Submitted to:	State Centers of Excellence Program
Submitted by:	University of Utah Center for Integrated Science Education (CISE) 2480 MEB Salt Lake City, Utah 84112
Project Title:	Developing a Science Education Industry in Utah
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Amount of Request:	$136,040
Duration:	Two years (24 months)

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CENTER FOR INTEGRATED SCIENCE EDUCATION

A State of Utah -- University of Utah Center of Excellence
Title: "Developing a Science Education Industry in Utah"

1.0 EXECUTIVE SUMMARY

Vision: Imagine a multi billion dollar industry expected to double every 5 years for the next 2 decades. Imagine that this industry is very fragmented and unstructured and therefore easy to penetrate. Imagine that it is clean, wholesome, and does not involve major research and development expenditures. Imagine this industry is based on Utah's science, engineering, and technology expertise, including existing high technology companies and research Universities. Imagine that this industry is ideal for new company formation, for spin off, and for entrepreneurship. Imagine that SBIR capital from the Federal government for this industry is expected to double every 3-4 years. Imagine that this industry will contribute to the enhancement of the skills and educational level of Utah's work force. Imagine that this industry will enhance Utah's image and reputation as a science and technology state. Imagine that a mechanism is in place to assist new and existing companies in product development, marketing, market penetration, and new product development for this industry.

Reality: This industry exists, although it is presently very small in Utah. Nearly every Utah science and technology-based company could participate in and benefit from this industry. The industry is science, engineering, mathematics, and technology education, from preschool through the University, including on the job training for business and industry.

We normally don't think of education as an industry, a contributor to the economy. We normally think of it as a consumer of tax dollars. However, mathematics, science, and technology education is a multi billion dollar a year industry in the United States and is growing very rapidly.

Operating under a small planning grant from the State Centers of Excellence Program, the Center for Integrated Science* Education (CIS*E) has already demonstrated the potential for such an industry. The Center has already been successful in aiding a Utah firm in obtaining federal SBIR support and in launching a set of products for science education.

The Center's preliminary activities will be enhanced and expanded as a State Center of Excellence. The State Center for Integrated Science Education will provide the technology, the marketing expertise, information, and other resources to permit new and existing Utah companies to fully participate in this major growth industry.

* The term "science" used here follows the common journalism/mass communications definition: science refers to issues and subjects involving science, mathematics, technology, engineering, and medicines.

Budget & Duration: $136,040 is requested from the Centers of Excellence Program for a 2 year contract.

Objectives: The Center for Integrated Science Education (CISE) will develop methods and materials to aid the education of teachers and students in *integrated*, multi-disciplinary science, mathematics, and technology. The materials and experiments will be based on genuine *discovery* -- simple and highly interesting experiments which utilize human *senses* for perception and detection. These materials will be developed and then tested in appropriate populations and market segments. The Center will work closely with existing local companies and will encourage and catalyze the development and growth of new spin-off companies. The Center's long-range goal is to develop a Utah industry which will supply the nation and much of the world with products which will be the key constituents of science education as we move into the 21st Century. The goal is to establish and maintain Utah as *the* leader in science curricula and materials for all education levels: K-12, the general public, and college/university.

Other Support: The National Science Foundation (NSF) budget for Science, Engineering, and Mathematics education has been increasing dramatically in recent years. J. Andrade and T. Stoddart (Dept of Educational Studies) have already submitted 5 proposals to NSF. We anticipate submitting an additional 10 proposals to NSF and private foundations over the next 18 months. The goal is for CISE to have a budget of about $1M/year within 2 years -- most of those funds to come from Federal sources.

Personnel:

The Director of the CISE is J. Andrade, Professor of Bioengineering and Materials Science at the University of Utah. Andrade is recognized for his inter- and multi- disciplinary approaches to science and engineering. He is very familiar with the State's Center of Excellence program and with its economic development objectives. He served as co-director of the Center for Biopolymers at Interfaces (CBI) for the past 5 years. He was one of the founders of Biomaterials International, now Ohmeda-Salt Lake. He founded Protein Solutions, Inc. (PSI) in 1988 to develop and market science education materials. PSI will be one of the initial corporate participants in the Center. Because J. Andrade is also directly involved with PSI, Gordon Jensen, Director of the Engineering Experiment Station, will serve as co-PI and will focus on financial matters to minimize potential conflict of interest issues between the Center and PSI.

This Project will strive to involve all faculty who have strong interests and motivation in improving and enhancing science education and in the transfer of the Center's activities to the private sector. We expect faculty and students to work closely with local industry in the research and development of novel, profitable science education products.

2.0 THE PROJECT

2.1 RESEARCH PURPOSE:

The major purpose and objective of this project is to develop and establish a science education materials industry in Utah. This is a part of the overall objective of the Center for Integrated Science Education, described briefly in Appendix A.

Recent national reports dealing with the issue and problem of science education have concluded that teachers "will need a new generation of books and other instructional tools... textbooks and other teaching materials in current use are, to put it starkly, simply not up to the job" (1). The same report goes on to say "the present science textbooks and methods of instruction, far from helping, often actually impede progress towards scientific literacy. They emphasize the learning of answers more than the exploration of questions... they fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their modern intellectual capabilities". "The present curricula in science and mathematics are over stuffed and under nourished" (1).

There is a growing national trend towards fully integrated, multi disciplinary science and mathematics education, and a parallel trend towards discovery and experiment based learning. A very new book, The Unschooled Mind: How Children Think and How School Should Teach (2) argues that children learn by only two processes.

One: emulation, that is seeing an adult doing the activity and trying to emulate that adult-this is the so-called apprenticeship school.

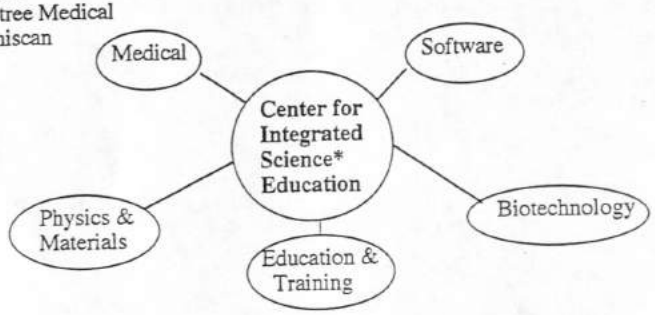
Two: by discovery, that is by doing something in an experimental or experential mode. This is the basis of the discovery/hands-on approach to learning.

The purpose of the Center and of this project is to aid in the reformation of science and mathematics education by encouraging and inducing Utah companies to produce novel, innovative, and effective teaching and self education materials. This array of new products will serve as the basis for a new industry in Utah: science education. This does not only mean materials for teachers and schools, but it means educational toys and educational gifts for all ages. It means hobbies and activities which have a science educational component. The breadth and expanse of this industry is discussed in Section 3 on Market and Marketing Strategy.

Note that this industry fits ideally into the State's economic development efforts. All four of the State's targeted economic development categories (aerospace technologies, biomedical technologies, information technologies, and natural resources) can play major and significant roles in a science education industry.

Applied Informatics
Biologies
Cran Tech.
IC Sensors
IOMED
Medical Systems
Non Invasive Med Tech.
OEC - Diasonics
Ohmeda
Planetree Medical
Techniscan

Acrobits
Access Software
CAI
ICD
Sculptured Software
Viewpoint Animation
Wasatch Education
WICAT



Adv. Holographics
Alpha Lab.
American Laser
Bonneville Science
Handtronics
HGM Medical
Holographic Products
Ivie Tech.
Logan Nova Tech.
National Laser
Wescor

Allen Communic
CAI
Career Research Corp.
Designing Minds
Protein Solutions
Robotronics
Wasatch Education
WICAT

Biotronic Energy
Cytozyme Labs
Gull Labs
Hyclone Labs
NPI
Protein Solutions

Figure 1: Components of the Utah Economy
Relevant to a Science Education Industry
(Source: Utah's High Technology Directory, 1991)

The U.S. National Science Foundation has already taken a leadership role. The U.S. Department of Education and the states of California and Texas are in the process of implementing a much more integrated approach to science education (3). It is our hope and expectation that Utah will be a leader in these reform efforts, permitting the Utah economy to benefit substantially from the rapidly changing, and even more rapidly growing, science education industry.

The major goal of CISE is to work closely with local industry and the business community to create a strong and large science education industry in the state of Utah.

There are already Utah companies involved in these activities. It is expected that these will grow and flourish and that other companies will evolve and expand to provide the materials and products which will be required. Utah would be the leader in science education nationally. Figure 1 based on information in the Utah High Technology Directory (4) shows, based on a very preliminary analysis, those existing Utah companies who could participate in a science educational products industry.

We have simply gone through the Directory and identified those companies which seem to have technologies and interests which may be suitable for science education products. We have categorized these roughly into medical, software, physics and materials, education and training, and biotechnology. These 40 companies, would be the basis of the Center's initial efforts and initial discussions.

2.2 TECHNOLOGY DEFINITION:

Our approach is similar to that of The Exploratorium -- the interactive science center in San Francisco (5). The Exploratorium relies on the individual's senses to perceive and to detect scientific and technological phenomena and events: the eyes in vision to detect light; the ears to detect sound; taste and smell to detect liquid and gaseous substances; and touch for the detection of pressure and mechanical phenomena.

One example of a unique, highly motivational subject is bioluminescence, which is already under development by the Center's Director, and is already the basis of a set of unique science education products (6).

Bioluminescence is light emitted by biological organisms, such as fireflies, and glow worms. A student's or teacher's first encounter with bioluminescence -- light generated without batteries, without wires, without bulbs, without electricity -- naturally, biologically -- is one of awe, mystery, and intense motivation and interest. The Center, in partnership with a local company, Protein Solutions, Inc., is developing a full product line based on bioluminescence.

One could consider a parallel approach using sound generated by living organisms. The production and detection of sounds range from the very high

frequency sounds of birds, dogs, and cats, which are undetectable by humans, to the ultra-low frequency pulsations in the sea, also not readily detectable by humans, but used by whales as a form of long distance communication. All of sound production and detection for communications and entertainment purposes can be taught via this approach. The detection of submarines by hydrophones, the noise problems of airplanes and automobiles, and noise elimination strategies of some modern high-tech companies can be presented and developed via bio-acoustic phenomena and observations.

Utah has a fairly large medical product industry and several companies are involved with medical diagnostic imaging. Imagine the thrill of having a small device into which you could stick one of your fingers and literally see the bone structure or in which one could put a mouse or other animal and see the skeleton and perhaps even other internal tissues.

Non invasive imaging is of course routine using very expensive equipment in hospitals. It has not normally been thought of for teaching or as an educational product. This is the kind of thinking which could lead to totally new and innovative products for a large mass market.

We are now talking with the new Task Force for a Utah Science Center about the possibility of an exhibition in which participants would literally be able to look into their own bodies and organs using various medical imaging and related techniques. Imagine the excitement of imaging your own fingers or toes and using that as the basis to study science.

There are several Utah companies involved in video games and related activities. Imagine a science educational activity based on video game technologies. This is already being used in interactive science centers to stimulate interest and develop motivation. Utah's existing software and hardware entertainment firms could play a very major role here.

What we mean by integrated science is to tie everything together. To show that biological sound is indeed physical pressure pulsations and that sound detection in living organisms relates to the sound detection schemes used in physics and engineering -- and that indeed acoustical physicists and engineers can learn a great deal from looking to biology for models and inspiration. The goal is to *integrate* science and to minimize the partitioning of science into chemistry, physics, biology, geology, earth science, environmental science, etc.

This is a growing national trend (1,3). A center focused on such interests and activities will benefit not only the University and the Center's participants, but more importantly, it will dramatically benefit the population and economy of the state of Utah.

2.3 EXISTING SUPPORT:

Support for the bioluminescence part of this activity has been provided by Protein Solutions, Inc. (PSI), a small start-up company. PSI has already funded $70,000 of work at the University of Utah on the development of bioluminescence as a science educational tool. The University and PSI have signed a technology transfer agreement in the bioluminescence area. An efficient, effective, technology transfer mechanism is already in place.

In addition, the Center faculty has submitted 5 proposals to the National Science Foundation, one to the Environmental Protection Agency, and proposals to selected private foundations.

2.4 IMPACT OF COEP SUPPORT:

The existing bioluminescent activities are likely to continue because of the interest of Protein Solutions, Inc. in their development. However, this is just the tip of the iceberg. The establishment of the Center, and the financial resources available via COEP, will provide a focus, an identity, and a vehicle with which to foster, and indeed to significantly encourage and enhance, science education activities throughout Utah.

Even more importantly the establishment of the Center will provide a means by which these science education activities can be spun off to new and existing companies, and form the basis of a growing educational materials industry in the state of Utah. The students, staff, and faculty involved with Center activities will provide the R & D, vision, and leadership with which to develop and expand the educational materials industry.

Figure 2 shows the types of services which CISE could provide to Utah firms.

One of CISE's first activities to be held in early September is indicated in Table 1 a workshop possibly called Science Education New Business Opportunities for Utah Companies. This would help make Utah companies aware of the Center and of opportunities in the science education industry.

Another Center service would be to establish a newsletter, which would be distributed to all Utah companies who have an interest in the science education materials industry. This newsletter will cover trends in the field, new innovations and developments, national and international corporate activities, and a variety of other topics. To our knowledge, such a newsletter does not exist anywhere, in part due to the highly fragmented nature of the industry today. The same report quoted earlier also says "decisions in educational policy and the use of resources for education are made by literally thousands of different entities including 16,000 separate school districts, 3,300 colleges/universities, 50 states, several agencies of the federal government, and the courts at every level" (1).

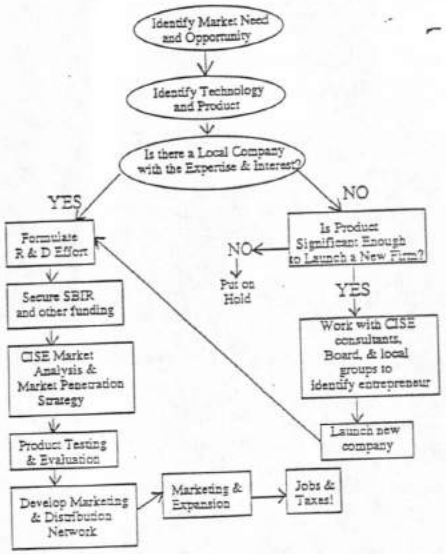


Figure 2: CISE Activities & Interaction with Industry

Table 1: CISE Workshop:
Science Education - New Business Opportunities for Utah Companies

New Directions in Science Education
The Education Market
Utah Initiatives in Science Education
Science Centers, Museums, and Gift Shops
Science Toys & Gifts - The Retail Trade
Science Fairs & Science Projects
A Case Study: NIGHT-LIFE™
A Case Study: The Chem Shop
A Case Study: The Explorabook
CISE and its Services for Utah Industry
Technology Transfer
Discussion Session - How can my Company Benefit?

The bad news is that this is a fragmented industry; the good news is that it is fragmented. There are no major nasty players. With a good infrastructure and mechanism available, such as the Center for Integrated Science Education, Utah firms should be able to readily penetrate and make a significant impact in this marketplace.

Without CEOP support these activities are likely to continue to be a one or two man show, and therefore the impact and return to the state would be relatively small. *With* COEP support it is likely that by the end of the first year the Center will have some 10 to 15 participating faculty, a large nucleus of federal and private support, and at least 10 companies directly involved in science education activities (Figure 1).

3.0 THE MARKET AND MARKETING STRATEGY

3.1 MARKET ANALYSIS:

Under the existing planning grant from the State Center's of Excellence Program, the Center has initiated a market analysis and market strategy study. Ms. Mary McDonald and Ms. Kelly Thorimbert have conducted a very extensive study using the computer data bases of the DIALOG information retrieval system and using the resources accumulated over the past 2 years by Andrade and co-workers. This information is summarized very briefly in the figures which follow. A more complete report will be submitted to the State Centers of Excellence Program in early July, upon the conclusion of the present planning grant.

In addition to the nearly 50 million public school students in the United States, and the nearly two million teachers, the U.S. has a population of some 220 million people, the world's largest economy and a wide variety of commercial sectors which are already involved with science education products and for which considerable growth and development can be expected. Figure 2 presents most of the components of an enhanced science education industry.

There is a major industry in pets and fish, particularly tropical fish for the home environment. Museum stores and giftshops provide a 1/2 billion dollar market. The toy industry is roughly 10 billion dollars a year in the United States, of which about 750 million is labeled as educational toys. The market for "science toys" is $50 million, but that does not include a large number of other toys with science and mathematics education components and does not take into account that the science component of the toys and gifts is growing very rapidly.

We would urge the reader to visit some of these stores, such as Gregory's Toys and Adventures and the science section of other major toy stores. Of particular interest is the rapid growth and proliferation of retail outlets focusing almost exclusively on science related products, such as the Great Basin Nature Company in the Foothill Shopping Center, The Chem Shop in Crossroads Mall, Magismos in University Mall in Orem, and national chains including Worlds of Wonder, The Nature Company, and others. The nation's

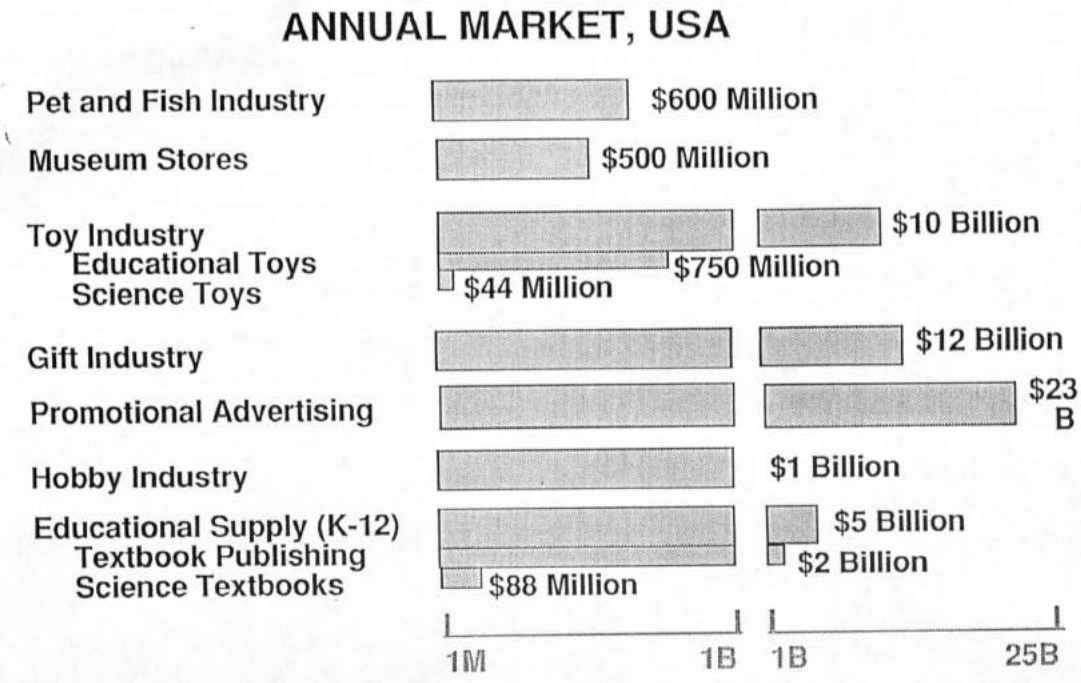


Figure 2: Major Industries and Outlets for Science-Related Products, Toys, and Novelties (Ref. 9)

growing interest in environmental and ecological issues has in part fueled this interest in science educational products; that interest is expected to continue and expand over the next decade or so.

The gift industry in the United States is over 12 billion, and right now there is a relatively small component of that related to science and educational gifts-this can increase dramatically. The Center expects to target such gift outlets as hospital giftshops, hotel giftshops, and airport giftshops.

Promotional advertising is a very major industry. Fast food restaurants are now using environmental and science related promotions.

The hobby and craft industry is a billion dollars a year. Much of that is science and technology related.

Education is a 400 billion dollar industry, roughly 5 billion of that is in educational supplies of which perhaps 2 billion plus is in textbook publishing.

Figure 3 presents the educational market in the publishing arena. Of the roughly $400 billion spent for year on education, about $3 billion is K-12 print materials.

There is a growing dissatisfaction with textbooks and other materials in the public education sector at all levels. In the 7 year period from 1982-1989, kindergarten through 12th grade science textbooks sales increased from about 60 million to nearly 90 million dollars. 1989 was about the time that the national reports on science education were being presented (1). It is likely that textbook sales will change dramatically over the next 5-10 years. An example of the new generation of textbook, which is likely to become available particularly at the elementary and middle school level, is the *Explora Book*, now published through the Exploratorium in San Francisco (7). We have attached one copy of the *Explora Book* to this proposal for perusal by the reviewers. We feel frankly that there could be hundreds if not thousands of such *Explora Books* for different age groups, different audiences, and on different topics.

The size of the market is perhaps best illustrated in Figure 4 on Demographics and Buying Trends in the United States. For example $75 billion was spent on children in 1990. 2 out of 5 adults bought toys within that year. Half of all parents average $150 or more a year on toys. 25% of toy buyers in the over 50 population are grandparents, and nearly half bought gifts with average annual purchases of nearly $500. With a growing national emphasis on education, particularly on science and math education, we feel that a significant part of this 75 billion which is spent on entertainment could be directed toward educationally related entertainment.

The international issue is both an opportunity and an example. Children in the United States spend about 1/4 of the time of their counterparts in Europe doing science related experiments and activities. However, our kids spend 3 times the amount of time on reading about science. So, in the U.S. we read

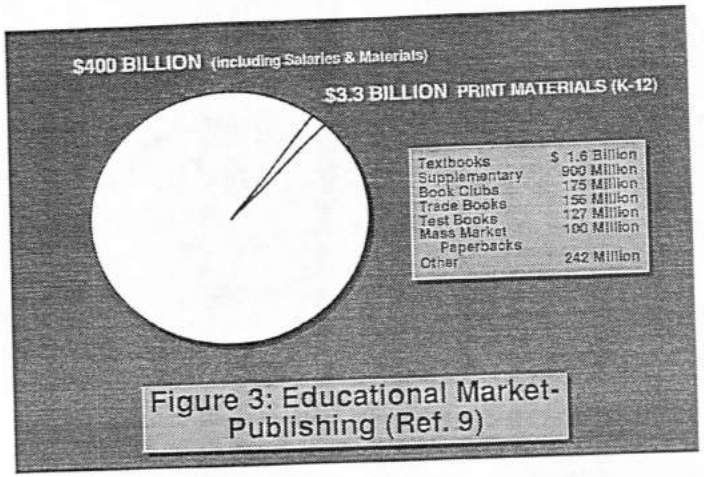


Figure 3: Educational Market-Publishing (Ref. 9)

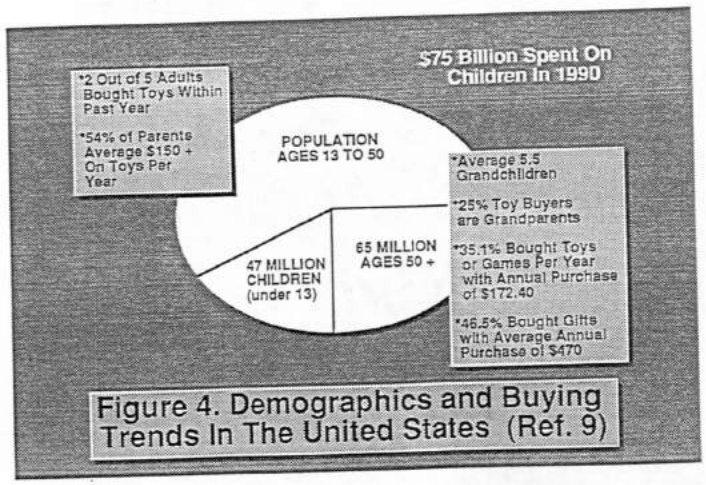


Figure 4. Demographics and Buying Trends In The United States (Ref. 9)

about science and mathematics, in Europe they do science and mathematics (10).

We are just beginning to get sales figures on science education products in Europe and Japan, but it is clear that on a per capita basis they are far in excess of that in the United States. It is no surprise therefore that U.S. children do not do better in the international measures of performance in science and mathematics.

This is both good and bad news. The good news is that we recognize the problem and there is a growing national interest and resolution to solve it. The other good news is that there is a large international market for science educational products, which Utah companies can utilize.

Finally, not shown in the above figures, is the business of science education in business. There is one estimate that U.S. companies spend $25 billion a year to upgrade employee skills (8). This is a very major market. The products which Utah companies will be producing in the science education arena will not only be used in the public schools and as gifts for the general public, but will be used by training firms who work directly with industry to train and educate their employees. The opportunities are enormous.

3.2 UNIQUENESS OF TECHNOLOGY:

Part of the problem with science education nationally is that science is perceived, often by science teachers, to be a cut and dried subject -- that science is something to be learned, to be memorized, to be applied, to be regurgitated -- not something to be discovered and to be constantly learned and relearned. That is the fundamental problem, and it is one which educators and particularly educational administrators have a difficult time grasping.

Practicing scientists know that science is a living, breathing subject, that it is rarely ever static, that it is constantly being challenged, modified, developed. The various so-called laws and theories of science are often disproven or superseded by better laws and theories.

One of our approaches to science education is to use phenomena which are not by themselves fully understood. Bioluminescence is a case in point. Although the phenomenon is readily observable, the reasons for its existence, the actual mechanisms of light emission, and other questions remain only partially answered. This means that students and their teachers need have no fear. There really are no absolute rights or wrongs. They can discover, experiment, and learn. Then, using the science curriculum materials which the Center and Utah industry will develop, those observations and that learning will be extended to other subjects and interconnected with the larger world of science and technology.

This is not to say that every student using these approaches will be discovering completely new and important science, but it is to say that those

students will indeed experience and discover something for themselves, which will be imprinted in their brains forever (2). More importantly, the teacher, with the new and novel materials at his or her disposal, will be able to extend that experience to many other subjects and to other areas of science (1,3).

There is at present no bioluminescence based science curriculum. There is at present no bio-acoustics based science curriculum. We want to take single, integrated themes which cut across all areas of science, and utilize these themes to motivate students and their teachers, and then to connect and extend those themes into virtually all science subjects and disciplines. This approach to science education is completely unique and will require a new generation of science materials (1,3).

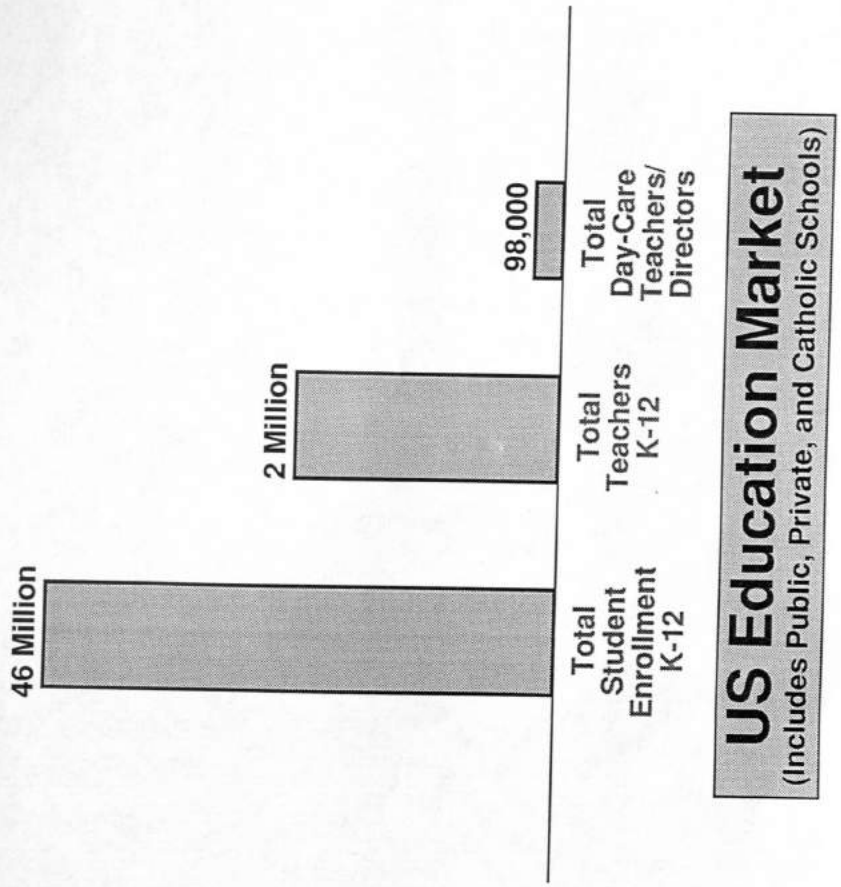
3.3 MARKET PENETRATION AND IMPACT:

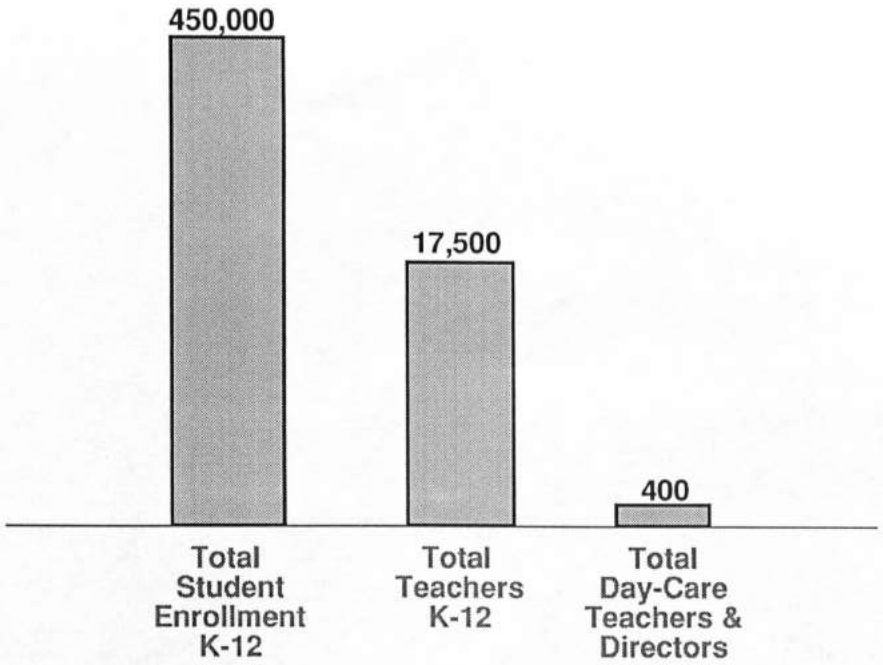
We will work with the Utah State Office of Education and participating regional school districts to present teacher in service education and training courses. The teachers would experience and use the materials and then incorporate them in their own classrooms. As the market develops, local and spin-off companies would begin to market and produce the materials, initially for local consumption by school districts and teachers using their appropriate budgets. In parallel, the faculty and staff involved with the Center, and the local teachers involved with the developing curriculum and materials, would participate in a very aggressive and active campaign of conferences, meetings, and conventions nationally, including running workshops, exhibits, and demonstrations. We will work with the National Science Teachers Association, the National Education Association, and related groups to make their members aware of and interested in the novel science materials which CISE will develop.

The goal would be to educate and to convince the educational community as to the benefits of this form of science education. We will work closely with offices of education in other states and with other major school districts nationally to educate and train their teachers and thereby help develop the market in neighboring states.

We are sure that we can involve students and teachers to serve as missionaries in other states and regions to help promote and promulgate the integrated approach to science education, and thereby develop a market for the materials produced by the Utah firms.

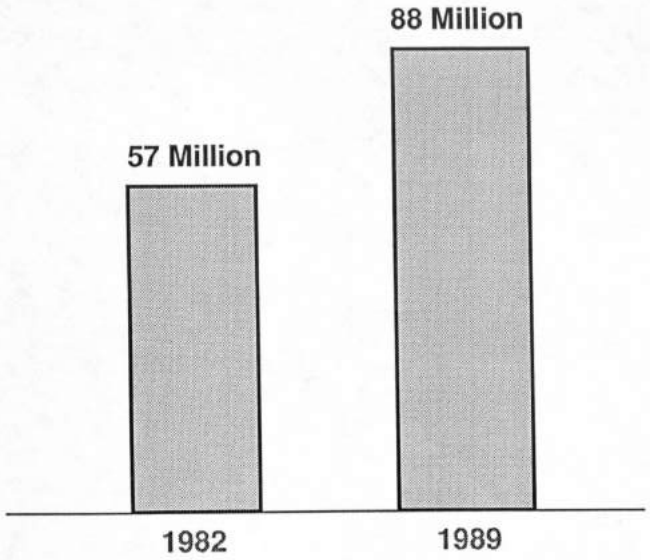
The potential impact on the Utah economy is difficult to accurately gauge. The present science educational materials market is probably $1-2 billion per year, and is expected to double over the next 10 years. It is perhaps reasonable to anticipate capturing up to fifteen percent of the that national market. That would amount to a total annual sales of $150M. Given appropriate multipliers, that should translate to 20,000 new jobs in the Utah economy.





Utah Education Market
(Includes Public, Private, and Catholic Schools)

124% Change 1982 to 1989



Estimated Industry Sales
Science Textbooks
K-12