NSF-Course, Curriculum, and Laboratory Improvement (CCLI) Educational Materials Development(EMD)

A proof of concept NSF-CCLI project proposal

A Web-based, multi-disciplinary, top-down, application-driven undergraduate physics resource for life science and general education instructors and students.

Project Summary

Undergraduate physics classes at two-year and four-year institutions that meet life science and general education requirements do not satisfy the developmental needs of these students. Physics basics taught using the 'bottom-up' approach from physics books to an audience of non-physics majors lacks relevance, imagination and sound pedagogy. One must trudge through mundane basics such as; trigonometry, vectors, velocity, and forces before ever adventuring into the fascinating territory of nuclear medicine, seismology, quantum computers or gamma ray bursts. Many students are left behind or discouraged by this 'weeding out' process. The main problem is not the students' lack of interest in Physics or mathematical ability but rather, the lack of interesting and relevant cross-disciplinary applications. Students will learn these basics with instructor preparation, relevant applications and initial enthusiasm. These undergraduate classes would better serve their students by redirecting the basic physics requirements into a more relevant 'top-down' application-driven curriculum.

This project answers the intellectual merit criteria by creating a learning tool that can be utilized by instructors and students from a variety of institutions and disciplines. This learning tool will be a much needed assist for instructors with undergraduate physics instruction. It will provide students with an innovative learning vehicle to understanding physics concepts. This project has a broader impact in that, it will allow more women, minorities and students who would have been scientists to gain access to the physics and science experience. Implementation of this project will take place on the Internet which will have the widest dissemination.

I. Project Introduction

Undergraduate Physics education in America is in dire straits. Many national taskforce reports such as, The National Task Force on Undergraduate Physics, The Boyer Commission on Educating Undergraduates in the Research University Reinventing Undergraduate Physics, New Practices for the New Millennium (2000) are all calling for immediate and substantial reform. There are many university physics programs across America that are answering this call such as, Modeling Theory of Physics Instruction, Workshop Physics Project, Physics Illuminations Project, The CPU Project at San Diego State University and Harvard's Peer Instruction. David Goodstein, a venerable Caltech physicist, says,[1]

> "*The purpose of teaching physics should not be merely to clone ourselves and keep a few poor souls out of medical school. A solid education in physics is the best conceivable preparation for the lifetime of rapid technological change that our young people face. The undergraduate physics major should be the liberal arts education of the twenty-first century!*"

Undergraduate Physics at both two and four year institutions need students. Physics is the basis of a solid science education. There should be more physics students than biology students. The fact that there are not, should make all physicists rethink the curriculum from top to bottom. Physics students planning for graduate school will certainly get there. The rest will find rewarding technical careers in many other sectors of the economy, such as; biotechnology, geophysical technical training, education, etc. It's even feasible and should be encouraged to obtain a Physics degree for one's own desire! Society needs more people who are scientifically literate. Real estate agents, economists, manufacturing workers, English teachers all need science literacy. Physics is for everyone. It does not belong to a few. The main goal of physics education is to educate the masses about the wonders of their natural world. . .nothing more. We are all in complete wonderment about the fantastic phenomena that occurs around us. . .we should encourage and welcome all those interested in discovering the principles that govern our universe. We need to open the gates to the rest of our population. Harvard's Eric Mazur,

> *"What is the point of doing science if society doesn't understand science? Concerned with the lack of public understanding of science we have embarked on a number of projects aimed at improving science education."*[2]

II. Project Goals and Objectives

Undergraduate physics classes aimed at life science and general education majors needs immediate and major reform.[3] The majority of the students (in any physics department) are not physics majors. We attempt to water-down the usual engineering physics by taking out the calculus and substituting it with less intimidating algebra. At most two and four year institutions, students in undergraduate physics classes for engineers and scientists are given three semesters to master the basic physics concepts. Our less mathematically and scientifically capable students are allowed only two semesters to master the same physics concepts. According to David Hestenes,

> *" Blame is usually placed on poor prior training in mathematics and science. However, cognitive research in the last decade has documented serious deficiencies in traditional physics instruction. There is reason to doubt that these deficiencies can be eliminated without extensive pedagogical research and development. Although deficiencies in physics instruction are most serious at the introductory level, there is no reason to believe that they are insignificant at higher levels."*

Students entering their first physics class should not have to be bludgeoned with the 'bottom-up' approach of vectors, motion equations and force diagrams. These mathematical and physical constructs take many years for even the best students to master yet, we only allow two semesters to our lesser capable students. Some students may have had a physics or chemistry class in high school, but not all. There is much research criticizing this inequity. Using the *Force Concept Inventory Test*, even Harvard graduates in physics have shown poor results! Whether we want students to understand Newton's Laws of motion or whether we want students to be able to intelligently read an article in a magazine on the ever changing technological society that they live in, our instruction is ineffective.[4] Students and instructors will heartily agree that the 'bottom-up' approach is non-interesting, non-motivating and lacks imagination.

The goals of this project are to ease life science and general education students into the world of physics and to reduce scientific illiteracy of everyone who takes this adventure. The objectives of this project are;

- To enhance the undergraduate physics curriculum with interesting and relevant 'top-down' science applications.
- To provide a resource for instructors to utilize along with their physics instruction.
- To demonstrate the pedagogical efficacy of the 'top-down' application-driven approach to learning the basics of physics.
- To provide a 24 hour-7 day a week tutorial for all physics and science students.

- To demonstrate the efficient use of the internet as an educational instruction tool in a physics classroom environment.
- To invite and encourage all students including, women, minorities and individual self-paced learners to the study of physics as a prerequisite to the study of anything else at any level of education.
- To add data to the physics education research base for further development of more successful strategies in instruction and learning.

III. Project Description

There is much physics education research that demonstrates that instructors need a scheme. Physics instruction and understanding do not necessarily follow one another simply because an instructor lectures about the fundamentals of force diagrams. There are many examples of new and innovative teaching strategies being developed at many diverse institutions. Eric Mazur at Harvard has devised a peer instruction method.[5] Dr. Priscilla Laws at Dickinson College in Pennsylvania, has implemented Workshop Physics into their undergraduate program.[6]

The prime objective of this project is to design, develop and implement the top-down, relevant science applications strands from each of the following disciplines, biology, chemistry, geology, astronomy and engineering. This project is a 'proof of concept' proposal of which the aim is to implement at least two fully developed science applications strands from each of the above disciplines to be utilized by any instructor at any level.

In this project, there will be five levels of physics understanding associated with each science application strand. These levels are from 'top-down';

- Level 1- Student Interaction
- Level 2- Spatial Modeling
- Level 3- Subsystem Diagram and Labeling
- Level 4- Physics Concepts
- Level 5- Mathematical Problem-solving

An example of the first level of this application would be reading a story or, an article in a popular magazine and providing a spoken (or, written) summary description of what is involved (as stated above). Student elicitation (response) with the material is fundamental to their understanding the physical principles.[7] The student needs to verbalize what they think they know about physical principles. The second level (Spatial Modeling) will be a diagrammatic approach to understanding the process. Drawing diagrams and correctly labeling the components will encourage more complete understanding of the physical principles involved. The third level will isolate any sub-system of the science application and produce a more detailed description and a more complex diagram. Transferring their understanding of one physical system to another reinforces the student's understanding of the underlying principles. The fourth level would bring maximum understanding of the physical concepts involved with this sub-system. Using basic equations and solving simplistic problems using the physical concepts that are now becoming more evident. The fifth level would allow for more complicated mathematical problem solving utilizing related mathematical and physical principles.

Top-Down Example: Medical Science Application Strand

This science application strand will allow the instructor to lead their students on a journey through many different scientific disciplines such as, biology, physiology, anatomy, chemistry, radiochemistry, solid state physics, scientific instrumentation and, the final goal, discovering and understanding the physics concepts involved along the way. This one relevant and interesting application strand will allow for many physics concepts to be fully investigated. They key to getting the students involved is to start at a level (top) that is immediately interesting and instinctually understandable. The instructor is the guide not the knowledge master. Students are quite intelligent and need only to be prompted into moving from the basic (top) level of understanding to a more complex (bottom) level of understanding.

The first level of understanding entices the student to become involved and to freely interact with their environment. After viewing a video, reading an article, or class discussion on Nuclear Medicine, students are asked to provide a summary (written, or spoken) of what they saw, read or heard. An example of a possible written, or oral response;

> *In an effort to discover cancerous tissue early in it's formation, researchers are investigating novel scientific techniques. If the researchers are successful, treatment can happen sooner to eliminate the cancer before it takes hold. The tools that scientists are using are radioactive tracers and solid state detectors. The radioactive tracer is injected into the blood stream and based upon uptake studies in animals, it finds it's way in to the cancerous tissue. The radioactive tracer is now mostly in the cancerous tissue radiating gamma rays. Researchers must detect where this radiation is coming from by using solid state gamma ray detectors. These detectors are the purest from of material anywhere on the planet. As gamma rays pass through the tissue and enter the detector they produce a current in this detector, and utilizing sophisticated computer algorithms an image is produced.*

Getting students to interact and vocalize what they experience is instinctual but, not when it comes to science. The student knows it is possible to be wrong. Students think that scientists know everything and, that other students may know more than they do. Students need to know that there are many unanswered questions. It's very important to demonstrate to our students that we are all afraid of being wrong or ignorant. It's also very rewarding to set an example of being both wrong and ignorant. Unsolicited and unprepared statements are what science is all about. There is always a tidbit of brilliance in what one says, that is illuminating. The instructor needs to detect this tidbit and give the students credibility, in an effort to get the students to refine their illogical or unfounded comments, for the sake of understanding physics concepts.[8]

The second level of understanding encourages students to demonstrate their ability to draw a diagram (see figure 1) of what they experience. Maximum learning comes when students (people) get physically involved with their learning.[9] Each students' unique spatial model of the process of radioactive tracers being taken up in cancerous tissue and radiating gamma rays that will be detected is the art and soul of their individual perception. This modeling allows us to eliminate extraneous or complicating factors in an effort to discover underlying physical principles. Words are hard to grasp but pictures and diagrams have a language all their own.

The third level of understanding would naturally call out to the instructor or to the student to isolate a sub-system such as, the gamma ray detector, the uptake and radiation of the radiotracer, the radioactive tracer, the molecular binding of the radiotracer, etc. By inquiring about a sub-system, the instructor or student is now becoming maximally involved. The physics principles are beginning to show more connections. Connections between the subsystems are being resolved and more physics principles are being discovered and developed.

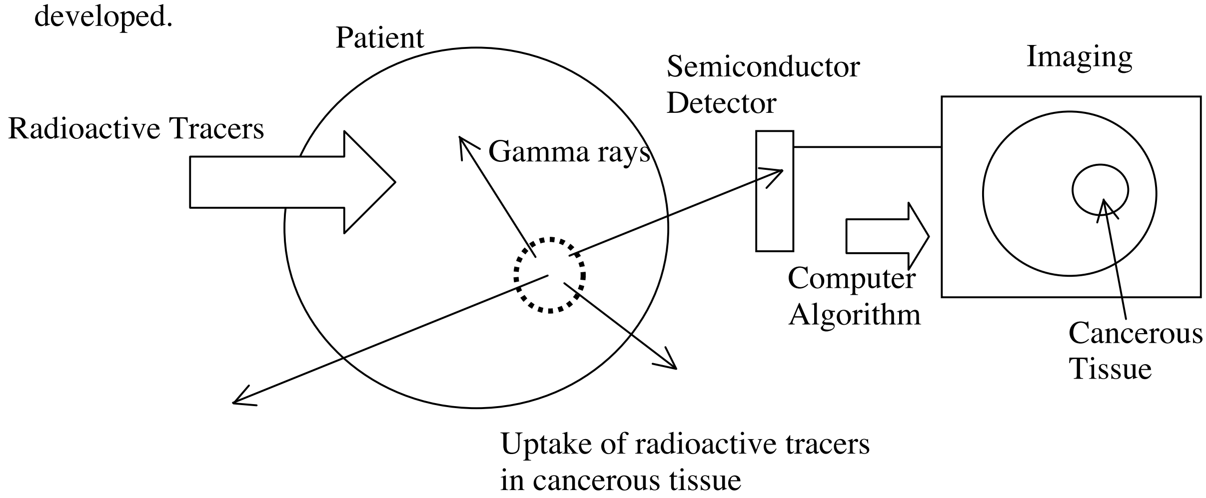

Figure 1. An example of a students rendition of the Nuclear Medicine article.

Moving to the fourth level of understanding students begin utilizing basic equations and solving simplistic problems using the physical concepts that are now quite evident. Making connections between the basic physics principles and the equations is crucial. Deriving the equation is acceptable since the instructor and students are now fully engaged with the inquiry.

The fifth and final level of understanding allows for more complex and involved problem solving relating the different physical principles. At this point, a step back to another sub-system and moving forward along another line of reasoning will maximize understanding of both sub-systems and connected principles.

Each of these strands will have diagrams associated with the relevant science application along with flash animations, links and sub-links to related material in other strands. All application science strands will be linked at each level. There will also be relevant science application strands without diagrams and associated material to allow students to create their own models, physics principles and equations.

There are many web sites that provide fantastic physics principles resources for instructors. What this project aims to accomplish is to bring these resources together through designing, developing and testing a real science application that will incorporate these distinct and separate physics principles from the many science disciplines. What is important is not the science application itself as much as getting the students involved in their education. With large college classes this can be difficult.[10]

This proof of concept project will be on the internet for all to utilize. The value of having a website is that it is always available, it is flexible, it's a place to meet people with similar interests, schedules of people do not conflict, and it can be customized to each individual. A help page will be available with a live physics instructor and peer support. Having already piloted many aspects of this project, I have noticed the willingness of students to both ask for and give help to others. The website evolves in many fascinating directions which will be unique to those that visit the website. The web site will be open source which means, that others will be able to add to the existing application strands in many different and exciting ways. The growth of the sub-systems and the multi-disciplinary concepts from each application strand will outpace possible upkeep of the website. There will be natural offshoots that will develop parallel to what is already planned. This project may be the precursor to a full development project that looks a lot like the many computer servers established to allow people to play games with one another over the internet. Instead of killing people, one may want to set out on an adventure of discovery and learning. What a concept! Along the way you will have the opportunity to learn as well as teach.

IV. Project Timetable

The project will commence in January 2004. The project group will be formed in the first semester. The group will consist of myself, a graduate student, an undergraduate student and selected faculty from Biology, Chemistry, Geology, Astronomy and Engineering. I will be meeting with advisors, faculty and students that feed into our undergraduate classes to gather data on specific physics requirements. The group will plan a conceptual model for the science applications strands and define measurable outcomes. We will be selecting two outstanding students from any of the above disciplines to assist in creating the needed illustrations and flash animations. The major work for this 'proof of concept' project will take place in the summer. We will be designing the science application strands with supporting physics concepts and developing the associated illustrations and animations at this time. We plan to have a website up and running in the Fall 2004 semester. There will be five science applications strands from five different disciplines available at that time to beta-test with select instructors from high school, community college and San Diego State University. An initial evaluation of the project will occur in the following semester. In the summer of 2005, we will create the remaining five science application strands to be beta-tested in the 2005 school year. There will be a total of ten science application strands two for each of the five disciplines. The final evaluation and report will be in the Spring of 2005.

Table 1. Timeline for Implementing the project proof of concept.

Year	Spring Semester	Summer	Fall Semester
2004	Collaboration and Planning	Designing and Developing Applications I	Implementation and Beta-Testing
2005	Initial Evaluation	Designing and Developing Applications II	Implementation and Report

V. Project Evaluation

We will be conducting a formative as well as an implementation evaluation to assess the effectiveness of the science application strands in delivering the promised outcomes.[11] In Spring semester of 2005, we will conduct a research questionnaire (survey) of both the students and the instructors in an effort to gather research data that will most certainly influence the direction of this project. A conceptual model will be developed to define measurable outcomes. We will be modifying the science application strands and the website to meet the needs of the students, instructors and the community at-large. We will be looking for problems associated with the mechanics of the website as well as with the applications strands. During the school year, we will be correcting mistakes in the science applications strands and adding physics enrichment components to all the science application strands as well as discovering and establishing needed links within the website.

In the Fall semester of 2005 school year, we will be evaluating the entire proof of concept. In an effort to especially appeal to women, minorities and self-paced learners, we will want to get statistics on the different people visiting the website. The idea is to present a website that attracts many diverse groups of students. We will disseminate this resource to select classes and gather information on the effectiveness of this website. Assessment in education has three main functions. The first is to record the achievements of individual pupils for the purpose of certification. The second is to record the achievements of groups, classes or schools, for broader policy purposes. The third is to serve teaching and learning.[12] With a few select teachers and students we will get more intensive data that will answer the more profound questions. Does the student know the concept? Can the student transfer this concept between disparate science applications? Can the student speak or write about the physical concepts in a literate manner? Can the student formulate a second interpretation of the concepts with words and diagrams? Can the student teach these concepts to an uninitiated person? Does the instructor understand the connections between the separate application strands and can this instructor show fluency in an open forum? Does the instructor use the strands in an effective way? Does the Website attract diverse groups of people? At what level do most people descend? Do students follow the links? Are some links better than others? These are all statistics that are easily obtained and analyzed.

We will then be in a position to write a report at the end of the 2005 school year based on the needs and effectiveness in delivering this project to instructors and students and the science community. We are positive in our attitude about applying for a Full Development Grant at that time.

VI. Principal Investigator

As the Principal Investigator, I have a Bachelors Degree in Physics, A Masters Degree in Radiation Physics, A Masters Degree in Educational Technology and a Single Subject Teaching Credential. I have taught Physical Science, Earth Science Chemistry, Integrated Science, Physics and AP Physics classes at the high school level. At San Diego State University, I have taught Natural Science 100, Physics of Sound and Speech 201, Natural Science 412 for Teachers, Physics 180B, Physics 197 and Undergraduate Physics Labs. As a new high school teacher, I was involved with the district's Coordinated Science Committee to integrate biology, chemistry, earth science and physical science. I prepared a *Matrix* for the teachers to use in adopting this new curriculum that enabled them to investigate the integration and spiraling of science concepts. Later, I was awarded a paid two-year *Resource Teacher* appointment to develop and implement a computer-based assessment program for science students in our district. My project included, a computer-based assessment for each student, internet access to student projects and rewriting the high school physical science curriculum. I was then awarded a $100,000 *Carl Perkins School-to-Career Grant* to establish a *Physics and Technology Lab* at our school. Wherein, I proceeded to rewrite the labs provided into labs that were more suited for high school. The grant included lab equipment for over 60 Physics and Technology labs and tables to store the equipment. Before leaving high school, I had 400 students waiting to get into the new program. At San Diego State University, teaching Physics

180B prompted me to create a website for myself and my students. All my notes and class materials are incorporated on my site. I also have a help page for my students as well. I have interacted with other department faculty to find relevant science applications to use in my instruction. I took a Geophysics class to learn more about how physics is used in Geology. I walked away wanting to be a Geophysicist and suggesting that all physics majors should take the same class. My instructor, Dr. George Jirasek, encouraged me to seek an advanced degree in this area. I do not like lecturing to 150 students that do not want to be there. I believe my students are quite intellectual and mostly motivated. As I have told my students, there is responsibility for all of us, I should bring my physics instruction to each student and each student should be prepared and willing to learn. Teaching is not a sideline it is a profession, one that requires a separate skill other than my love for physics.

VII. Commitment to Project

San Diego State University is in the forefront of educational research and physics education research in particular. Our department has the proud distinction of being home to Dr. Fred Goldberg and Dr. Phoebe Roeder who have pioneered physics education around the nation. SDSU is home to the CPU Project (Constructing Physics Understanding).[13] I teach the courses that have been developed for future elementary school teachers. The pedagogy that is developed and administered is fantastic. The initial phase of the strategy, Elicitation, is eye-opening for all participants. All participants in the classroom have a piece of the answer. Watching educated and mature people discuss magnetism and it's properties is both amusing and enlightening. It's fascinating listening to what people bring to the classroom from prior experiences. It's a teaching experience that is second to none. San Diego State is committed to the development of science teachers for our ever changing student populations in an ever changing technological environment. San Diego State graduates more teachers than any school in California.

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BIOGRAPHICAL SKETCH Principal Investigator

Anthony J. DiMauro

Professional Preparation

Institutions Attended	Years	Degree	Major Field
University of Nebraska	1973-75	--	History
U.S. Navy	1976-77	--	--
Small Business Operator	1980-1993	--	--
San Diego State University	1989-92	B.S	Physics
National University	1993-94	Credential	Single Subject Teaching
National University	1995-97	M.S.	Education & Technology
San Diego State University	1999-01	M.S.	Radiation Physics

Professional Experience

Institution	Rank	Date	Classes Taught
Grossmont High School District	Teacher	1993-2001	Physics, Chemistry, Earth Science
San Diego State University	Instructor	2001-present	Physics, Natural Science

Synergistic Activities

Curriculum Development and Teaching Innovations:

- Member of the *Grossmont Union High School Curriculum Committee*. Our mission was to develop and implement an Integrated Science Curriculum. Our task was to integrate biology, chemistry, earth science and physics into a two-year integrated science curriculum. I created a matrix to assist teachers in developing a curriculum that would be multidisciplinary and scaffolding. URL: http://tonydude.net/resume/coordinatedsci.html
- Selected to a two-year *District Resource Teacher* position to produce physics labs and an innovative computerized assessment vehicle in an effort to get students to develop their verbal skills in explaining physical phenomena. URL: http://tonydude.net/resume/rproject.html
- Recipient of a $100,000 *Carl Perkins School-to-Career Grant* to upgrade the physics instruction at my school. The funds went to purchasing lab equipment, desks, computers and lab manuals. The *Physics and Technology* Curriculum included over 60 different labs that covered many basic physical principles. I proceeded to rewrite the lab manuals for the high school level. URL: http://tonydude.net/radiationphysics/reshighschoolphysics.html
- Created 'helppage' website at San Diego State University to help undergraduate physics students receive help at anytime of the day or any day of the week. Created an instructor resource website to utilize during my lecture. URL: http://tonydude.net/
- Taught Natural Science 412 for future elementary school teachers. This class is part of the CPU Project at SDSU under the direction of Dr. Fred Goldberg. Worked with Dr. Phoebe

Roeder in an effort to add a new Lesson Plan feature to the assessment. I will be teaching this class again in the upcoming year. URL: http://tonydude.net/natsci412/natsci.html

- I was given a scholarship by Dr. George Jirasek in the Geology Department to attend *SAGE 2000 (Summer of Applied Geophysics Experience)* in New Mexico for a month. This internship was provided to 28 selected students to give hands-on actual experience in seismology, gravity, magnetotellurics, and ground penetrating radar techniques to find and map a fault zone.

Graduate Advisor and Masters Project

Dr. Patrick Papin was my Graduate Advisor and Chairperson (San Diego State University) My Masters Project was in the area of Intravascular Brachytherapy. I collected dose distribution data in a phantom that modeled the human artery in the heart. Using Radiochromic Film and a catheter filled with Iridium-192 we gathered pictures of the dose distribution inside the artery. I had to calibrate the Radiochromic Film with our own X-ray machine then compare intensities with the experimental film. Our work is currently under review by Medical Physics. URL: http://tonydude.net/radiationphysics/resmedphyspap.html

Budget Justification

The Principal investigator: Anthony DiMauro will organize and oversee research for all phases of this project. Responsibilities will include consulting with faculty in biology, geology, astronomy and engineering, Interacting with two student assistants in designing, developing and implementing the Science application components for the website, and directing the research efforts. I will pilot test this project with the community at large involving high schools, community colleges and SDSU to acquire data for evaluation of the project. Salary request for the PI is for 2 months in the summer only (at 100%).

Student Assistants: One graduate student and one undergraduate student from SDSU will receive a yearly stipend. The responsibilities of the students will include flash animation development, illustrations, and technical assistance for web development. Creating 10 science application strands for the proof of concept project will require approximately 200 diagrams and associated components and 50 to 100 flash animations. The student assistants will also participate in the analysis and writing up of the data and will present findings in a report.

Other Direct Costs: A server/computer set-up with appropriate software will be purchased to provide the SDSU Physics Department complete control over the resources that are developed and shared via the World Wide Web. Expected future full development of this project will require a server with suitable memory for the large database of information that will be uploaded and shared on the internet.

National Science Foundation (03-558)

Educational Materials Development (EMD) and National Dissemination (ND) Tracks

Proof of Concept Project---Course, Curriculum, and Laboratory Improvement (CCLI)

Web-based Instructor / Student Physics Teaching Resource Database

PI	SDSU	Tony DiMauro	Full-time	25,692
Travel				2,000
Flash Developer	SDSU	Grad Student	Part-time	9,627
Illustrator	SDSU	Undergrad Student	Part-time	4,011
Computer Hardware	Apple	Server		5,000
Computer Hardware	Apple	Computer		3,000
Computer Software	Apple	System Software		1,000
Computer Software	Apple	Misc		4,000
Indirect Costs	SDSU			23,629
			TOTAL	**74,959**

Flash Developer	The Project needs many animations. We expect to have over 100 animations
Illustrator	The Project will need many diagrams and illustrations We expect to have well over 100 illustrations
Apple Server	Will store all creations of the project. Will be available to any instructor at any college or university
Principle Investigator	Will produce Biology, Geology, Astronomy and Chemistry tracks These separate tracks will demonstrate the physics involved in these disciplines. This will all be brought together on the internet. Instructors will be encouraged to use the different tracks. Students can access the tracks via the internet.

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