaborators, who will shortly be at Northern Illinois University, and will conduct portions of the project in that environment; two thirds of the consultant funds are for our education and technical advisors, listed in Table 2. We anticipate paying our consultants $500 per day for the days in which they are directly involved with project work. Many of these individuals will be invited to campus to give lectures and seminars in collaboration with the appropriate departments and with the Center for Integrated Science Education so the costs of their visits will be spread over these various areas. Thus the amount budgeted ($5,000) is less than the full costs.

Summary. We hope that it is clear that we have proposed a project which is extremely cost effective in terms of NSF funds and support. A budget for three years has been proposed; we anticipate requesting additional funds in year three to permit a continuation of the activities, and a broadening of the approach.

The Center for Integrated Science Education (CISE):

The University of Utah is now establishing a Center for Integrated Science Education (CISE), which would complement existing activities by developing materials and methods by which to teach science in a fully integrated, highly inter- and multi-disciplinary way.

J. Andrade, Director of CISE, argues that there is a revolution developing in science education, particularly at the elementary and high school levels, in that science must be taught as an integrated discipline, rather than in the highly piecemeal fashion of biology, chemistry, physics, and mathematics, which is now the norm. He and his co-workers feel strongly that the major problem with science education in the United States is that elementary school teachers, jr. high teachers, and even high school teachers either have a strong and fundamental fear and anxiety about science, or their science skills are in one of the classical disciplines, which therefore makes them unable, or ineffective, to teach science as an integrated subject, or even to relate their discipline to other disciplines and to the students' personal experiences.

The problem is in large part due to the way universities are organized, i.e. in *departments* of chemistry, physics, mathematics, biology, etc. The Center's fundamental argument is that science teachers must have an integrated and coherent view of science.

The Center's objectives are to develop courses, curricula materials, laboratory experiences, and a variety of inquiry and discovery -based modes with which to educate an entirely new generation of teachers, and with which to provide in-service and other education activities for existing teachers.

The Center will strive to involve all faculty who have a strong interest and motivation to improve and enhance science education, especially faculty in the College of Science, the School of Education, and the College of Engineering.

There are a large number of faculty who are outstanding science teachers and who have a genuine interest in improving science education. The Center will serve as a focus, a catalyst, a vehicle to integrate and encourage science education activities throughout the campus and the community. Science curriculum coordinators, science teachers, and elementary teachers

In addition, the Center has argued that there is a new industry evolving along these lines, now that the nation has indeed recognized that science teaching must be made integrated and made far more coherent. Project 2061 of the American Association for the Advancement of Science and other reports have argued for the need for a totally new approach to science and mathematics in our public schools.

THE UNIVERSITY OF UTAH

May 9, 1991

National Science Foundation
Directorate for Science and Engineering Education
1800 G Street, N.W.
Washington, D.C. 20550

Sir/Madam:

It is my pleasure to endorse the proposal, Night-Life: Integrated Science Education Materials Based On Bioluminescence, submitted to the Materials Development, Research, and Informal Science Education Program by Dr. Joe Andrade, Professor and Chairman of the Department of Bioengineering in our College.

Dr. Andrade is co-principle investigator with Dr. Trish Stoddart, Department of Educational Studies. Joe has strong interests and activities in the area of science education. In addition to his talents and experience at teaching science and engineering at the college level, he has had some experience in elementary science instruction at the fourth through sixth grade level, and helped work his way through graduate school in Denver by teaching high school general science, biology and chemistry. He is a dynamic inter- and multi-disciplinarian who feels that science should be taught as an integrated subject and who recognized that we must make science education more attractive and exciting if we are to attract sufficient students for the year 2000 and beyond.

Within the last several years he and his group have been researching bioluminescence and it has become clear that this is a phenomenon which can be effectively used to interest and motivate students, and through which an integrated science curriculum can be developed.

Although Joe is continuing to manage an active research program and is one of the most outstanding researchers in my College, he has chosen to devote an increasing percentage of his time to the area of integrated science education. I enthusiastically support his endeavor. The integration of biology, chemistry, physics, mathematics, and technology are really all part of the scope of our Department of Bioengineering, probably the most inter- and multi- disciplinary activity on our campus. The area of integrated education, in my opinion, easily falls within the scope of this Department.

I am pleased to confirm that the University and the College will provide a match to this N.S.F. application in the form of a significant proportion of Joe Andrade's time and effort. Joe is scheduled to be on sabbatical leave during the 1991-'92 academic year and will devote a major part of his time to the NIGHT-LIFE project

Sincerely,

David W. Pershing

D. Pershing, Dean
College of Engineering

mm/n7

College of Engineering
Office of the Dean
2202 Merrill Engineering Building
Salt Lake City, Utah 84112
Telephone (801) 581-6911
FAX (801) 581-8692

Project Description

Objectives:

We propose to develop, test, and disseminate NIGHT-LIFE, an integrated science "discovery" curriculum based on bioluminescence -- light generated by living systems.

Nearly everyone who discovers and observes bioluminescence is impressed and motivated to see and learn more. In these times where children have their senses constantly stimulated to near exhaustion, bioluminescence is a relatively unknown, unexperienced phenomenon which can readily compete for a student's attention and interest.

This project will develop integrated science materials which involve student-centered and parallel teacher education activities, allowing teachers to develop new scientific concepts and a practical understanding of science via the observation of bioluminescence.*

The basic idea is to have the students *discover* something completely new -- and then participate in group and classes discussions that lead to the development of scientific reasoning and the formulation of questions, hypotheses, and experiments. The teacher and the materials serve as resources to *aid* their discoveries and education.

The materials will aid in the observation, discovery, and learning of basic concepts in various science fields (Figure 1). Teachers and their students will develop new and expanded understandings of science concepts in a completely new domain -- bioluminescence. The concepts and understanding derived from bioluminescence are general and applicable to the full range of scientific and technical subjects.

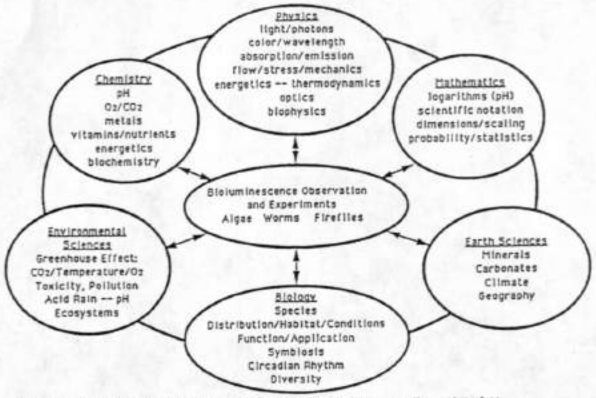


Figure 1: Bioluminescent organisms and their observation are shown as the center of an integrated science "wheel". Each of the classical specialties or disciplines are indicated with selected subject examples. These subjects and topics can all be directly observed and experimentally studied via bioluminescence.

* One of the many bioluminescent materials is in the attached packet. Take it with you into a dark room. A bathroom or closet with the door closed and lights out will suffice. Wait a few seconds for your eyes to adapt to the dark. Then wet your finger with a little tap water – touch your wet finger to the powder. Observe, play, and discover! Formulate questions, hypotheses, experiments!

The project involves science and teacher education professionals and interdisciplinary scientists knowledgeable in bioluminescence. The project includes the development of novel materials and curriculum aids for grades 4-6 *and* means for teacher motivation and education. There is also a cooperation with a local company which will scale up the production and dissemination of the materials. Teacher and student participants will be from the Salt Lake School District, the Davis School District, and Northern Illinois University (Table 1).

Table 1: Local Participants and Test & Dissemination Sites

Name:	Affiliations(s):	Location:	Functions:	Phone:
Andrade, JD, PhD	University of Utah, Center for Integrated Science Education (CISE), Dept of Bioengineering	2480 Merrill Engr Bldg University of Utah, Salt Lake City, Utah 84112	Principle-Investigator Project Director	(801) 581-4379
Stoddart, T, PhD	University of Utah, CISE and Dept of Educational Studies	307 Milton Bennion Hall University of Utah Salt Lake City, Utah 84112	Co-Principle Investigator	(801) 581-7158
Winters, S,PhD	University of Utah, CISE and Dept of Bioengineering	2480 Merrill Engr Bldg University of Utah, Salt Lake City, Utah 84112	Project Manager	(801) 581-4379
Stoiflett, R, PhD	Northern Illinois University, Asst Professor, (effective Fall, 1991)	Northern Illinois University School of Education De Kalb, Illinois 60115	Consultant & Co-Investigator	(801) 581-7158 (before 9/91)
Griffin, Bruce Allred, LaMar	Utah State Office of Education	Utah State Ofc of Education 250 East 500 South Salt Lake City, Utah 84111	Local Advisors	(801)538-7762 (801)538-7791
Steele, David Jensen, LaMont	Research & Evaluation Director Science Coordinator Davis County School District	Davis County School District 45 East State Farmington, Utah 84025	Local Advisors	(801)451-1129 (801)451-1108
Powell, Ken	Curriculum Director Salt Lake County School District	Salt Lake County School District 440 E 1st So, Suite 208 SLC, Utah 84111-1898	Local Advisor	(801)328-7297
Chamberlain, Von Del	Director, Hansen Planetarium; Task Force for a Utah Science Education Center	Hansen Planetarium 15 South State Salt Lake City, Utah 84111	Local Advisor	(801)538-2104 ext. 227
Morris, Richard	Director, The Children's Museum of Utah	The Children's Museum of Utah 840 North 300 West Salt Lake City, Utah 84103	Local Advisor	(801)328-3383

We will develop and produce four different bioluminescent systems (each based on a different organism), develop materials and experiments, use these to assess student preconceptions and interest levels, and use them to assess teacher preconceptions and interest levels. We will then develop modified and enhanced materials. A detailed assessment plan is proposed -- and a comprehensive plan for publication and dissemination. The various sub-projects and task outlines are given in Figure 2.

The "mapping" and relation of the NIGHT-LIFE curriculum supplements to the Utah State Curriculum, Grades 4-6, is given in Figure 3. We are examining other 4-6 curricula, including the Grades 6-8 recommendations of Scope, Sequence, and Coordination (SSC) Project of the National Science Teachers Association (NSTA) [24].

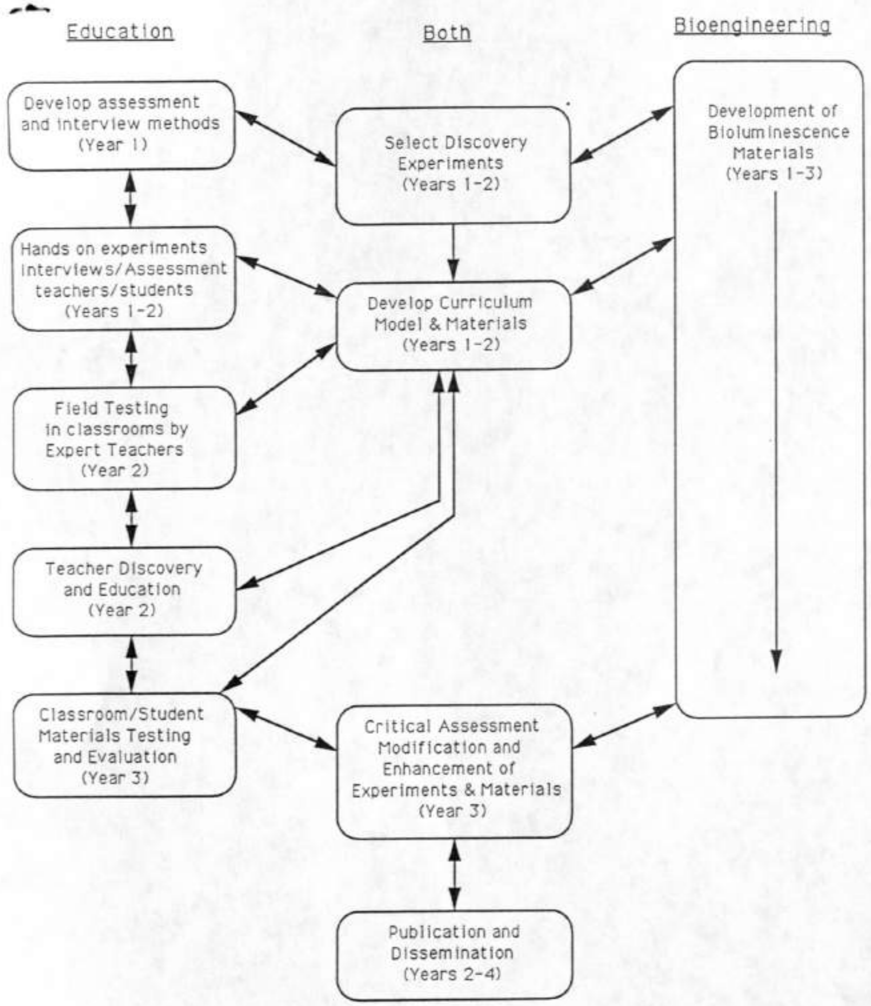
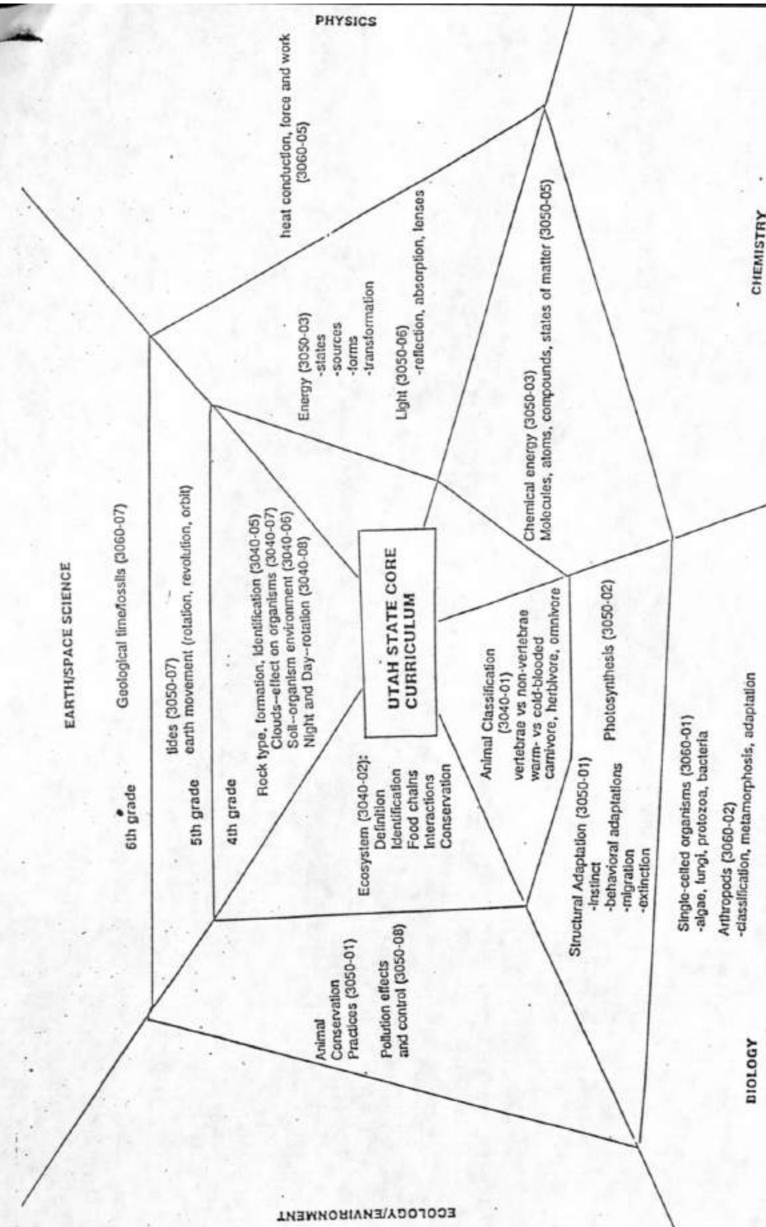


Figure 2. The major subprojects in this proposal.
The right side refers to the research and development aspects (headed by Andrade); the left side refers to student and teacher assessment and education (headed by Stoddart); both groups will be closely involved in the selection and development of experiments and materials (center). The double arrows (◄──►) refer to the continual improvement of each subproject based on experience and input from the other. The duration of each subproject is indicated.



Background and Rationale -- Bioluminescence:

Those who have observed and experienced bioluminescence generally never forget it. Fireflies on a dark summer night, glow worms or millipedes on a dark path, bioluminescent algae in a dark sheltered bay or on the surface of the sea, or the light emanating from disturbed marine crustaceans in tide pools on a dark night [1-6].

In our present age of intense artificial lighting, video games, and environmental problems, most of the population has not observed bioluminescence. When they first experience it they are generally amazed and almost awestruck -- it seems to be magic.

Bioluminescence is a relatively common and yet largely unknown phenomenon. It has developed and evolved many times. At least seven different independent systems are known and reasonably well characterized [4]. The major functions of bioluminescence are for sexual displays/mating and for predator aversion in the dark. Its only major commercial or economic application at present is as a label or detection aid in diagnostic and clinical chemistry laboratories.

We have been studying and working with bioluminescence for several years [7]. When we first discovered and observed it, we, too, became fascinated and "hooked." We have used every opportunity to demonstrate and explain the phenomenon to colleagues, co-workers, friends, family, and children. We have painted ourselves with it for the benefit of infants and preschoolers on dark nights, and we have demonstrated it at numerous dinners, cocktail parties and meetings, for its novelty and conversation enhancement characteristics. We have demonstrated and presented it to preschoolers and to high schoolers, to college undergrads and to engineering graduate students, always with the same effect: an intense interest, awe, and curiosity and a genuine desire to learn more.

Our long range aim is simply to develop and produce integrated science teaching materials based on bioluminescence. We are inter- and multi-disciplinarians with a strong belief that all of science and technology is closely interrelated. Society's problems are not mono-disciplinary, and there is no need for science to be taught in a separated mono-disciplinary fashion. Students know that the physical and biological worlds are indeed interrelated. If we can build on their innate creativity and their natural curiosity and help them see how all phenomena are interrelated and coupled, then we think they will find their school experience, their teachers, and their studies far more credible and interesting.

Depending on the observations and the questions, students and teachers can probe into biology, chemistry, physics, mathematics, earth sciences, and environmental sciences [Figure 1]. The approach is to teach by discovery and observation. As long as the student remains motivated and in a discovery mood, he/she will learn science. Our goal is simply to help guide -- to help them discover that science is integrated -- is a coherent whole -- and that they can discover, appreciate, and understand it.

A major advantage in employing bioluminescence is that it is new and interesting -- and that it is not yet fully understood. Thus students and their teachers will experience science as a living, growing, evolving field of inquiry. They will make observations and generate questions for which there are few "answers" -- thereby learning to understand and appreciate the continued growth and development of science.

Background and Rationale -- Education:

Throughout the past 35 years a series of curriculum reform movements have attempted to upgrade the teaching and learning of science in the public schools. Most of these projects have focused on the development and dissemination of innovative curricula and instructional methods for use in the public schools [8]. Such reforms have focused on the development of "hands on" inquiry-oriented instruction aiming to promote students' conceptual understandings through their active engagement and experimentation with scientific content[9]. Many of these science

education reforms, however, have been largely unsuccessful. High school students in the 1980's were less interested and less literate in science than ever before[10].

A main source of the problem is that the innovative curricula developed have not been effectively implemented in the public schools. Previous approaches to reform in science education focused on what students need to know but ignored the needs of the key players -- the teachers who prepare them. It is typically assumed that teachers, if provided with innovative curriculum and instructional methods, will be able to implement them [11]. This, however, has not proved to be the case; despite a substantial investment of time and resources, science teaching remains primarily didactic, dominated by lecture, demonstration, textbook readings and memorization [12,13]. This approach to teaching science does not engage student interest or develop conceptual understandings of subject matter. [14,15].

If new science curricula are to be effectively implemented, research and development projects must not only focus on the development of student conceptions, but also on the development of the teachers' knowledge and skills. An effective science curriculum, therefore, will involve the integration of subject matter knowledge with knowledge about the development of scientific conceptions in both students and teachers.

This project will develop integrated science materials which will involve both student-centered and parallel teacher education activities. The inter-disciplinary team includes a subject matter specialist, a science educator and a teacher educator. The project is based on six assumptions about student and teacher learning:

1. Learners construct understandings as a consequence of their experiences in the physical and social world.
2. Students' learning of the subject matter is the product of an interaction between what they bring to any learning situation and what they are taught.
3. Students' prior knowledge and beliefs powerfully affect the ways in which they make sense of new ideas. Such preconceptions may interfere with the acquisition of scientific information and concepts.
4. Learning involves a process of knowledge construction, reconstruction, and concept change.
5. Teachers are also learners. Their approaches to science instruction are influenced by preconceptions about science content and pedagogy developed through their own learning and teaching experience.
6. Development of a science curriculum must be based on knowledge about both the student and the teacher.

Bioluminescence was selected for three reasons:

1. The topic of bioluminescence is intrinsically interesting. Children and adults are awed by the dramatic light emission which they are unable to explain;
2. The topic involves concepts in biology, physics, chemistry, geology and the social sciences (Figure 1). Bioluminescence shows that science is integrated, not isolated subjects as portrayed in the typical science curriculum;
3. The topic of bioluminescence is relatively unknown by teachers. They have little or no prior knowledge of the subject.

Our materials will allow teachers to develop an understanding of important science concepts and science pedagogy within a novel domain. In service courses will provide valuable new science content knowledge, with the influence of prior knowledge being minimized. Teachers will feel less threatened about restructuring their views.

It will be important to point out to these teachers how this curriculum fits into their local curriculum. As an example, Figure 3 shows the Utah State 4-6 grade curriculum topics which are related to bioluminescence.

Our emphasis and focus is on the development of *materials*. The materials will permit inquiry and discovery-based activities for teachers and students. Concept and understanding assessment will take place before and after the bioluminescent discovery activities. Such teacher and student-derived information will be used to modify and enhance the materials, which will then be more widely tested and evaluated (see Figure 2).

Work Plans (refer to Figure 2):

Development of Bioluminescence - General:

We have been studying bioluminescence for about 2 years, supported by a small contract from a local company, Protein Solutions, Inc. (PSI). PSI is interested in developing bioluminescent-based education products and children's toys and novelties.

In this section we briefly discuss the bioluminescent organisms to be used and show the relationship between bioluminescence and common science disciplines (please refer to Figure 1).

We will concentrate on four organisms:

1) Bioluminescent algae or plankton. The phyto/photoplankton, responsible for bioluminescent bays and seas, are easy to grow and maintain. They are an ideal means by which to introduce the concepts of cells, cell division, photosynthesis, pH, acid-base, minerals, vitamins, growth rates, and doubling times.

Bioluminescence from these organisms can be mechanically stimulated by gentle agitation. Loud noises will also result in light emission. One of the initial discovery modules may involve students/teachers "talking" to the bioluminescent organisms! The sound waves can actually elicit light emission (are the creatures communicating?!)

Several of the organisms exhibit circadian rhythms --- their bioluminescence is 100 times more intense at night than in the day. Such observations will lead to discussion of biological rhythms and "clocks" (we will reset their "clocks" so they are bioluminescent during normal school hours).

We already have access to NIGHT-COLONY and NIGHT-LIFE, prototype science education toys using bioluminescent plankton[25,26].

2) Crustaceans of the vargula family are readily found in the Caribbean, the coasts of Florida, the southern coast of California, Japan, and other regions. These contain a totally different type of bioluminescence than the plankton. The biochemical system in these crustaceans is very stable and can be stored in dry powder form for indefinite periods. The packet of bioluminescent powder you experimented with on the first page of this proposal is a dry Japanese crustacean, vargula hilgendorfi, which was simply ground up and placed in the packet together with a little drying agent. This system will be used in powder and ink form and for its novelty and attention getting characteristics, as well as a teaching tool.

3) Fireflies. Bioluminescence is widely represented in the beetle families, including the North American firefly commonly seen in the eastern United States in the summer. Live fireflies are collected and maintained in Japan where they are sold and released once a year in a firefly festival, sort of a living biological version of fireworks. We have already talked with Japanese and

United States firefly experts and feel that is possible to accomplish the same in the United States. This is an important goal, because the motivational factor involved in the observation of flying light is even more impressive than swimming light. Fireflies are found in Utah and Colorado; we will obtain fireflies from the Utah Lake region, about 40 minutes from Salt Lake City.

The firefly bioluminescent system is unique in that it requires ATP (adenosine triphosphate), a major source of biochemical energy. Although ATP in this process is not used as an energy source, its involvement can be the key to a unit on energy in biology. ATP is biology's major chemical fuel and is usually the source of energy for the powering of muscles and other processes. In this case, firefly bioluminescence is used as an entree and serves as a vehicle to connect to and expand upon other very important topics.

4. Worms. There are many bioluminescence earthworms [16-18], particularly in the southern and semitropical regions. At least two species are found throughout most of the world. A terrestrial one goes by the scientific name Microscolex phosphoreus; a common marine worm lives at the high tide line and is called Pontodrilus bermudensis[18]. Both are readily collected and maintained and exude a bioluminescent fluid when disturbed or agitated.

Although most students and teachers are familiar with earthworms, few realize that many are bioluminescent. It takes a walk on a lawn or along the shore on a very dark night to spot them.

John Wampler, a professor at the University of Georgia, is a national expert on bioluminescent earthworms [16-18]. J. Andrade and J. Wampler discussed the use of bioluminescent earthworms on April 30, 1991 in Athens, Georgia. Dr. Wampler will advise and help us in the development and use of earthworms as NIGHT-LIFE educational materials.

We envision a transparent "WORMLAND" container for the terrestrial worm, a geometry similar to the popular Ant Farm educational toy. WORMLAND would be designed so the worms could be observed undisturbed in their natural state. Means to stimulate their bioluminescence would be provided.

Imagine the interest level and questioning rate of students observing bioluminescent worms in the dark!

Although many other bioluminescent systems are available, these four are the most interesting and stimulating, and through them we can represent a significant part of science (Figure 1).

Development of Bioluminescent Science Education Materials:

1. Microalgae (Year 1):

a) Complete development of self-contained cultures of the marine algae (dinoflagellates) pyrocystis lunula and p. noctiluca;
b) Map the acid and mechanical stimulation characteristics of these organisms;
c) Demonstrate the light-dark (circadian rhythm) cycles, and the acid, CO_2, and mechanical (flow, turbulence) dependence of their bioluminescence..

2. Vargula (Year 1):

a) Acquire quantities of vargula from No.Carolina Biological Supply (commercial) and J. Morin at UCLA (advisor);
b) Study and develop optimum means of powdering, storing, and reconstituting the material, including use of additional amounts of vargula luciferin;
c) Using available data and experience, map the locations and distribution of vargula worldwide and the conditions required for their existence and growth[5].

3. Fireflies (Years 2-3):

a) Using the experience and advice of John Buck, James Lloyd, Nobuyoshi Ohba, and N. Ugarova (see later section on Experts), map the locations and distribution of firefly bioluminescence;
b) Acquire firefly larvae, store and maintain them, and facilitate their development to fireflies[19];
c) Collect mature fireflies, dissect the firefly lanterns and demonstrate the extraction and concentration of the active products;
d) Study the temperature, salt, pH dependence of the bioluminescence. Demonstrate short flash versus long duration behavior and ATP and luciferin concentration aspects;
e) Working with Buck, Lloyd, Ohba, and Ugarova, culture and grow fireflies in captivity in order to develop an inexpensive source of material and to study the organisms' needs for growth and multiplication.

4. Earthworms (Year 2):

a) Work with Wampler and Jamieson to identify, collect, and maintain those bioluminescent earthworms which are the easiest to handle, probably pontodrilus bermudensis (a marine worm) and micro scolex phosphorous (a terrestrial worm) [16-18];
b) Select the brightest individuals which are readily stimulated to bioluminesce;
c) Study temperature, pH, light, and mechanical effects on their growth, maintenance, and bioluminescence;
3) Map the distribution of earthworms nationally and globally.
3) Work with fish bait suppliers to search and find other bioluminescent worms and environments (for example, a large worm used for fish bait in the South is the "Louisiana Pink," which is bioluminescent in its natural environment.

Relation to Traditional Disciplines:

Although our emphasis is on the 4-6 grade level, here we briefly show how bioluminescence is related to traditional disciplines at the secondary and undergraduate levels.

Chemistry is directly involved, as bioluminescence and chemiluminescence are due to oxidation processes in which an organic molecule in an excited state releases a photon. Through the coupling of chemistry and physics, primarily optics, one can directly show the existence and importance of atomic and molecular orbitals, and the nature of organic chemistry. By analogy, and by the use of filters, absorbance, flame emission, and ultraviolet or "black" light and fluorescent materials, we can develop the important physical concepts of absorbance, florescence, excited states, and energy levels. This will be done at the elementary level using analogies and metaphors based on everyday experiences.*

Acid base concepts will be brought in naturally through the acid stimulated release of the microalgae bioluminescence. The algae are plants and consume CO_2 by day which leads naturally to a discussion of CO_2 equilibria in water, and the $pH/pO_2/CO_2$ relationships in sea water and aqueous solutions. Such environmental concepts as acid rain and the greenhouse effect can be directly coupled as well.

Once the basic chemical concepts are developed, we can move on to a brief consideration of molecular machines --- proteins and enzymes, making the analogy with everyday machines with which they are familiar. The concept of size and scaling can be readily experienced [20,21]

* We will use bioluminescence, phosphorescence, and conventional light emission (light bulbs) to show the differences in these processes. Many children are familiar with phosphorescent toys and novelties (glow in the dark products).

Nearly all bioluminescence is catalyzed by a class of enzymes called luciferases. The concept of the enzyme as a biochemical catalyst is readily developed. The role of enzymes as chemical transformers, synthesizers, etc. can be developed. Various environmental topics, including toxins and pollutants can be easily presented through their effects on enzymes and other biochemical processes. They can be dramatically demonstrated by showing how enzyme inhibitors turn off and shut down bioluminescence in the organisms used.

We have already shown how physics can be closely coupled to chemistry in the previous section. In addition we can explore the various colors of bioluminescence and relate them to energy levels and excited states. We can go deeper into biology and talk about the design of the light emitting organelles and even organs in the various bioluminescent fishes, such as the flashlight fish in the sea. Although we cannot actively demonstrate and produce these various organisms at this time, we can use one or more of our four model bioluminescent systems to explain and show how such organs could be produced and, with the use of appropriate pictures and videotapes, show how biology has indeed accomplished it in real living systems.

A physics module would show and demonstrate how biology builds filters, reflectors, lenses and shutters in the photofishes and other organisms which inhabit the deep, dark sea. This discovery can be coupled back to biology by seeing that the light emitting sources in these fishes are much smaller organisms (bacteria) who are there as part of a symbiotic relationship.

Geology and metallurgy can be included in terms of the nutrient requirements for these organisms, particularly for the algae. They require small amounts of iron, copper, zinc, selenium, and other metals. We will use that as a means to talk about the weathering of minerals on the sea and on land and how minerals are delivered to the soil and to the sea. The bioluminescent algae are sea organisms -- leading to units on fresh versus salt water and related topics. We will actually use carbonate minerals as the means to deliver CO2 in quantity for the algal cultures. We will connect the carbonates and CO2 release to the concept of carbonated waters and the natural carbonation and pH control in both fresh waters and sea waters.

Environmental Sciences are also readily included. We have already mentioned how acid rain, the greenhouse effect, and toxic pollutants can be studied by observing their effects on living bioluminescent organisms. We will also consider pollution in marine bays and see how such pollution changes the nature and distribution of sea life We could also use bioluminescent bacteria (photobacteria), which are already used commercially as a toxicity test.

Although the emphasis in this project is science education, it can be easily connected with other subjects in the curriculum. One easy example is geography. We will of course present the international location and distribution of the various bioluminescent species used in the project. For example, in the case of the fireflies, we can talk about the Japanese firefly, the North American species, and the Asian species using the expertise and experience of Dr. J. Lloyd, Florida, Dr. Y. Hanada and Dr. K. Ohba, Japan, and Dr. N. Ugarova of the Soviet Union. This will relate not only to political geography, but also to environmental geography, that is, what are the conditions in these parts of the world which permit these organisms to live and multiply? The same is, of course, true for the plankton species and for the crustaceans.

One of the advantages of bioluminescence is that it is not a fully understood set of phenomena --- it is a constantly growing and evolving field. This gives the students and teachers the opportunity to experience science in action -- they can actively participate in the generation of truly new knowledge.

Relation to 4-6 Curricula and Content:

Figure 3 presented those portions of the 4th-6th grade Utah State Core Curriculum which can be addressed using bioluminescence-based materials and modules. The inner circle in Figure 3 represents 4th grade, the outer is 6th grade, and the middle contains 5th grade topics. The relation of those topics with traditional disciplines is also shown.

Since bioluminescence is light emission, via chemical processes, we will prepare a module based on living light, to be used in conjunction with one of the many excellent modules on light and energy [22]. The student will discover light without wires, bulbs, batteries, or heat. Why? He/she will examine the "solution." The light comes from discrete sources -- can we observe them? With a magnifier, the student discovers the dinoflagellates -- the microalgae. Is it producing the light? Where is its "flashlight"?

Now we are into biology. What is this creature? How does it live? Where? What is the light used for? Where does the light energy come from? What does the "animal" (actually, it's a plant) "eat"? How can it eat only air and water? What is photosynthesis?

The idea is to let the questions flow -- prompted mainly by inquiry and observations.

Our goal is to develop modules which address key parts of 4th-6th grade science content, including:

- Light & Energy
- Photosynthesis
- Atoms & Molecules
- O_2/CO_2/pH
- Night, Day, Tides, Rhythms
- Ecosystems and Biosphere
- Diversity
- Pollution & Ecology

We will analyze the major existing curricula and stay abreast of changes and improvements so that the materials developed are useful to the widest possible audience.

In the third year of the project we will initiate bioluminescence-based science fair projects and probably a journal/newsletter. The journal would encourage the students, parents, and teachers to submit their observations and analysis for review and possible publication. This would require additional funds and will probably be funded by Protein Solutions, Inc., a local company developing bioluminescence-based toys and educational products.

Curriculum:

The project will develop integrated science materials to teach key concepts in biology, chemistry, physics, earth science, and environmental sciences via bioluminescence for students and teachers at the 4th to 6th grade levels. In the first stage of the project interviews with students and teachers will be conducted to identify common perceptions held about the phenomena by both groups at the different grade levels.

The student-centered materials will include a series of modules which will involve the use of science centers, individual and group projects, using concrete activities that require observation, measurement, hierarchical classification, inference, space/time relationships and cause and effect.

The teacher education component will include a series of activities designed to enhance teachers' science content and pedagogical understandings[23].

In order to develop materials about bioluminescence for elementary teachers, it is necessary to determine what the teachers are currently using in their instructional practice, what their conceptions are about science content and effective science pedagogy, and what the teachers perceive as their needs (both for teacher-as-teacher and teacher-as-learner).

It is important to identify what teachers are currently using in their practice for several reasons:

1) if teachers are unable to make a connection between the curriculum materials and the curriculum they are most comfortable with (their own), they will likely disregard it;

2) if teachers do not already use hands-on science curriculum materials effectively, they will need to be trained to use the bioluminescence materials. Although in-service training will be provided, materials will also be developed so that self-training will be facilitated;

3) it will be important to identify the content teachers are teaching at various grade levels so that we can include information that will help teachers use the materials in an appropriate way. This identification process will be conducted through a document analysis of current lesson plans.

If teachers are to effectively use these curriculum materials in their classrooms, they need to have accurate scientific conceptions themselves. Once teachers' conceptual inadequacies are identified, then corresponding materials can be developed to assist teachers in learning the new content. Not only must the teachers have an understanding of the content, but they must also understand effective science pedagogy. To identify their conceptions of science content and pedagogy, clinical interviews will be conducted with the teachers who provided the lesson plans for the document analysis[23].

Teachers are more likely to accept a curriculum if they feel some ownership over it. A way to achieve this is to first determine what the elementary teachers' perceived needs are for their science teaching and then design the curriculum to meet those needs. Teachers express desires both as educators and as learners. Teachers give many reasons for not teaching science: lack of content preparation, cost of laboratory supplies, lack of time, and lack of interest. Since elementary teachers frequently have very inadequate science knowledge, they frequently avoid teaching science altogether. Our materials will help meet teacher' science teaching needs, thus they will more likely use the materials.

<u>Subjects:</u> The subjects for this study will be practicing elementary teachers in the Northern Illinois area and from several Utah school districts. These teachers will have at least two full years of teaching experience so that their ideas about science teaching have had a chance to develop. The teachers will also have been teaching science on a regular basis during the last two years. The teachers will be selected from a variety of locations in order to balance the curriculum for widespread use. One teacher from each grade level (4th, 5th & 6th) will be selected from each school.

<u>Document Analysis:</u> The participating teachers will be asked to supply lesson plans and materials they have used over the past two years in their science programs. We will request lesson plans that correspond to the core curriculum objectives for the teachers' particular grade level. These lesson plans will be analyzed for content, instructional methods, and types of evaluation. Comparisons will be made between the teachers at the same grade level so that trends can be identified. The results will be used to determine the general structure of the curriculum currently being used by these teachers, along with the pedagogical practices most commonly used. This will help define the type of teacher support that is needed to accompany the materials.

<u>Clinical Interviews:</u> Each teacher will be interviewed in three parts: interview-about-events (bioluminescence content), pedagogical conception interview (including perceived needs), and interview-about-documents[23]. These interviews will help us determine potential problems in teachers' content and pedagogical knowledge and their perceived needs for enhanced science teaching. This will aid in the development of our teacher support materials.

Discovery Experiments (see Figure 2):.

Four different initial discovery experiments will be developed: dry powder, algae "communication", fireflies, and worms.

The dry powder experiment will be an enhanced version of what the reader has already experienced (the packet at the beginning of this proposal). The experiment will lead to an array of questions, such as:

- Where does the light come from? (no batteries, bulbs, or wires),
- Why is the light blue? Can it be green? red?
- Why do you have to wet it?
- Why does the light go out? Can you make it come back?
- Why does it smell fishy?

The algae communication experiment was mentioned briefly earlier. A concentrated suspension culture of pyrocystis lunula will be observed in the dark.* The lead student will then "communicate" with the organism by talking or singing. After some question and discussion as to how and why the organisms are "responding", the student will then lightly tap the container, resulting in a bright flash. More questions and discussion. Then the student will gently swirl and agitate the suspension -- resulting in more light.

The firefly experiment will be available in year two. We expect to develop a module using live, captive fireflies and induce them to luminesce in response to a short light flash (from a small flashlight). Their flashes can lead to many questions:

- Why does it flash?
- Can it see the first flash? How?
- Where does the bioluminescence come from?
- Can a dead firefly flash?
- Why is it yellow? (the other examples were blue).

The worm experiment is also scheduled for year two. A flat transparent container with 10-25 worms will be observed, darkened, stimulated, and re-observed.

- Is that a blue liquid?
- Where did it come from?
- Why does the worm release it?
- Does it help him to crawl in the dirt?
- Why does he crawl away from his own light?

The responses to these discovery experiments by both teachers and students will aid us in the development of effective bioluminescence materials and experiments with enhanced inquiry and content characteristics (Figure 2).

The elementary student curriculum models will involve the use of science centers, but the teacher will serve as a discussion leader to develop the purpose of the centers before students use them, to probe student thinking while they are working at the centers, and to lead student discussions in the desired direction following the discovery activity. These centers and discussions will follow the guided discovery approach recommended by several science educators.

We also expect to develop materials which are appropriate for home experiments, to facilitate the involvement of parents and family in the inquiry and discovery science learning

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* We anticipate a science center containing an inexpensive cardboard dark box so individual students can perform these experiments in a well-lighted classroom. The box would have individual hooded observation ports for a small group of students.

process. One of the problems with many students is that the home environment is not particularly supportive of academic activities. Small, very inexpensive modules and materials for the home environment will allow the student to share what he has discovered and learned in the classroom with family at home, encouraging parent involvement in the student's learning and discovery processes.

The home experiments and demonstrations will be of minimum cost and complexity and will be designed for less than ideal home environments. We frankly feel that the parents will be as equally impressed and excited about the observation of bioluminescence as are their children.

The teachers in our initial discovery, assessment, and development activities will serve to test and evaluate the materials produced. They will then use the materials "solo" in their classrooms, followed by student assessment and critique, which will lead to even more enhanced materials (Figure 2).

Project participants and teacher "experts" will then provide workshop and inservice training for additional teachers.

Initially, the materials will be provided by the project. As the modules and become fully developed and ready for more wide-spread application, they will be produced by a local company, Protein Solutions, Inc., and made available as inexpensively as possible.

Experts and Advisors (Table 2):

We have assembled a group of scientific experts to function as advisors and critics to ensure that the materials we develop are as scientifically accurate as possible:

W.G. (Woody) Hastings, Professor of Biology, Harvard University, is internationally recognized for his work on bacteria and dinoflagellate bioluminescence[4]. He and his co-workers have worked out the basic chemistry of dinoflagellate bioluminescence. He has applied these systems for the study of biological circadian rhythms, and is published widely on the subject. His laboratory and work were recently featured in the Public Broadcasting System program, "The Infinite Voyage" in the recently aired segment dealing with biological rhythms, "The Living Clock."

James Morin is Professor of Biology at UCLA in Los Angeles. Dr. Morin is an expert on the small bioluminescent crustaceans, vargula, formerly called cypridina. One of the Japanese vargula organisms constitutes the powder which you experienced on the first page of this proposal. Professor Morin has discovered and categorized some 50 new species of these organisms in the Caribbean and the Gulf of Mexico, and has observed that one of the major functions of bioluminescence is for sexual mating displays. His recent, plenary lecture at the 6th International Conference on Bio and Chemiluminescence, "Shedding Light on Shedding Light", included dramatic videotapes of vargula's underwater luminescent activities.

William McElroy is Professor Emeritus and Chancellor Emeritus of the University of California at San Diego (USCD). He is also a former Director of the National Science Foundation. He pioneered bioluminescent studies in the United States and worked out the biochemistry of firefly bioluminescence. His students and post docs have gone on to form and develop a significant portion of the bioluminescence field.

John Buck, National Institute of Health, Bethesda, Maryland, is well known for his work on fireflies. He has worked with fireflies since the mid 1930's.

James Lloyd, University of Florida, Gainesville, is responsible for the most complete and thorough study of firefly species in the United States.

Yata Haneda, Yokosuka, Japan is Director Emeritus of the Yokosuka City Museum and has been involved with bioluminescence in the Pacific for his entire life. As Director of the Yokosuka City Museum, he established a comprehensive exhibit on bioluminescence which is unique in the world. Although over 80 years old, he is in good health and is probably the single most knowledgeable individual today on the bioluminescent organisms in the Pacific. The exhibitions in his museum are a major resource in expanding and enhancing the biology component of this proposal. Nobuyoshi Ohba is an expert on Japanese fireflies and now works at the Yokosuka City Museum. (J. Andrade visited Drs. Haneda and Ohba in Yokosuka in May, 1990.)

Keith Wood, a former student of Marlene DeLuca and W. McElroy at UCSD, is now with The Promega Company in Madison, Wisconsin. Dr. Wood is internationally recognized for his work on firefly luciferase and particularly the cloning of the gene and its expression in bacteria. He has produced at least four different luciferases by this method, which produce four different colors of bioluminescent emission. He has a particular interest in the educational potential of these materials, particularly for the teaching of genetic engineering and molecular biology using recombinant DNA techniques. Indeed, he has already developed a teaching kit, using these materials, for possible use in college molecular biology and genetics courses.

J. Wampler is with the University of Georgia and is an expert on bioluminescent worms.

N. Ugarova is the world's expert on the Russian firefly and has studied the mechanism of firefly bioluminescence.

Over the past two years, J. Andrade has personally met and talked with each of these individuals except Lloyd and Buck. Andrade has talked with Lloyd extensively by phone and has corresponded with Buck. Meetings are planned in the near future.

There are many other individuals who are expert and active in various phases of bioluminescence. Those listed above comprehensively represent the field. We will, of course, seek the advice and counsel of all with expertise and interests appropriate to this project.

Our education/curriculum consultants include Lawrence Lowery, Lawrence Hall of Science, Berkeley, Allan Voelker (Northern Illinois University), and Dale Baker (Arizona State University).

Dr. Dale Baker is Chair of the Department of Curriculum and Instruction at Arizona State University. She is an expert on student attitudes towards science learning, gender differences in science achievement, and the relationship between instruction and student performance in science. In 1989, she was the recipient of the "Outstanding Research Award for Practical Application in Science" from the National Association of Research in Science Teaching (NARST) and in 1988 received the NARST award for the best publication in science education.

Dr. Lawrence Lowery, Professor of Science Education in the Department of Mathematics, Science and Technology in the Graduate School of Education, University of California, Berkeley, is Director of the Educational Research and Applications Teacher Credential Program and a Senior Researcher at the Lawrence Hall of Science. Dr. Lowery is an expert in the development of children's scientific concepts and the design of science curriculum and instructional methods. He is principle investigator of Full Option Science System (FOSS), EQUALS in Technology, Science, Education for Rural California (SIRC) and Family Math. He is Co-PI on the bay Area Math Project. He has received many awards including "Science Educator of the Year" in 1989 from the Association of Educators of Teachers of Science (AETS) and the "National Exemplary Project, Science Instruction for Rural California" in 1987 from the U.S. Department of Education.

Dr. Alan Voelker is Professor of Science Education and Chair of the Department of Curriculum and Instruction at Northern Illinois University. His area of expertise is in the development of science curriculum and materials and the relationship between mathematics and science education and industry. He is currently Principal Investigator on the Scientific Literacy Project for the Illinois State Board of Education, which focuses on developing a K through 12 science and mathematics curriculum linked to the needs of business and industry and a Needs Assessment Study for the Museum of Science and Industry in Chicago. He has been involved in

several large national studies including the National Public Affairs Study and the Longitudinal Study of American Youth.

Table 2: National Advisory Committees

Topic A: Elementary Science Education

Lowery, L.	Lawrence Hall of Science, Berkeley
Voelker, A.	Northern Illinois University
Baker, D.	Arizona State University

Topic B: Bioluminescence -- Science & Technology

Hastings, W.G.	Dept of Biology, Harvard Univ., Cambridge MA (bacteria, dinoflagellates)
Morin, J.	Dept of biology, UCLA, Gos Angeles, CA (crustaceans, fish)
Buck, J.	National Institute of Health, Bethesda, MD (fireflies)
Lloyd, J.	Dept of Biology, University of Florida, Gainseville, FL (fireflies)
Wampler, J.	Dept of Biochemistry, University of Georgia, Athens, GA (earthworms)
McElroy, W.	(retired), La Jolla, California (fireflies)
Wood, K.	Promega Corp., Madison, Wisconsin (genetic engineering)
Haneda, Y.	(retired), Yokosuka, Japan (all organisms)
Ugarova, N.	Dept of Biochemistry, Lomonosov State University, Moscow (fireflies)
Ohba, K.	Yokosuka City Museum, Japan (fireflies)

Project Schedule (Figure 2):

In year one we will develop the assessment and interview methods, perform research and development on the various types and classes of bioluminescence, and select and implement two basic discovery experiments. Given the assessment and interview methods and the discovery experiments, we will then initiate the student and teacher demonstrations and the interview and assessment process. All of this is to be completed in year one.

In year two the development of bioluminescence will continue (with emphasis on the worms and fireflies) in order to have available a more complete and appropriate understanding and a wider range of experiments and observations. Given the bioluminescent materials available at that point, and the responses from the interviews, we will then develop preliminary materials. This will be done in close collaboration with local school districts and with our collaborator at No. Illinois University, R. Stofflett.

These activities will require much of the first part of year two. The curriculum model and materials will be available towards the latter part of year two, and will then be field tested in classrooms by expert science teachers and selected other members of the faculty and of the participating schools.

Given the results of the field testing and the initial model curriculum and materials, we will then initiate appropriate in service training for a selected group of interested teachers. This will be completed at the end of year two, or early in year three. The group of educated teachers will then introduce the bioluminescence materials to their particular classrooms.

Meanwhile, bioluminescence research and development will continue with better and more enhanced bioluminescent materials and modules being produced.

Towards the middle of year three there will be a critical assessment of the model curriculum, of the materials, and of the results; and we will then modify and enhance the experiments and the materials.

The overall goal is, by the conclusion of year three, that a well tested, integrated partial curriculum, based on bioluminescence, will be available. In addition, we will have learned a great deal about the fundamentals of teacher and student discovery and education in science.

We will publish and disseminate information about this project during the entire three year period (Table 3). At the end of year three even more extensive publication and dissemination activities are planned.

Monitoring and Evaluation

Two different Advisory Committees are being formed (Table 2). See earlier section on Experts and Advisors.

A set of experts on bioluminescence will be asked to review and critique all of the materials produced to minimize any scientific inaccuracies or misinterpretations. Several will be individually invited to campus to give seminars and lectures on their bioluminescence work and to observe and to assess the activities and developments in this project. We expect them to be active partners throughout the entire project.

A second group of experts, consisting of recognized and accomplished science educators, is also being assembled. These individuals will provide criticism and advice regarding the implementation and application of the bioluminescence modules to the student and teacher populations. They will also participate in critical assessment of the curriculum later in the project.

Organization and Management

This project is a cooperation between the Department of Bioengineering and the Department of Educational Studies at the University of Utah. Bioengineering is an inherently inter and multi disciplinary program, which merges all areas of science, engineering, and medicine. J. Andrade, Professor of Bioengineering, will serve as Principle Investigator and will be responsible for the scientific and technical side of the project (the right side of Figure 2). He will directly supervise all of the bioluminescence research and development activities, the preparation of materials and experiments, and the scientific and technical evaluation of all written materials.

Dr. Trish Stoddart, Assistant Professor of Educational Studies, is Co-Principle Investigator and will be responsible for the educational studies aspect of the project (left side of Figure 2). She will work with Rene Stofflett, who will be at No. Illinois University. Both have a strong science and science teaching background. Drs Stoddart and Stofflett will be responsible for all of the direct education and teaching aspects of the project. Dr. Gess-Newsome will assist Dr. Stoddart. Dr. Suzanne Winters will manage the technical aspects of materials development and will work closely with Drs. Stoddart and Stofflett in developing suitable materials and modules.

Both groups will work closely together and will be responsible for the selection of topics and the design and development of experiments and materials (the central portion of Figure 2).

Utilization & Dissemination (Table 3)

Presentations and progress reports on the NIGHT-LIFE bioluminescence curriculum will be presented at regular intervals to the annual conferences of appropriate professional societies, including the Utah Education Association, the Utah Science Teachers' Association, the National Science Teachers' Association, the International Conference on Bioluminescence and Chemiluminescence, and to other appropriate national and international meetings. We will strive to obtain input and advice from both the education and science communities.

Table 3: Dissemination Activities 1991-'92

National:	
American Association for the Advancement of Science	Andrade
American Education Research Association	Stoddart
Northern Illinois University, Colleges of Education & Science	Stofflett
National Association for Research in Science Teaching	Stofflett
National Science Teachers Association	Andrade
Local:	
Center for Integrated Science Education (CISE)	Andrade
Colleges & Schools of Education (University of Utah, Utah State University, Brigham Young University, Weber State University)	Stoddart
Utah Association of Supervisors & Curriculum Development	Winters
Utah Education Association	Andrade
Utah Science Teachers Association	Winters
Utah Teacher Education Association	Stoddart
Inservice Courses:	All

Cooperative Relationships

During the first three years of this project the materials will be produced on campus. The scientific and technical materials will be produced in Dr. Andrade's laboratories. The curriculum will be made available to participating teachers in schools in Utah and in No. Illinois on a gratis basis with the costs covered by project budgets and resources.

In year three a small set of curricular materials will also be available to others who inquire and appear to have a strong interest in implementing the curriculum.

The bioluminescence concept for science education is being developed in partnership with Protein Solutions, Inc. (PSI), a small Utah company whose goal is to develop bioluminescence-based education products for children. PSI has provided the funding and motivation which led to the existing bioluminescence expertise in Dr. Andrade's laboratory.

The University of Utah and PSI have mutually agreed that PSI will produce, market and distribute the materials. At the conclusion of this NSF sponsored project, the company would subcontract with the University to maintain, enhance, and expand the bioluminescence integrated science curriculum, NIGHT-LIFE.

We, therefore, have in place a mechanism to develop outstanding materials for science education and a means to distribute and disseminate the curriculum to the widest possible audience, thereby insuring its wide acceptance and implementation.

References, Bibliography, and Notes:

1. National Geographic Magazine has had many articles and photos of bioluminescence:

   P.A.Zahl, "Nature's Night Lights," July, 1971, p.45.
   P.A.Zahl, "Fishing in the Whirlpool," Nov, 1973, p.579.
   D.L. Teimann, "Nature's Toy Train, The Railroad Worm," July, 1970, p.58.
   P.A. Zahl, "Fireflies," July, 1962, p.48.

2. Several major encyclopedias include articles on bioluminescence:

Encyclopedia Britannica
McGraw Hill Encyclopedia of Science and Technology

3. Popular science articles include:

K.H. Nealson and C. Arnesan, "Marine Bioluminescence: About to See the Light," *Oceanus 28*(3)(1985)13.
P. Huyghe, "Wheels of Light, Sea of Fire," *Oceans*, Dec, 1987, p.21.
M. Root, "Glow-in-the-dark Biotechnology," *Biological Science 38* (11)(1988)745.
A.K. Campbell, "Living Light," *Trends in Biological Sci. 11* (1986)104.
A.P. Neary and C.S.J. Walpole, "Bioluminescence-Chemical Light," *Science Progress 70*(1986)145.
P.J. Herring, "How to Survive in the Dark: Bioluminescence in the Deep Sea," in M.S. Laverack, ed., *Physiologic Adaptation of Marine Animals*, Soc. of Experimental Biology of Great Britain, *39*(1985)323-351.

4. J.W. Hastings, "Biological Diversity, Chemical Mechanisms, and the Evolutionary Origins of Bioluminescent Systems," *J. Molecular Evolution 19*(1983)309.

5. Although bioluminescence is largely unknown in the K-12 and college curricula, there is an extensive scientific literature:

E.N. Harvey, *Bioluminescence*, Academic Press, 1952.
A.K. Campbell, *Chemiluminescence*, VCH Publ.,1988
F.H. Johnson and Y. Haneda, *Bioluminescence in Progress*, Princeton Univ. Press, 1966.
P.J. Herring, *Bioluminescence in Action*, Academic Press, 1978.
P.J. Herring, A.K. Campbell, M. Whitfield, and L. Maddock, *Light and Life in the Sea*, Cambridge University Press, 1990.

Much of the current scientific information is being published in the *Journal of Bioluminescence and Chemiluminescence*, John Wiley and Sons.

6. There is a limited discussion of bioluminescence in science and nature books for children. the most complete is:

A. and U. Silverstein, *Nature's Living Light*, Little, Brown, & Co., 1988.

7. Our interest in bioluminescence began in 1985 when J. Andrade became interested in the subject and began doing some simple "discovery" experiments. Work began in earnest in the Fall of 1987. Protein Solution, Inc. (PSI) was established in early 1988 with the goal of developing bioluminescence for the children's education and toy markets. PSI has been funding bioluminescence work in Andrade's lab for nearly 3 years (about $60,000 total to date). It was already clear in 1987 that bioluminescence was a real attention getter and motivator of children and adults. Andrade's wife, Barbara, is a first grade teacher. Together they developed several demonstrations and experiments. The phenomena were presented to Dr. T. Stoddart and R. Stofflett in the Department of Educational Studies. Science curriculum specialists in the State Office of Education, several local school districts, and local educators and students were all excited (Table 2). It was decided that there was sufficient interest and commitment among all involved to prepare a proposal to NSF in order to develop integrated science discovery materials based on bioluminescence.

8. H. Smith, A report on the implications for the science community of three NSF-supported studies of the state of precollege science education. In National Science Foundation,

What are the needs in Precollege Science, Mathematic, and Social Science Education? Views from the Field. Washington, DC: Government Printing Office, 1979.

9. J. Zacharias & S. White, The requirements for major curriculum revision, *New Curricula*, New York: Harper & Row, 1964.

10. The National Commission on Excellence in Education, *A Nation At Risk*, Washington, DC: Government Printing Office, 1983.

11. L. Shulman, "Those who understand: Knowledge growth in teaching," *Educational Researcher, 15* (2), (1986), pp. 4-14.

12. J. Renner, M. Abraham, E. Grzybowski, & E. Marek, "Understandings and misunderstandings of eighth graders of four physics concepts found in textbooks," *Journal of Research in Science Teaching, 27* (1), (1990), pp.35-54.

13. R. Biddulph, *Primary Science: the views of teachers and pupils*, LISP Working Paper no. 102, 1982.

14. R. Driver, *The Pupil As Scientist?*, Milton Keynes: Open University Press, 1983.

15. M.G. Hewson & P.W. Hewson, "Effect of Instruction Using Students' Prior Knowledge and Conceptual Change Strategies on Science Learning," *Journal of Research in Science Teaching, 20* (8), 1983, pp.731-743.

16. J.E. Wampler & B.G.M. Jamieson, "Earthworm Bioluminescence," *Comp. Biochem. Physiol.*, (1980), pp. 43-50.

17. J.E. Wampler, "Bioluminescence System of Microscolex Phosphoreus," *Ibid, 71A* (1982), pp. 599-604.

18. J.E. Wampler & B.G.M. Jamieson, "Cell Bound Bioluminescence From Pontodrilus Bermudensis," *Ibid, 84A* (1986), pp. 81-87.

19. J. Buck, "Fireflies," and "Rearing of Firefly Larvae," Internatl Report from NIH; personal communication with J. Andrade, March, 1991.

20. P. & P. Morrison, *Powers of Ten*, Scientific American Library, 1982.

21. T.A. McMahon & J.T. Bonner, *On Size and Life*, Scientific American Library, 1983.

22. National Sciences Resources Center, *Resources for Children*, National Academy Press, 1988.

23. R.T.S. Stofflett, "NIGHT-LIFE: The Development of an Instrument Assessing Teachers' Knowledge of Bioluminescence", paper for Bioengineering 695 -- Independent Study, April, 1991.

24. National Science Teachers Association, "The Content Core: Scope Sequence and Coordination," March, 1991.

25. J.D. Andrade, et at., "NIGHT-COLONY: A Science Discovery Tool," abstract, Pacific Division, Amer. Assoc. Adv. Science (AAAS), Logan, Utah, June 23-27, 1991.

26. Protein Solutions, Inc., "NIGHT-LIFE Owner's Manual," Draft; March, 1991.

CURRICULUM VITAE

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AREAS OF SPECIALIZATION:

Cognitive and social development
Teacher thinking
Teacher education
Educational Policy

I. EDUCATIONAL HISTORY

University

1987 Ph.D. University of California, Berkeley
Educational and Developmental Psychology

1969 M.A. University of Birmingham, England
Educational Psychology

1964 B.A. University of Leeds, England
Psychology

Awards and Fellowships

Outstanding Research Presentation Award. Annual Conference of the American Association of School Administrators, San Francisco, CA. 1986.

Edgar and Camilla Mophet Fellowship: UC Berkeley Foundation, 1982-83.

Gleason Fellowship: School of Education, University of California, Berkeley, CA. 1981-82.

Department of Education and Science Postgraduate Fellowship: University of Birmingham, England. 1968-69.

Undergraduate Scholarship: University of Leeds, England, 1961-65.

Suzanne Winters Ph. D.

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EDUCATION

1986 Ph.D. Pharmaceutics: University of Utah, Dissertation: "Immobilized Heparin via a Polyethylene Oxide Spacer for Protein and Platelet Compatibility", Joseph D. Andrade, advisor

1976 B.S. Zoology, Ohio Wesleyan University, Delaware, Ohio, cum laude

PROFESSIONAL EXPERIENCE

Feb, 1991 to present — Vice President, Product Development, Protein Solutions, Inc. Salt Lake City, Utah

- Submission of grant applications
- Research and development on bioluminescent educational products

October 1986 to Nov. 1990 — Director, Membranes Technology, CardioPulmonics, Salt Lake City, Utah

- Responsible for a group of 9 professionals plus technicians for R&D projects for start-up medical devices development company
- Supervised and assisted in the installation and set-up of a wet chemistry laboratory for small start-up research and development business
- Managed an $800K annual budget and approved all capital expenditures for installation and maintenance of two laboratories totaling $1.1 million;
- Submission of grant applications, proposals (success rate 75%) and patent applications
- Primary responsibility for wet and analytical chemistry labs and development of plasma polymerization coatings laboratory
- Coordination between research and development departments; significant responsibilities in marketing technology
- Development of a gas permeable, pharmacologically active membrane coating for a totally implantable artificial lung resulting in two patent applications
- Development of plasma etching techniques for chemical functionalization of silicone plastics and subsequent chemical modifications
- Provide an interface for technical and business development personnel

January 1986 to June 1986 — Symbion, Inc., Salt Lake City, Utah: Senior Materials Scientist

- Analysis and interpretation of retrieved Jarvik 7 artificial hearts for protein and cellular deposition and materials failures
- Preparation of reports to Food and Drug Administration on retrieved hearts for follow-up of original Jarvik-7 PMA
- Development of testing protocols for Jarvik 7-70 and supervision of animal experiments for PMA submission
- Development of a quantitative analysis system of animal data
- Functioned as the primary interface between development engineers and clean room manufacturing personnel for design revisions and production problem solving

CURRICULUM VITAE

NAME: Julie Gess-Newsome

RANK: Assistant Professor

APPOINTED: 1991

AREAS OF SPECIALIZATION:

Science education
Teacher education

I. EDUCATIONAL HISTORY

Ph.D.	Oregon State University Science Education Dissertation: Biology Teachers' Perception of Subject Matter Structure its Relationship to Classroom Practice	1991
M.A.	University of Northern Colorado Greeley, CO Curriculum and Instruction Outdoor Education	1982
B.A.	Northland College, Ashland, WI Secondary Education/Biology	1979

Honors and Awards

Honors Scholarship, Northland College, 1975-197
Who's Who in American Colleges and Universities, 1978
Distinctions in Education, Northland College, 1979
Phi Delta Kappa Education Honor Society, University of Northern Colorado, 1979
Wyoming Teacher in Space Finalist, 1986
Wyoming Biology Teacher of the Year, National Association of Biology Teachers, 1986
Phi Kappa Phi Honor Society, Oregon State University, 1990
Spencer Dissertation-Year Fellowship for Research Related to Education, 1990-1991
Oregon Merit Scholarship for Outstanding Graduate Students, Oregon State University Graduate School, 1990-1991

Predoctoral Positions

1987-1990: Teaching Assistant, Dept. of Science, Mathematics, and Computer Science Education, Oregon state University, Corvallis, OR
1980-1987: Science Teacher, Evanston High School, Evanston, Wyoming
1982-1983: Teacher (Summers) Wyoming State Hospital - Adolescent Program, Evanston, Wyoming