Solar power curriculum: A project-based technology education unit for middle school students

David Charles Ulinder
SOLAR POWER CURRICULUM: A PROJECT-BASED TECHNOLOGY EDUCATION UNIT FOR MIDDLE SCHOOL STUDENTS

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
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in
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by
David Charles Ulinder
June 1996
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ABSTRACT

A solar-energy unit was developed to incorporate computer assisted instruction (CAI), hands-on science and technology education activities, and student collaboration. The solar power curriculum (SPC) and accompanying solar energy software (SES) were designed for implementation in an exploring technology education (ETE) laboratory. Current literature was examined and adapted for the SPC from the fields of: CAI, technology education, and environmental education (EE). This curriculum supports educational reform, reinforces the academic core, and develops problem solving skills. These instructional goals can be met through: CAI, designing and building a model solar-powered vehicle, historical and career investigations, and student presentations. In addition, constructivist learning theory and student authentic assessment are discussed as pedagogical methodologies.
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To my wife, whose loving and unselfish patience made this undertaking possible. I love you Debby.

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CHAPTER ONE

Introduction

During the Industrial Revolution, our educational system taught students trade skills for employment in an industrial society. Industrial Arts classes were established to prepare students to live and work in an industrial economy. Industrial Education has served the needs of our society for well into the second half of the 20th century. During the latter part of this century, the Information Age was born. As a result, technology education was developed to prepare students for the workplace of the 21st century.

Technology education is currently taught in this country as part of primary, secondary, and post-secondary curricula. Technology Explorations has almost entirely replaced traditional Industrial Arts programs at the middle school level. The Exploring Technology Education (ETE) Program at the middle school level is a broad-based exploratory experience designed for both boys and girls. (ETE Curriculum Changes, 1992). The activities in the explorations program are grouped according to the ETE Performance Standards of Biotechnology, Machine and Tool Safety, Production, Materials, Communication, Construction, Power and Energy, and Transportation (see Appendix A).
Statement of Needs

Education today is at the crossroads of reform, both nationally and internationally. In the past, our educational system followed the mass-production model to prepare students to follow a regimented work day in a factory system. This type of education was authoritarian, teacher-centered, departmentalized according to subject areas, and it followed a standardized schedule. By contrast, today's educational system aims to prepare students to live, work, and recreate in an information-based society that is highly mobile and ever-changing. In order to prepare our children for this type of society, education must become student-centered and performance-based. As technology progresses, students must be able to think critically, solve problems collaboratively, and be technology literate. Therefore, educators must develop curricula to teach these skills, and use assessment techniques that allow students to demonstrate competency.

Public school educators need to develop a curriculum that develops higher order thinking skills and effective communication in order to meet the needs of different student populations. If this challenge is met, there will be a much greater chance for economic success on a global scale.

The focus of schooling must shift from teaching to learning, from passive acquisition of facts and routines to the active application of ideas to problems. That transition makes the role of the teacher more important, not less. (Caught in the Middle, 1987, p. 36).
If educators do not make this transition, American students will continue to fall behind students from Europe and Japan. The reasons why American students are falling behind students on the international level in particularly critical areas such as math and science, can be traced back to the issues raised by the 1983 publication *A Nation at Risk*.

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Pointing to declining test scores, poorly prepared high school graduates, declining enrollment in science and mathematics, low academic achievement in comparison to many European and Japanese students, and low levels of literacy, significant questions concerning the quality of the American educational system were raised. (NAAEE, 1994 p. 2).
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Six years after *A Nation at Risk* was published, the government responded with a national education summit. This summit was led by then Governor Bill Clinton, who along with a bipartisan group of the nation’s governors, agreed with the Bush administration on six national education goals, referred to as Goals 2000 (see Table 1). These goals are “based on the premise that every child can learn and that education is a lifelong process.” (NAAEE, 1994, p. 2).

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In order to implement Goals 2000, today’s educators and policy makers must be willing to prepare the nation’s youth to live and work in an ever-changing global village. “Respected futurists rightly claim that the future belongs to the nation that most effectively learns to manage information.” (Fenwick, 1995, p. 5). Today’s students will spend most of their adult lives in the 21st century.

Therefore, American students must be taught how to be economically viable in an information-based society; and at
the same time become responsible members of a technology based global village. As global citizens, there is a need to teach students about environmental responsibilities. Future generations need to realize their part in creating and maintaining a sustainable environment for all living things on the planet. For this to occur, educators need to develop critical thinking and moral reasoning skills in today's students.

In order to prepare students for the next century, America's educational system needs to offer a student-centered curriculum that emphasizes math, science, collaborative problem solving, critical thinking, technology literacy, moral reasoning, and the responsible use of technology. By addressing these needs, teachers can help to create a technology literate and globally responsible work force for the next century. To bring this about, one should look closely at Goals Three, Four, Five, and Seven from Goals 2000, as these goals address the fundamental aspirations of the educational community with regards to student achievement and citizenship, science, mathematics, adult literacy, and lifelong learning. Furthermore, Goal Seven guarantees the nation's teaching force equal access to professional development programs. These programs will provide teachers with the "...opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century." (NAAEE, 1994, p. 2). The remainder of this section will examine four different goals from Goals 2000, and relate them to Technology Education.
Table 1.

Goals 2000: Educate America Act

Goal 1: Readiness For School - By the year 2000, all children in America will start school ready to learn.

Goal 2: High School Completion - By the year 2000, the high school graduation rate will increase to at least 90 percent.

Goal 3: Student Achievement And Citizenship - By the year 2000, American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject matter, including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, future learning and productive employment in our modern economy.

Goal 4: Science And Mathematics - By the year 2000, U.S. schools will be first in the world in science and mathematics achievement.

Goal 5: Adult Literacy And Lifelong Learning - By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
Goal 6: Safe, Disciplined, and Drug-Free Schools - By the year 2000, every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning.

Goal 7: The nation’s teaching force will have access to programs for continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century.

Goal 8: Every school will promote partnerships that will increase parental involvement and participation in promoting the social, emotional, and academic growth of children.

________________________________________

Technology Education

The National Education goals are directly related to the ETE course goals (see Table 2). Education 2000 goal number three states: "...American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject areas,..." (NAAEE, 1994, p. 2). Likewise, "the explorations program at the middle school level allows boys and girls to learn about technology that affects their daily lives through hands-on activities while reinforcing the academic core." (ETE Curricular Changes and
Design Solutions, 1992 p. vii). Furthermore, the current educational literature states the need for educators to develop new approaches to teaching and learning that support subject matter competency and occupational skills for the 21st century. For example, ETE student outcomes expect students to work together in challenging, interdisciplinary projects and problem solving activities that develop critical thinking skills. The ability to solve problems cooperatively will be paramount for people entering the work force in the next century. Together, Goals 2000 and ETE course goals support technology literacy, career education and job skill training.

Career Education

Another focus in Technology Education today is career preparation and workforce development. Beginning at the elementary level, students are taught career awareness. This is followed by career exploration at the middle school level. Students then select a career path, and corresponding coursework by eleventh grade. Upon graduation from high school a student should continue his or her education, which can lead to a variety of certificates and degrees. In order for this process to succeed, interdisciplinary teams of teachers, counselors, and employers must be formed to carry out the goals of career education.
Exploring Technology Education Course Goals

Students will:

*Learn to transfer knowledge and skills from one discipline to another.
*Develop problem-solving and critical thinking skills.
*Become independent thinkers.
*Learn about the effects of technology on their daily lives.
*Become adaptable to the changing world around them.
*Start thinking about a career.
*Develop a strong positive work ethic.
*Identify the basic tools and processes related to technology.
*Learn to interpret plans and build objects.
*Use tools, equipment and supplies in a safe and efficient manner.
*Develop a basic technology vocabulary.

Just as important, funding for career awareness programs must be provided through "legislation consolidation and block grant funding." (Kershaw, 1995, p. 2).
As careers within this country become increasingly complex and technology-dependent, education must respond accordingly. Technology educators must prepare students to face this challenge with the appropriate knowledge and skills to succeed in an ever-changing employment market. This process needs to begin at the middle school level, where students can identify possible career paths. In 1987, the California Department of Education released Caught in the Middle, an education reform document for public school students in grades six through eight. As part of the educational restructuring movement, the Caught in the Middle report called on schools to develop and/or improve existing exploratory and elective courses such as: visual and performing arts, computers, music, foreign languages, home economics/life skills, and technology education. These programs

...allow students to survey broad themes and topics of potential interest to them. These studies can open doors to new categories of knowledge and skills and can give students a broadened sense of the scope of academic, vocational, and avocational possibilities as adults (Caught in the Middle, 1987, p. 10).

As a result, in 1992 the ETE Career Performance Standards (see Appendix B) were established to facilitate this process. The Career Performance Standards were designed to develop the following outcomes: personal skills, thinking and problem solving skills, communication skills, occupational safety, employment literacy and technology literacy. These standards prepare students for the “real-world” that middle school students so eagerly yearn for (Caught in the Middle, 1987).
Rationale

In addition to the identified curricular needs stated previously, the other emphasis of this project will be the responsible use of technology. There is a growing need within the educational community to prepare students to be responsible and contributing members of a technologically oriented society. Students should be taught the social consequences of technology, both its good and bad sides (Grauman, 1993), because the way our society chooses to use technology will determine the quality of life for current and future generations. In order to create a better future for today's students, the symbiotic relationship between the economic and environmental concerns of America should be taught within the educational system.

During the last 100 years humankind has made enormous technological advancements, which have led to increased economic progress for the world's industrialized nations. However, during this same time period, the world has witnessed numerous ecological disasters. According to Higgins (1975), of

the seven enemies of mankind: six were population explosion, food shortages, resource scarcities, environmental degradation, misuse of nuclear capabilities, and uncontrolled technology. The seventh enemy was the nature of humanity itself, and he was pessimistic. (Smyth, 1995, p. 7).
All of Higgin's "enemies of mankind," revolve around the use and misuse of energy. For without the production and utilization of energy, humankind would not have been able to develop such a high standard of living, which has been embraced by North Americans. The modern way of life depends heavily on fossil fuels to produce electricity, to provide transportation, and to fuel industrial and agricultural production. By relying on fossil fuels, societies around the world are endangering the global environment. "Carbon dioxide emissions resulting from the burning of fossil fuels—especially coal—are huge contributors to the rising risk of climate change, and they are projected to increase relative to other greenhouse gas emissions." (Krozloff, 1994, p. 4). Increased levels of carbon dioxide may also decrease agricultural production, increase ocean levels, interfere with ecosystems and cause widespread human suffering (Vogel, 1990, p. 1).

Due to the increasing evidence of global degradation related to the use of fossil fuels, students should be taught about alternative forms of energy. Alternative forms of energy, such as wind, solar, and hydroelectric energies can serve the needs of people with less adverse affects to the environment. Among these, solar power seems to have the greatest potential as an energy source, because "solar advocates point out that this energy source is nonpolluting, poses few environmental risks, will lessen the world's dependency on fossil fuels, and will create many more jobs than other energy sources." (Vogel, 1990, p. 3).
general public is to see the benefits of using solar electricity, they must be informed about solar technologies. “Through better understanding, the public will be in a better position to judge the relative merits of solar electricity, consider using solar powered devices in their personal lives, and advocate its wider acceptance in society.” (Vogel, 1990, p. 4). One of the best ways to achieve this goal is to teach the next generation about the advantages—as well as the disadvantages—of solar power. Research has shown that “…early attitudes and knowledge shape the later thinking of adolescents and adults…” (Leeming et al., 1995, p. 23).

To help meet the needs for a curriculum that fosters technology education/literacy, career awareness, and environmental education, the author developed a software program and an ETE curricular unit. The title of the software is Solar Energy: an Attractive Alternative, and the ETE curricular unit is titled Solar Power Curriculum (SPC).

The student-centered activities from SPC were designed to develop engineering techniques that reinforce math and science, and at the same time, promote environmental awareness. These academic, vocational, and moral skills are critical for the future success of our students. In addition, they will enable students to contribute to the social and economic well-being of our nation. By working with the SPC, students are expected to learn engineering skills. For example, students will produce a small and efficient solar-powered vehicle using integrated math and science concepts, such as energy, gear ratios, distance and MPH.
formulas, power transmission, and aerodynamics. Students are also expected to acquire aesthetic judgment when it comes to creating an esthetically pleasing finished product, in which form follows function. Finally, students will be taught moral reasoning through the concept of responsible energy management, with the aid of solar energy.

Through the SPC’s computer-assisted instruction and hands-on activities, students will be introduced to real world problems that can be solved with technological solutions. The SPC addresses many of the key elements of educational reform stated in Goals 2000. The SPC will provide teachers with student-centered learning activities designed to develop collaboration and critical thinking skills. Upon completion of the SPC, the student(s) will be able to complete six objectives: 1) to describe the difference between renewable and non-renewable energy sources, 2) to explain at least three different applications of solar power, 3) to design, test and build a small solar-powered vehicle, 4) to describe two advantages and two disadvantages of utilizing solar power, 5) to identify several career options in this field, and 6) to demonstrate communication skills through written and verbal expressions. In order to meet these objectives, the SPC curricular materials were designed to be technology based, to include hands-on activities, and were structured according to constructivist learning theory.
CHAPTER TWO

Literature Review Introduction

If the Solar Power Curriculum (SPC) is to achieve the objectives stated at the end of chapter one, it must be structured according to current standards in environmental education (EE) and exploring technology education (ETE); be rooted in constructivist learning theory; and introduce technology in the curriculum. As a result of a review of current educational literature, this chapter will show the link between these objectives and the design of the SPC. This chapter will first present the rationale for widespread use of renewable energy sources, and advocate the use of solar energy. The next section will introduce the concept of sustainable development, and how this concept fits into the Environmental Education arena. Then, the effectiveness of Computer Assisted Instruction (CAI) will be examined. Finally, the learning theory of constructivism will be introduced, and related to the Solar Power Curriculum (SPC), CAI, EE, and ETE.

Renewable Energy Sources

As of 1992, the renewable energies: biomass, wind, solar, geothermal, and hydroelectric (also referred to as renewables) accounted for only nine percent of the energy production in the U.S. "If current policies and market
trends persist, their share will not exceed 11 percent by 2010, even though the United States would benefit—both environmentally and economically—from increasing its reliance on renewable energy" (Kozloff, 1994, p. 4). There are many economic and political reasons for this nation's lack of interest in alternative energies: renewables are developing technologies; there are difficulties in finding suitable sites; local communities bear the financial burden, and renewable energy sources are a long-term investment.

These factors can be overcome through a cohesive sustainable energy strategy that includes a heavier reliance on renewables. A sustainable energy policy would: encourage energy conservation, environmental protection, renewable energy development, and increased efficiency of existing energy sources. In order for this to be successful, a new energy policy must be endorsed by the state public utilities commissions (PUCs). The PUCs should provide financial incentives to the producers and consumers of renewable energy. If the local PUCs rewarded those who produce and consume renewables—in the form of tax breaks, subsidies, and/or energy credits—a sustainable energy policy could be developed. In addition, monetary incentives must be made available to investors from non-governmental financial institutions, for no technology will ever be successful without investment from the private sector. Unfortunately, there is not enough financial motivation for private investors to back alternative forms of energy, because they are such high-risk investments.
By using renewables as part of a sustainable energy policy the U.S. could improve the quality of its environment, for most renewables cause less pollution than conventional energy sources. At the same time, renewable energy use will help save the world’s dwindling oil supplies. If reliance on fossil fuels continues, the nation will have to use its untapped domestic supplies of oil, and many of these are located near or on pristine national parks and refuges. Furthermore, continued use of fossil fuels will increase the nation’s reliance on undependable foreign sources, which affects our country’s security. Currently, the United States uses about one-fourth of the world’s oil reserves to produce energy, and this figure is expected to rise (Wilbanks, 1994). As a result, we are the main contributor to greenhouse gas emissions, which contribute to global warming. Fossil fuel emission "... accounts for about three-quarters of global carbon dioxide emissions and more than one-half of total greenhouse gas emissions..." (Wilbanks, 1994, p. 16).

In order to reverse this trend, increased use of renewable energy sources can help to retard the effects of global warming, by reducing the amount of greenhouse gasses released into the atmosphere. Renewable energy can also be used to help reduce the costs of honoring the 1992 climate change convention held in Rio de Janeiro.
"...The Earth Summit at Rio, and the anxieties incurred by well-publicised disasters such as Bhopal and Chernobyl or by the unpredicted effects of pollutants such as CFCs and oestrogenic chemicals, have raised the level of demand for action." (Smyth, 1995, p. 14).

Environmental education is one way to respond to public outcry regarding environmental issues, and to prevent potential environmental disasters that will inevitably be repeated in the future. Public opinion is beginning to influence policy makers to create a paradigm shift from societies based on economic-gain, to a global village which emphasizes environmental-sustainability. Therefore, there is a great need to convince the next generation of the importance of responsible energy management. Moreover, if today's students become environmentally conscious energy consumers as adults, they may be willing to pay higher energy bills to support renewables for a clean and healthy environment.

**Sustainable Development and Environmental Education**

One way to achieve an environmentally responsible society is through Environmental Education for all citizens of the world. In 1980, the ICUN (World Conservation Union) developed the World Conservation Strategy. "It was based on three requirements: the maintenance of life-support systems, preservation of genetic diversity, and the sustainable use of natural resources." (Smyth, 1995, p. 11).
The World Conservation Strategy advocates prevention of environmental disasters as opposed to dealing with the aftermath. In addition, it calls on people at the community level to actively participate in managing their own environments.

This view sees mankind as part of the environment, and encourages conservation via sustainable development. The sustainability approach to the environment is proactive and holistic. However, throughout Western history, mankind has used the reductionist approach, which characterizes man as the controlling force within his environment. By contrast, an environmental sustainability philosophy sees humankind as embracing the natural world.

A major part of the environmental sustainability vision is Environmental Education. Sustainable development is a relatively new approach to EE.

... The new Generation of Environmental Education include all people being involved in solutions (not just environmentalists and educators), emphasizing harmony with our descendants (rather than with ‘nature’), ethics relating to behavior between people (rather than environmental ethics), the social sciences and humanities as the main subject matter (rather than natural sciences), sustainable use as a man created measurement (rather than nature-centered), emphasis on equality between people (no such emphasis). (Breiting, 1993, in Smyth, 1995, p. 13).

This vision of EE emphasizes people as part of the system, and recognizes that through education, people can change their relationship with the environment. But, just because people are knowledgeable about the environment, does not mean that they will take action to preserve it.
Research shows that people are more likely to take environmental action if they are knowledgeable about environmental issues (Leeming, et al. 1995, p. 23). People are also more likely to be influenced by what others do, and the media. As a result, educators need to be "environmentally-literate" and be prepared to present both sides of an issue equitably.

The SPC advocates environmental awareness and responsibility by providing teachers and students with current, non-biased information. Furthermore, the SPC will deliver Environmental Education concepts through CAI, cooperative learning, and project-based learning activities. In addition, it will reflect the recent advances in CAI techniques and multimedia technology.

**Computer Assisted Instruction (CAI)**

Computers and other instructional technologies are now commonly infused throughout this country's educational system. Therefore, "as teachers, we need to be conscious of the cultural, political, economic, and technological environment in which we nurture our successor generations" (Murphey, 1995, p. 510). Educators must be aware of the needs of their students, and be willing to meet those needs to the best of their ability, by using a variety of instructional techniques and tools. Educational practices and technologies have changed dramatically since the days of the one-room school house.
Today, one of the most promising new educational technologies is the computer. However, in order to integrate the computer and related technologies into the classroom effectively, teachers must understand that computer assisted instruction (CAI) should be infused into their existing curriculum, instead of replacing it.

Computer assisted instruction should support and reinforce the teacher's curriculum. CAI is the term used to describe any instructional application of computers, from a stand alone computer to complete course delivery on a network of computers (Venezky & Osin, 1991). The latest innovation in the field of CAI is multimedia, which is "...the seamless digital integration of text, graphics, animation, audio, still images, and motion video in a way that provides individual users with high levels of control and interaction" (Dyrli & Dinnaman, 1995, p. 46). For example, computers equipped with multimedia technologies can create authentic learning environments in the classroom through multimedia. Current research at Vanderbilt University and the University of Connecticut is beginning to provide evidence that multimedia technology can be used to link classroom instruction to real-world activities (Dyrli & Kennaman, 1995). As a result, educators should consider the use of multimedia based CAI to supplement classroom instruction wherever possible.
Advances in educational technology have made it possible for teachers to help motivate students to learn, to meet the needs of students with different learning styles and abilities, and at the same time achieve curriculum objectives. In any type of learning environment, the following essential principles of learning should be addressed: motivation, feedback, pacing, repetition, variety, and active participation (Terrel, 1994). Today's computers are capable of delivering these learning principles.

Students can be motivated to continue if they are successful in four out of five learning attempts. For example, with sophisticated software teachers can adjust the level of difficulty in order to challenge each student according to his or her ability. Motivation can also be increased if students receive immediate feedback, which today's computers are capable of doing. Furthermore, students should be taught in small incremental steps while gradually increasing the level of difficulty. Computers can deliver immediate feedback, and can be programmed to increase or decrease the level of difficulty. In addition, computers equipped with multimedia technology can help meet these challenges. For example, learners should have the subject matter repeated in different ways, if they fail to master it the first time. Here again multimedia technology allows students to "... explore topics in the way that the human mind works, rather than the way textbooks deliver information." (Solomon, 1992, p. 329).
With a multimedia equipped computer and graphic user interface, a student can intuitively navigate through a CAI program at his or her own pace, and decide which path to pursue according to the information branches available in the software. Finally, students should be actively engaged in their learning, for one learns by doing. Computers allow students to actively participate in their learning, as opposed to learning passively, where the student is only an observer or a listener. "Classrooms equipped with well prepared teachers who are skilled in instructional technology will greatly facilitate more efficient application of these essential principles of learning." (Terrel, 1994, p. 9).

**Research and Computer Assisted Instruction**

"In the view of most researchers..., numerous studies have...generally found that computer-based instruction produces significant gains in test scores. And, it appears to improve student satisfaction and participation." (Templin, 1995, p. 24). Apple computer's scientist David Dwyer says that students typically make 10%-15% gains in test scores through the use of CAI, and students can take up to one-third less time to complete written assignments (as cited in Templin, 1995, p. 24). According to SRI, a non-profit research group, sixteen out of seventeen teachers from across the U.S. reported students were "more willing to work more intensely and more willing to revise their
writing" (as cited in Templin, 1995, p. 24). Computer use by students has also been found to increase motivation and creativity (Sakamoto 1992, and Sakamoto 1993).

A meta-analysis of 31 studies conducted over a 20 year period found that the Effect Sizes (ESs) for students using computers were positively related to the use of CAI (Liao, 1992). Seventy-four of these research reports found that ESs were "...positive and favored the CAI group, while 26% of them were negative and favored the non CAI group" (Liao, 1992, p. 373). Furthermore Liao's (1992) meta-analysis found that students who used CAI, generally scored 18% higher on different cognitive ability tests. These findings suggest that students can increase their cognitive skills through CAI.

On the other hand, critics of technology in the classroom claim that the research on CAI has been inconsistent. The SRI report found that the computer does not guarantee success for all students in all subjects. "In one school using computers, the math scores of lower-performing students rose, while declining slightly for above-average students." (Templin, 1995, p. 24). Miller and McInerney (as cited in Templin, 1995) who studied 289 fourth and fifth grade students who were given home computers, found "no significant difference between the two groups." "If people think they are going to put technology in and raise test scores, technology alone will not do that." (Miller, as cited in Templin, 1995, p.24). Moreover, most research conducted on students using computers is done in
"... well run computer programs with clear objectives which often isn't the case with other schools." (Templin, 1995, p. 24).

On the other hand, what the critics of CAI cannot ignore is the fact that computers and technology are here to stay. As a result, there is a need for today's students to become computer literate, because they will be living in a society that requires its citizens to conduct business with current and future technologies. Therefore, educators need to infuse computers throughout the various disciplines whenever and wherever possible.

Infusion is a unique approach to curriculum construction which uses the structure of existing disciplines. In this case it would involve teaching a segment of the computing curriculum wherever it applies within existing academic disciplines. (Alexander, 1991, p. 68).

The evidence supporting educational technology at present, suggests technological media can produce gains in learning. But, meta-analysis on the effects of technological media on learning has been inconsistent. The reason for this may be that the method of instruction is what leads to direct and powerful learning, and not necessarily the media itself (Clark & Sugrue, 1995).

Moreover,

even in the few cases where dramatic changes in achievement or ability were found to result from the introduction of a new medium such as television or computers, it was not the medium per se that caused the change but rather the curricular reform that accompanied the new medium (Clarke & Sugrue, 1995, p. 354).
Therefore, it is imperative for schools to reform existing curricula, to reflect new advances in instructional technology.

The research also reports that computers can help students become active and motivated learners. Since the early 1980s research has shown that learning improves when learners take active, not passive roles. (Disinger, 1984, p. 5). Over fifteen years later, this still seems to apply. One way to increase active learning is through cooperative learning. The Secretary's Commission on Achieving Necessary Skills (SCANS) report--from the U.S. Department of Labor--recommends collaborative skills as among the most critical for the 21st century workplace. The SCANS report also stated the importance of students being able to use and understand technology. When computers are combined with cooperative learning, the potential for learning increases dramatically. "Technology allows kids to do things in ways they could not do before, and that gets added to the group process;...it builds on the best of both worlds." (Strommen, 1995, p. 33).

For computers to be utilized to their full potential, they should be combined with current instructional practices and theories. For example, CAI should be integrated into interdisciplinary student-centered projects. These projects also need to develop collaborative problem solving skills. If technology projects meet these requirements, the result can become a very powerful CAI application. "Experienced educators tend to agree that students learn best through a
project based approach, in which they are able to discover things for themselves." (Graumann, 1993, p. 25). Teachers who integrate technology with long-term, collaborative projects report that this approach fosters enormous potential for effective instruction and learning. For example, Science teachers can use technology to simulate traditional lab experiments, present science with less intimidation, and increase hands-on learning (Wygoda & Cain, 1994). At the same time, students work in cooperative learning groups to create team-building skills to solve problems that involve the scientific method.

Schools that use technology as part of project-based activities are becoming more commonplace in the U.S. For example, in Vermont, all junior high schools are required to offer courses in technology. However, remote rural schools cannot afford expensive technology programs. So Tom Keck, who is funded by the National Science Foundation, travels to these remote schools to engage teachers and students with his technology learning projects. "The common ingredient in all of these experiences is the necessity for students to be methodical yet creative" (Graumann, 1993, p. 25). Keck also keeps his lectures to a minimum, and discusses both sides of any social-technological issue. Educators who combine technology and cooperative learning to create open-ended learning activities, generally recognize that this approach fosters problem solving and critical thinking skills.
The ETE curriculum model provides middle school students with the ability to create their own learning experience. Students work cooperatively in an ETE lab, to complete self-paced learning activities that emphasize: past, current, and future technologies. The teacher acts as a facilitator of knowledge, and offers assistance only when all members of the group fail to find a solution. If this occurs, the teacher will tell the student(s) where the answer can be found, instead of simply providing the answer for them. This way it is the group's responsibility to find their own answers. As a result, students are responsible for their own learning, which is one of the goals of ETE.

Therefore, the SPC will utilize this student-centered approach to learning and instruction. Students will work collaboratively to: build and test their solar-powered vehicles, and complete the CAI package. Finally, the students will share their experiences with the class to develop public speaking and communication skills, which will be necessary for their future success in the information age.

Constructivism

Chapter One discussed the implications of EE, CAI, cooperative learning, project-based learning, and ETE as they relate to this project. The SPC brings all of these elements together to educate middle school students about sustainable energy management through solar energy.
This project-based approach to education can be applied as a model for constructivist teaching and learning. The foundation for the learning theory of constructivism centers on the belief that learners create or "construct" their own meaning. In other words, "to learn meaningfully, individuals (must choose to) relate new knowledge to relevant concepts and propositions that they already know." (Robertson, 1994, p. 23). This chapter will discuss the merits of constructivist theory and how constructivism relates to: CAI, EE, ETE, and the Solar Power Curriculum

**Empiricism and Objectivism**

In order to validate this MA project, the author will now examine the educational literature and research that is related to the SPG. Educational research is a new field of inquiry, that was originally modeled after scientific research. Scientists have traditionally embraced the positivist-empiricist view of knowledge. This viewpoint defines knowledge as that which can be proved through the senses. For example, in order to validate a theory a researcher must prove his or her hypothesis via empirical research. According to empiricists, a theory must be proven by research that can be duplicated, and subsequently confirmed by other researchers within a professional community.
This quantitative world view of empiricism has dominated the sciences since the turn of the century. Similarly, objectivism has also followed this model for educational research.

Instruction in this country has, for the most part, followed the objectivist tradition. The goal of learning from an objective standpoint is for learners to gain a shared understanding of the world. Objectivist instruction is based on transmitting this shared knowledge from the external environment (Jonassen, 1991). This viewpoint holds that knowledge exists outside the learner. Therefore, it is the teacher's job to interpret the world for his or her students. Learning will occur if: the student pays close attention, practices and, then demonstrates mastery (Duffy & Jonassen, 1991). In order for a student to demonstrate mastery, he or she must typically pass an objectives-based test. This type of assessment is separated from instruction (Jonassen, 1991). By contrast, from a constructivist standpoint, assessment would typically be embedded within instruction.

Behaviorism is a classical example of empirically-based objectivist research. The Behaviorist school of psychology attempted to apply the natural sciences to the social sciences in order to explain human behavior. A behaviorist view of learning would state: "to educate is to cause change in behavior along prespecified objectives." (Gowin, as cited in Robertson, 1994, p. 22). Educators have typically followed this behavioral approach to objectivist lesson
planning. Today, many teachers still utilize the objectives-based lecture for instruction, which is rooted in behaviorist philosophy. "Yet, the most common behavior in schools, the listening of pupils, is not observable." (Gowin, as cited in Robertson, 1994, p. 24).

**Cognitivism**

By contrast, constructivist education provides a learning environment where the learner can inductively process information to construct meaning, and to link new experiences to prior learning. Constructivist theory is based on two principles:

1) knowledge is not passively received but actively built up by the cognizing subject.

2) The function of cognition is adaptive and serves as the organization of the experimental world, not the discovery of ontological reality. (Von Glasserfeld, as cited in Robertson, 1994, p. 23).

Constructivism is based on cognitive learning theory, which is "less reductionist, more holistic, and concerned with the developing mind and its organizing cognitive structure (Bourne, as cited in Cooper, 1993, p. 16). In the last three decades behaviorism lost ground to Cognitive theory. This is because behaviorism failed to take into account differences between individual learning styles (Cooper, 1993). Cognitive learning theorists recognize that learners have different cognitive styles and strategies for interpreting stimuli from their environment.
Central to the notion of cognitive analysis is a model of the internal workings of the mind, the identification of functional components to handle information, filtering, storage in short-term memory, semantic encoding for storage in long-term memory, and retrieval when required (Cooper, 1993, p. 14).

The constructivist theory of learning derives much of its structure from Piaget's theory of cognitive psychology. The Swiss psychologist Jean Piaget developed three concepts of how the brain processes information: schemata, assimilation, and accommodation. Schemata are the mental strategies that an individual uses to classify experiences and information into categories. When a person is confronted with a new learning experience, he or she integrates the information into existing schemata through assimilation. Assimilation is the process by which one adds new learning and experiences into their schemata. As we gain experience, our ways of processing information become more abstract, and our schemata changes to comprehend new stimuli. This mental process is called accommodation. If a person cannot assimilate a new concept, then one of two forms of accommodation come into play

1) The learner can create a new schema into which the new stimulus is placed.

2) The existing schema can be modified so the new stimulus will fit. (Heinich, et al. as cited in Robertson, 1994 p. 23).

Piaget developed a theoretical model for how the human mind develops critical thinking skills. However, he was criticized by behaviorists for attempting to probe the inner workings of the brain.
In contrast, behaviorists concentrate only on observable behavior to prove learning has occurred.

Both behaviorism and cognitivism have implications for good instructional design. For example, behaviorist methods of instruction work well for individualized instruction, lesson planning, teaching basic skills, (e.g. computation) and to teach psychomotor skills (e.g. keyboarding). However, behavioristic instruction is not well suited for developing problem solving and collaborative skills. Therefore, the author has chosen to concentrate on the cognitive nature of constructivism. The constructivist model of education can help students to acquire cognitive skills. As a result, the SPC will attempt to develop cognitive strategies through CAI and hands-on activities.

**Constructivism and Environmental Education**

Constructivist theory can also be applied to the field of environmental education. Within our public school system environmental education is most frequently infused into the existing science curriculum, instead of being taught as a separate subject. This is because the nature of EE lends itself to the "hard" sciences. However, many students have misconceptions about scientific theories, and as a result, attempt to construct meaning based on misinformation. The aim of Science Education is not about students developing their own theories (Millar, as cited in Robertson, 1994, p. 25). Instead, Science Education should allow students to be "initiated into the 'ways of seeing' which have been
established and found to be fruitful by the scientific community" (Driver, as cited in Robertson, 1994, p. 25).

Current research in science education has focused on a postpositivist constructivist epistemology (Robertson, 1994). This research examines how students internalize information based on their prior experiences, following the Piagetian model.

Thus, many researchers in science education have based their research studies on Ausubel’s statement ‘the most important single factor influencing learning is what the learner already knows. Ascertaining this and teach him accordingly.’ (Ausubel, as cited in Robertson, 1994).

As a result, science educators should be focusing on the human constructivist paradigm (Novak 1987, in Brody, 1991, p. 26). This paradigm assumes that a child’s cognition stems from his or her current interpretation of the present environment, and how these conceptualizations form the basis for acquiring new knowledge (Brody 1991, p. 26). Therefore, EE curriculum must be designed with the existing knowledge that the student brings to the learning environment, in order to foster the creation of new learning and cognition.

Constructivist theory receives little attention in EE literature. However, it can serve as an effective model for developing EE curriculum. Constructivism implies that knowledge is created by the learner. Consequently, instructional design should be learner-centered, because the student is ultimately responsible for his or her learning. As a result, constructivist learning theory presupposes that “no one true reality exists, only individual interpretations of the world.” (Klein & Merrit, 1994, p. 15).
Therefore, different people have varying degrees of motivation for learning. Consequently, students need to be motivated to learn about environmental responsibility. The ultimate goal of EE is to motivate students to take positive environmental action (Volk, as cited in Klein & Merritt, 1994). Therefore, in order to be effective, Environmental Education needs to engage students in learning using hands-on activities, the scientific method, and multidisciplinary modes of instruction. Students should not be passive receivers of information. Instead, they should be actively constructing meaning from existing knowledge, in order to make informed decisions regarding our environment.

**Science, Technology, and Society**

In addition to constructivism, Science, Technology, and Society (STS) is an important concept that is beginning to be addressed in EE literature. This issue regards these three constructs as being inseparably linked in today’s world. “If science educators are to adopt modern paradigms for curriculum development, such as Science, Technology, and Society or Human Ecology paradigms, they must consider the multidisciplinary nature of children’s conceptions of the world in which they live” (Brody, 1991, p. 26). Moreover, it is important for everyone who lives in a democratic society to realize that the relationship between Science, Technology, and Society affects the quality and biological diversity of their environment. “This is important for all
citizens who are directly affected by STS through their environment and not the 2% of the population in science-related fields" (Yager, as cited in Robertson 1994, p. 26).

**STS and the Solar Power Curriculum**

The SPC will focus on STS in accordance with the schools of education discussed in this paper: EE, CAI, and ETE. For example, middle school students will be presented information, through student-centered activities, about how scientists and technologists have developed traditional forms of energy—such as the burning of fossil fuels—during the course of the SPC. The SPC will also present information about how alternative forms of energy—such as solar power—have been developed to decrease our reliance on fossil fuels. The inherent advantages and disadvantages of both types of energy production will also be included in the curriculum. Finally, the SPC will explain how solar energy can be utilized to help supply the energy needs for different societies of the world. At the same time, the SPC teaches students about how a better quality of life can be achieved for humans and their environment via solar technologies, due to their environmentally friendly natures.
Computer Assisted Instruction and Constructivism

The Solar Power Curriculum has been developed according to: environmental education standards, constructivist learning principals, and CAI design models. As stated earlier, both objectivism and constructivism have applications for CAI. The first technology based programs were rooted in behaviorism. Behavioristic software is task-based and functions under the stimulus-response model. Feedback is provided by informing the user of his or her correct and incorrect responses. These types of programs have been shown to be effective for developing basic skills, and for students with low academic skills (Cooper, 1993). Behavioristic software programming is typically linear, and the student advances from frame to frame as he or she masters each level of difficulty.

Behaviorist attributes are found in most technology-based instructional applications in the learning of small chunks of material related to a single skill and the use of reinforcement through reward. Golub (1983) suggests that behaviorally based instruction seems most useful for clearly delineated content where the branching is constrained and learner responses are categorized as right or wrong. (Cooper, 1993, p. 13).

By contrast, CAI that is developed according to constructivist learning theory allows the user to intuitively navigate through the software at his or her own pace. This type of instruction is non-linear, and the user can access information through hypertext. Hypertext is "when words are keyed or indexed to other words," or when "sections, and thoughts are linked together, the user can
navigate through text in a nonlinear fashion, quickly and intuitively" (Vaughn, 1994, p. 228). For example, with a click of the mouse, the user can access new information. Additionally, the user can also access information that is presented in greater detail. Moreover, information may be displayed in a variety of ways including: text, illustrations, photos, animation, or video. Hypertext allows the user to make connections between webs of information. With hypertext "...content is automatically re-edited to produce a particular kind of crisscrossing of the conceptual landscape that visits a large set of case examples of a given conceptual structure in use" (Spiro et al., 1991. p. 30). Hypertext lets the user determine which information path to follow. If the user determines that the chosen path is not productive, he or she can change navigational paths. "That is, the instructional content is re-edited upon demand to present just those cases and parts of cases that illustrate a focal conceptual structure (or set of conceptual structures)" (Spiro et al., 1991. p. 30). However, the learner can become lost in a labyrinth of unnecessary information. Therefore, the student must be provided with an intuitive and graphically explicit interface. The software’s interface serves as the user’s navigational system within the software program. A typical CAI user interface allows the user to traverse a piece of software using familiar icons such as directional arrows and universally recognizable symbols. These graphic icons are controlled by using the computer keyboard or mouse.
This type of software supports a constructivist theory of learning, because the user can examine and re-examine any part of the program that he or she chooses. In the process the learner constructs his or her interpretations of the information based on that person's unique learning style. This type of software has only recently been made possible, for the complexity of hypertext requires mass storage and memory capabilities that have only been made available within the last five to ten years.

In addition to hypertext, computers can also support a constructivist learning environment by enabling students to interact with images as well as text. In order for learners to construct their own meanings, they should be offered a wide variety of stimuli to account for differences in learning styles. Therefore, there needs to be a "shift from verbal thinking to the integration of visual and verbal thinking." (Bagley & Hunter, 1992, p. 25). Computers can provide this link, because they have the ability to provide the user with a wide variety of images via multimedia. Moreover, images can oftentimes be perceived and retained more readily than textual information (Pavio, as cited in Bagley & Hunter, 1992, p. 25).

Constructivism and Instruction

Computer assisted instruction should be integrated into an instructional sequence whenever possible. Constructivism supports an open systems view of instruction that is less
defined by objectives, and one that is open to student and teacher initiatives (Wilson, 1995). This type of instruction is dependent upon context-based learning supported by appropriate resources including, but not limited to: instructional tools, classmates, the teacher, texts, charts, and instructional technologies. An ideal learning environment for constructivism would provide students with a variety of resources. Students should be able to choose among different resources to solve problems in the classroom. Through the problem solving process, students begin to make sense of the world around them, and start to make connections with real-world problems and solutions. This type of learning environment fosters knowledge construction by providing a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuit of learning goals and problem solving activities. (Wilson, 1995, p. 27).

When using this model for constructivist learning, the teacher must provide sufficient support and guidance to the learners. This type of task management must include appropriate feedback and directional changes (Wilson, 1995). Usually, this is been the role of the teacher, but in a constructivist learning environment, students are expected to be more responsible for their learning. However, some teachers may have a problem with allowing students to control the learning environment, as individual students need different amounts of assistance at various times. However, the teacher can accomplish this task by having
students work in cooperative learning groups. This way students can help each other, or consult other resources in the class to solve their problems. With this type of classroom management, the teacher can monitor and assist each group, and offer help when necessary.

**Constructivism and Computers**

In a constructivist learning environment, the computer should be one of the primary resources available to students. The computer can provide a self-contained learning environment that can stand alone, or be supported by a larger classroom environment (Wilson, 1995). One way a computer can be used constructively is to program it to function as a "construction-kit." Examples of familiar construction kits include: Lego sets, Tinker Toys, Erector Sets, and the like. Computer software can also serve as a construction kit, for with a computer, "...learners can assemble not just things, such as Tinker Toys, but more abstract entities, such as commands in a programming language, creatures in a simulated ecology, or equations in an environment supporting mathematical manipulations" (Perkins, 1991, p. 19).

Another application of CAI that supports knowledge construction through the use of computer software is called a phenomenarium, which is a type of computer simulation. Perkins (1991) describes a phenomenarium as being an area where the learner is exposed to real world situations that
can be scrutinized and manipulated via the simulated experience. Examples of phenomenaria include: aquariums, experimental lab equipment, simulation games, and computer simulated micro worlds. "The key idea is that aspects of the world are brought and made available to student inspection and exploration" (Wilson, 1995, p. 28).

The computer can serve as a vehicle to deliver a phenomenarium by providing a simulation to the user that may otherwise be impractical or dangerous. For example, a flight simulation program can give one the feeling of flying an airplane without really doing so. However, it is not possible to develop a software program or classroom environment that can replace the real thing.

Therefore, "it seems more likely that schools will benefit from environments that support a wide variety of different tools, including simulations, construction sets of all kinds and communication tools that extend the community of practice to include participants beyond the school walls" (Morrison & Collins, 1995, p. 44).

In order to facilitate individual knowledge construction, constructivist instructional designers should structure the learning environment to accommodate learners with a wide variety of stimuli and instructional techniques. One of the most fundamental premises of constructivism is the view that each individual interprets the world differently. Therefore, the author has structured the 'Solar Power' curriculum according to constructivist learning principles.
Constructivism and the Solar Power Curriculum

The instructional sequencing for the student-centered activities of the Solar Power Curriculum will begin with students using the CAI software developed for this project, which will provide a foundation for further knowledge construction related to the field of solar energy. This is followed by a class discussion about the different concepts of solar energy that were presented in the software. Students are then shown a video about solar energy, followed by a class discussion. Then another video is shown, that introduces students to how they can make their solar powered vehicles in the technology lab. The teacher then leads a class brain-storming session, in which students are asked to share ideas with each other about how to best go about building a model solar powered car. The students are divided into teams of two or three to design, build, and test their vehicles. At this point, the teacher provides the class with different resources for the students to choose from to carry out this task. Throughout the instructional unit, students can choose from a variety of resources including, but not limited to: computer software, informational handouts about solar vehicle construction and physics principles, videos, CD-ROMs, tools, machines and materials. All the while students are encouraged by the teacher to share: designs, ideas, successes, and failures with each other. One way to achieve collaboration is to have students demonstrate their progression through
regularly scheduled "research-summits," where each group reports their progress and experiences to the class. Furthermore, students should be encouraged to share design ideas using outside resources—including their parents—at each stage whenever possible. To make real-world connections, outside speakers who have expertise related to the use of solar energy, should be invited to speak with the class. However,

the context need not be the real world of work in order to be authentic. Rather authenticity arises from engaging in the kinds of tasks and using the kinds of tools that are authentic to that domain (Duffy & Jonassen, 1991, p. 11).

Research has shown that student-centered learning environments, that are embedded in an authentic context, can lead to significant transfer of learning. (Sherwood, Kinsner, Bransford & Franks, as cited in Duffy, 1991, p. 11). Furthermore, “teachers and students need to be genuinely engaged in and reflecting upon authentic exploration of the subject matter.” (Brown, Collins and Duguid, as cited in Duffy & Jonassen, 1991, p. 11). The ‘Solar Power’ software and curriculum guide attempt to create a constructivist learning environment by engaging the learners in knowledge construction via CAI and hands-on activities that are project-based. In doing so, the SPC will assist in addressing the needs for restructuring education. Hixton and Jones (1990) named five strategic issues about restructuring schools:

1) Schools and teachers need to make use of a variety of instructional resources.
2) There must be a recognition that the design and delivery of instruction has to reflect changing needs of individual students.

3) Classroom environments have to be altered to foster more personalized and collaborative learning.

4) Schools, workplaces, and the community have to be linked.

5) There is a need for a revised curricula along with a realistic assessment (Bagley & Hunter, 1992, p. 22).

**Constructivism and Assessment**

Thus far all of the above descriptions for restructuring schools have been addressed by the SPC, except student assessment. This is because assessment is one of the most difficult aspects of constructivism. “If each individual is responsible for knowledge construction, how can we as designers determine and insure a common set of outcomes for learning, as we have been taught to do?” (Jonassen, 1994, p. 35). One way to solve this problem is through authentic assessment that is embedded in—rather than separated from—instruction. What is needed is “a shift from assessment based on test performance to assessment based on products, progress, and effort” (Bagley & Hunter, 1992, p. 25). However, these types of assessment are hard to measure quantifiably, which “…make them less useful for driving performance-based systems and processes” (Wilson, 1995, p. 26). Reliance upon standardized testing has almost always been the number one measure for student success. In order for educational restructuring to be
successful, reliance on objectives-based testing should be supplemented with constructivist methods for assessment. Because, “students in restructured schools will be responsible for demonstrating understanding not just memorizing ideas” (Bagley & Hunter, 1992, p. 25).

**Authentic Assessment**

One way to develop a reliable measure of achievement from a constructivist learning environment is through authentic assessment techniques. “Authentic tasks are those that have real-world relevance and utility, that integrate those tasks across the curriculum, that provide appropriate levels of complexity, and allow students to select appropriate levels of difficulty or involvement” (Jonassen, 1991, p. 29). Examples of authentic assessment include: portfolios, journals, logs, and formal oral presentations. All of these types of measures are subjective in nature, but they can become objective, if expectations are clearly articulated and negotiated.

Because learners interpret the world somewhat differently, the outcomes of learning will vary somewhat, and so objectives, if they are useful at all can best be used as a negotiating tool for guiding learners during the learning process and for self-evaluation of learning outcomes” (Jonassen, 1991, p. 32).

To accomplish the goal of meaningful assessment an individual portfolio should be created for each student and it should include several products,
By evaluating a variety of student work samples, the assessment is more realistic. By contrast, objectivist assessment techniques typically use only a single product, such as an objectives based true-false/multiple-choice test. Here again, the authentic assessment process is more subjective than objective, on the part of the teacher. In order to reduce subjectivity, Jonassen (1991) recommends using a panel of evaluators to obtain the most authentic measure from a constructivist learning environment. Moreover, it need not be a panel of experts to be successful. "A mixture of experts, novices, and journeymen, may be the most useful mix of evaluators of learning products" (Jonassen, 1991, p. 31).

**Solar Power Curriculum Assessment**

The authentic assessment approach will be utilized for the SPC. For example, the recommended procedure for student assessment will be threefold: 1) through individual portfolios, 2) through teacher assessment, and 3) through panel assessment. Students will be required to keep a daily journal outlining his or her progression throughout the instructional sequence. It will be the teacher's responsibility to schedule approximate due dates for all of the above, and to make this an integral part of the curriculum.
As a culminating event, students will be required to give a final presentation to the class, which must be written and rehearsed. The presentations will be evaluated by the teacher and students in the class. Students will be asked to evaluate their peers by an agreed upon method, that must be negotiated ahead of time. One way to improve this process, and to add realism, is to include evaluators from outside the classroom. For example, math and science teachers could be asked to participate in the evaluation process. Moreover, if at all possible, community members could be asked to join the evaluation team, which could foster real-world connections outside the classroom walls. If this were not practical, then the presentations could easily be video taped and viewed at the outside evaluator’s convenience. All in all, the SPG can be assessed meaningfully and quasi-objectively, in order to satisfy both the subjective nature of constructivism, and objectivist setting of the public school system.

Summary

This chapter has provided a rationale for the use of solar energy. The author has contrasted the use of renewable energy production with the use of fossil fuel energy production, and solar energy production was found to be the most promising among the alternative energy sources. The advantages of using solar energy can be attributed to its inexhaustibility and environmentally-friendly nature.
Furthermore, solar energy was presented as one method of supporting the concept of sustainable development. Sustainable development is characterized by active environmental protection, and responsible environmental management, at the community level. The concept of sustainable development was also examined as a new conceptual framework for teaching environmental education. Moreover, sustainable development should be taught as an integral part of this nation's public school curriculum. If the public is taught early on about environmental responsibility, future generations will be able to maintain a higher quality of life, which stems from a healthy and ecologically balanced environment.

Computer assisted instruction and its potential as an effective instructional tool were also presented. CAI has been found to increase student motivation, and can support authentic learning environments via multimedia. However, research on CAI has been inconsistent, and this has important implications for educators. Teachers should realize that CAI should be used as one pedagogical method among many instructional delivery systems. Furthermore, CAI can be used to support both objectivist and constructivist learning environments.

Out of these two educational theories, the author has chosen to focus on the constructivist framework. The theory of constructivism lends itself to the development of critical thinking and collaborative problem solving skills, which are the goals of Exploring Technology Education.
Constructivism was analyzed and adapted to provide a conceptual framework for this MA project. Constructivist education supports an open systems view of education, and presupposes that each individual creates his or her own reality. In addition, the main components of EE, CAI, and ETE were integrated into the SPC to develop a student-centered constructivist approach to the concept of solar energy. This chapter will conclude with two narrative charts (see tables 3 and 4), which are designed to assist the reader in synthesizing the main concepts presented.
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<thead>
<tr>
<th><strong>Objectivist Framework</strong></th>
<th><strong>Constructivist Framework</strong></th>
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<td>Shared knowledge is transmitted externally</td>
<td>Knowledge is actively constructed by the learner</td>
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<td>Knowledge exists outside the learner</td>
<td>Cognition is adaptive in the individual's experiential world</td>
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<td>Instructors transmit knowledge</td>
<td>The learner integrates formal and informal learning experiences</td>
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<tr>
<td>Students learn by observation and practice</td>
<td>Students bring ideas, beliefs, values and emotions to new learning experiences and assimilate these constructs to form new schemata</td>
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<tr>
<td>Thought is separated from individual experience</td>
<td>Physical and social experiences determine thought</td>
</tr>
</tbody>
</table>
Structure can be modeled.

Assessment is measured by the attainment of prespecified behavioral objectives.

Emphasis on competitive learning.

Reality is constructed through symbols, which are used as cognitive tools.

Assessment is embedded in the instruction via authentic assessment.

Emphasis on cooperative learning.
Table 4.
Comparing and Contrast CAI, EE, and ETE as Constructivist Models of Instruction

<table>
<thead>
<tr>
<th>Environmental Education</th>
<th>Computer Assisted Instruction</th>
<th>Exploring Technology Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-on learning, field trips and scientific experiments</td>
<td>Electronic webs of information, which the learner can choose from</td>
<td>Use of a wide variety of resources</td>
</tr>
<tr>
<td>Development of environmental attitudes and moral reasoning through interactive instruction</td>
<td>The learner uses intuition to navigate through computer software experimentation</td>
<td>The learning environment encourages experimentation</td>
</tr>
<tr>
<td>Ecological concepts developed from prior experiences</td>
<td>The learner makes connections between information webs</td>
<td>Informal learning provided through independent lab assignments and collaboration</td>
</tr>
<tr>
<td>Sociopolitical knowledge developed by “thinking globally and acting locally”</td>
<td>The learning environment can be simulated to provide context specific instruction</td>
<td>Students draw on individual strengths within their groups</td>
</tr>
<tr>
<td>The goal of EE is to promote environmental action</td>
<td>The goal of CAI is for learners to use computers as a tool to solve problems</td>
<td>The goal of ETE is to develop technology literacy</td>
</tr>
</tbody>
</table>
CHAPTER THREE

Solar Power Curriculum Objectives

The main goal of this M.A. project is to develop a student-centered exploring technology education (ETE) curricular unit, designed to teach middle school students about solar energy through computer assisted instruction (CAI) and "hands-on" activities. In terms of cognitive skills, upon completion of the Solar Power Curriculum (SPC), the student(s) will be able to:

1. describe the difference between renewable and non renewable energy.
2. explain at least three different applications of solar power.
3. design, test and build a model solar-powered vehicle.
4. describe two advantages and two disadvantages of utilizing solar power.
5. identify several career options in this field.
6. demonstrate communication skills through written and verbal expressions.
7. apply problem solving skills.
8. acquire employment skills for the 21st century.
9. explore careers that may be of interest.
10. choose to be environmentally responsible.
11. state how technology can be used responsibly.
12. state the need for alternative forms of energy.
13. state the potentials of solar energy usage.

**Solar Power Curriculum Goals**

The SPC will allow teachers to achieve the following instructional goals:

* meet several exploring technology education (ETE) curricular standards.
* show the relationship between technology education and the academic core.
* reinforce science and math curricula.
* provide experiences that allow students to make the connection between the classroom and the "real world."
* incorporate CAI into a project-based unit.
* introduce environmental education (EE).
* meet some of the key aims from Goals 2000.
CHAPTER FOUR

Design and Development of the Solar Power Curriculum

The Solar Power Curriculum (SPC) is part of the Exploring Technology Education (ETE) framework, which has been adopted by the California Industrial and Technology Education Association (CITEA). The Exploring Technology Education Association—a chapter of CITEA for middle school technology teachers—has developed the following career-technical performance standards for ETE students: biotechnology, communication, construction, machine and tool safety, production, materials, power and energy, and transportation. The SPC incorporates most of these standards, but this curriculum was specifically developed as an eighth grade power and energy unit, to be implemented in an ETE middle school lab.

Prerequisite Skills

As prerequisite, students using the SPC should have a working knowledge of machines, tools, and materials processing. Students should also be able to perform basic communication skills, including the ability to express their ideas verbally, graphically, and in written form. SPC is an introductory power and energy unit; students however should have prior experience of the ETE instructional delivery system, which is described further in the following section.
Classroom Set-up

Teaching in an ETE lab involves dividing the unit into separate learning modules (workstations) that reinforce the ETE performance standards (see Appendix A). An ETE module is designed for two students working together to complete "hands on" learning activities, including those that utilize modern technologies. Students work cooperatively using self-paced instructions to complete assigned learning tasks.

For example, during the course of the SPC, students will complete activities that are outlined in the student syllabus (see Appendix C). The teacher will use group instruction for the main parts of the unit, and students will receive individual instruction as needed. Every student will be assigned a lab partner, and each group will be responsible for completing the SPC requirements in the specified sequence (see Table 5). The SPC is designed as a four week unit (see Appendix D), that introduces students to solar technologies.

Teacher's Role

Throughout the SPC, the teacher acts as a facilitator guiding students through each of the requirements step by step (see Appendix E). Each group of students works independently; when a problem arises, the teacher guides the students on how the answer can be found, instead of providing the needed information. In this way, students are taught to solve problems using critical thinking and collaboration.
Table 5.

Solar Power Curriculum Flowchart

Scope of SPC

The Solar Power Curriculum (SPC) was developed from the Exploring Technology Education (ETE) Career-Technical Performance Standard Number Seven. This standard states: “Students will understand sources and systems of power and energy (e.g. electrical, simple machines, solar, thermal, water, wind). Students will build models/products incorporating different sources” (Exploring Technology Education Association, 1995).

As a unit, the SPC is a collection of activities that address multiple goals and objectives. The SPC is designed to fit a four week time frame in an ETE lab setting. Most ETE labs are equipped with: computers, software, tools, machines, and equipment that is similar to what is currently used by the manufacturing and business sectors of America and other developed nations.

SPC Learning Activities

The SPC is made up of seven major student-centered activities, including a CAI lesson. These activities support the overall goals and objectives of the curriculum, and were designed to meet many of the challenges of educational reform. SPC activities are project-oriented, support collaborative learning, reinforce math and science skills, teach the responsible use of technology, and develop critical thinking and problem solving skills.
During the first SPC activity, each group of students must complete the "Solar Energy" software (SES) package, developed by the author. This piece of software will provide students with background information about solar power. SES allows students to put the entire SPC in perspective with the rest of the unit, and to make "real world" connections. Details of the design and development of the CAI software are given in the section titled: "Solar Energy Software (SES): Content, Design and Development."

The author has designed the SPC as a series of activities that build upon prior knowledge, gained from each preceding step. The main components or activities of the SPC include: the SES, a historical perspective paper, solar car design, solar car construction, and final presentations. In order for students to proceed to the next step, they must complete each learning activity in sequence. The teacher will make sure that each step is completed before allowing the group to continue.

In the first SES activity, students must complete the SES pretest (see Appendix E). Then each group works through the software, and takes the post test. In order for students to proceed to the next activity, they must successfully complete the SES post test with at least 70% accuracy.
The second activity to be completed is the historical perspective paper. Each student will be required to write and submit a one to two page paper describing the development of solar power, how the project relates to other subject areas, and how the use of solar energy can affect society.

The third activity is to have each group perform a series of engineering analysis experiments before the construction of their solar powered vehicles. These experiments include:

1) Experiment One (see Appendix F): Drive Belts, to find out the most efficient type of belt transmission.

2) Experiment Two (see Appendix F): Gear Transmission to find out the most efficient type of gear transmission.

3) Experiment Three (see Appendix F): Transmission Investigation A, to figure out the correct ratio for a belt transmission.

4) Experiment Four (see Appendix F): Transmission Investigation B, to figure out the correct ratio for a gear transmission.

5) Experiment Five (see Appendix F): Friction Investigation, to find out how to reduce friction from wheels and axles.

6) Experiment Six (see Appendix F): Aerodynamics Investigation A to observe the effects of aerodynamic drag.
7) Experiment Seven (see Appendix F):
Aerodynamics Investigation B, to determine the
effects of aerodynamic drag created from cars with
different frontal areas.

The fourth activity of the SPC is for students to make
rough sketches of their solar energy vehicles. Each student
is required to make at least three thumbnail sketches.
Thumbnail sketches are multiple solutions to the problem in
the form of quick sketches. Then, group members must decide
on an idea to proceed with. Students are to come up with a
final sketch and design for their solar powered vehicle.
This needs to be a scaled working-drawing that includes
dimensions and materials, and it should include as much
detail as possible. In addition, each student must complete
at least one detail drawing of the component(s) that they are
responsible for designing and making. For example, one
student can work on the chassis and transmission design, and
another student can work on the solar cell and body design.

The fifth activity is career investigation, where
students are required to investigate a career from any field
that is directly related to this unit. This activity is
done so that students can make connections between their lab
activities and the "real world." Examples of appropriate
career fields may include: power and energy, engineering,
utilities, or any similar field. Each student will be
required to complete a one to two page report about the
career field of their choice. "The report will include
information about the skills and experience necessary,
physical and mental qualifications, locations and length of training programs, range of wages, geographic areas of possible employment, opportunities for advancement, and related career fields" (ETE Curriculum Changes, 1992, p. 128).

The report will be submitted in writing, and must be delivered to an audience during the group's final presentation.

The sixth activity is for each group to construct and modify their solar-powered vehicles. Students will be given a basic kit consisting of: a solar cell, electric motor, and a 12"x 3"x 1/8" piece of balsa wood. Students will also have access to the other necessary vehicle components including: gears, belts, pulleys, wheels, axles, bearings, and any other available materials. Furthermore, students will be able to use any machine, tool, or piece of equipment in the lab. After building their vehicles, each group should have an opportunity to test and to modify their prototype vehicles prior to the final vehicle competition.

As a culminating event, each group will be required to give a final presentation to the class, which must be written and rehearsed. If possible, students can create multimedia presentations, that could be video-taped and taken home. These presentations should also be evaluated by the teacher and students in the class. In order for this type of assessment to be successful, requirements should be negotiated ahead of time with the students. Furthermore, the SPC offers a great opportunity for cross-curricular instruction with interested teachers. Moreover, outside experts, teachers, administrators, district personnel,
community members, school board members, and the local media could be invited to attend the final presentations. If this were not possible, these presentations could be video taped, and shared with the community. Interested audiences could also be invited to attend the final vehicle competitions during a school-wide assembly. Throughout the SPC, the student-centered philosophy of constructivism is embedded in the student activities.

**Student Assessment**

There are many ways of assessing students during the course of the curriculum. Authentic assessment through individual student portfolios can be an effective measure of student achievement (see Appendix D). In addition, students can be held accountable for deadlines (see time line in Appendix C), journals, working drawings/sketches, participation points, lab reports, written assignments, and student presentations.

**Solar Energy Software: Content, Design and Development**

**SES Content and Structure**

Infused into the SPC is a CAI activity “Solar Energy” software (SES). The purpose of the SES is to provide interactive information about solar energy, and to use technology as the delivery medium for instruction. SES contains six information sections and one instructional game.
Included in the multimedia features of SES are seven digitized pictures or illustrations, and one video segment that are copyrighted. These media elements were incorporated into the SES under the Fair Use Act (1992), which allows for the reproduction of copyrighted material for educational use. Sources for these works are cited where appropriate in the SES, and a complete listing is provided in Appendix H.

The opening screen of SES is the title screen. This introduces the user to the program, and credits the author. From this screen, the user is advanced to the main navigational menu titled: “Solar Navigator” (see Figure 1).

The “Solar Navigator” is the program’s “home card,” and allows the user to access the main sections of SES. Each screen within SES is called a card, and the entire program is referred to as a stack. From the menu (or home) card, the user can choose to investigate any of the six information sections: introduction, history, uses, power in space, animation, satellite movie, and the instructional game.

The sections of this program are in chronological order in a clockwise sequence (see Figure 1). This design is an organizational strategy that supports learning by allowing the user to easily identify the software’s “concrete concepts.”

Gagne (1992), defined a concrete concept as an object, property, or object attribute, such as color or shape.

An important variety of concrete concept is object position. It is clear, however, that the position of an object must be in relation to that of another object. Examples of object positions are above, below, beside, surrounding, right, left, middle, on, in front of (Gagne, 1992, p. 44).
The "Solar Navigator" follows Gagne's model, by offering the user graphically familiar icons with titles, to explore the different sections of the SES. These icons surround a graphic representation of the earth's sun. The rays of this sun point to the program's sections (see Figure 1).

The introduction section is accessed by "clicking" on the SES introduction button, identified by an open book icon (see Figure 1). "Clicking" means to put the program's navigational icon, or "button-activator," on the icon that advances the user to a different part of the program. In other words, when a button is clicked, the user will be advanced to the next screen in the software. After the user clicks the introduction button, a simple animation will appear, which includes an audio clip that says: "in just 15 minutes the sun can provide enough energy to meet the world's power needs for a whole year" (see Figure 2). The multimedia effects of animation and narration reinforce the content for visual and auditory learners. The purpose of the introduction is to serve as an anticipatory set.

The "History of Solar Power" is the next section in the SES. This section includes information about how prehistoric societies took advantage of the sun when designing shelters, the development of photovoltaics, and how solar energy can be used for modern and developing societies. The history section provides background information about solar power, which will be expanded in the other sections of the software.
Figure 1. Solar navigator.

Figure 2. Introductory animation frame.
The next SES section is “Uses of Solar Energy.” In this part of the program the user can investigate the following: active and passive solar energy systems, solar power generation, solar power on spacecraft, and solar-powered transportation. Each of the topics in this section includes a picture(s) of one application of solar power, and textual information about that application. This section of SES offers an alternative to traditional textbook instruction. The user is provided with high-resolution color graphics that are accompanied by brief textual descriptions. “Visuals can also motivate learners by increasing their interest in a text or presentation” (Heinich, et al., 1993, p. 66). Furthermore, the text in these sections has been kept to a minimum in order to convey information in small chunks, which
can facilitate learning. Moreover, the end users, middle school students, need "...clear, precise explanations, illustrations, or other appropriate techniques to teach skills, content, and/or processes" (Caught in the Middle, 1987, p. 38).

After the "Uses" section, the user can explore the "Solar Power in Space" module. This part of the software presents a brief slideshow that is accompanied by music. There are three slides, with each one showing a different angle of the Hubble Space Telescope's solar array (power system), and each slide contains a caption. The purpose of this section is to teach users how solar power is essential to power modern spacecraft.

Using animation (see Figure 3), the next section presents the concept of the photovoltaic effect. The photovoltaic effect is the process by which sunlight is converted into electricity by an exchange of electrons between silicon atoms. During the animation, the user is shown the exchange of electrons. In addition, there is a narration that describes this process. "Animation catches the eye and makes things noticeable. But like sound, animation quickly becomes trite if it is improperly applied" (Vaughn, 1994, p. 310). As a result, the SES includes animation and sound to maintain interest and to reinforce content, but it is not used to simply amuse the user.

The last information section of SES includes a short video segment about the use of solar power on satellites. This film clip shows a satellite being released by a spacecraft. This is accompanied by the following narration:
“solar panels can be used to recharge batteries on satellites.” Here the user can identify another example of how solar power is used in today’s spacecraft. In addition, the user is presented with the familiar informational media of video. “Digital video is the most engaging of multimedia venues, and it is a very powerful tool to bring computer users close to the real world” (Vaughn, 1993, p. 320).

After the user has traversed through the six information sections, an instructional game on solar energy, titled “Solar Car Game,” can be played (see Figure 5). The game cards include an animated solar car, which moves along a background that displays a race track. It is possible to access the game section before exploring the information sections of SES. However, the user will quickly find out that to successfully play it, one needs to learn the concepts from the information sections of the program. In the “Solar Energy” game, there is one question from each of the six sections (see Figure 6). If the user clicks on the correct answer, he or she will be advanced to the next question screen. However, if the student clicks on an incorrect answer, he or she will be automatically transferred back to the solar navigator card. From this “home card,” the user can choose to investigate the topic(s) that they need to know, in order to proceed with the game. The “Solar Car Game” was designed to reinforce the informational sections, maintain student interest, and provide motivation for the user to explore each section of the program.
Overall, these multimedia techniques are employed to provide a rich variety of visual and auditory stimuli, which can enhance the CAI learning environment of the SES.

**SES Navigation**

Navigating through the SES is facilitated by providing the main menu, where users can click on any section title and go to that part of the program. To navigate through the program the user clicks on a "button." Within the program, users continue to navigate by clicking on buttons, which are usually identified by easily recognizable icons. For example, the history section icon is identified by a set of books, and is used to provide a visual clue to the content of the section.

Main navigational buttons are provided at the bottom of each screen in the information sections, to allow the user to traverse through any part of the program, and be able to return to the main menu anytime (see the bottom of Figure 4). The user may click on the right arrow to proceed to the next card in the section, or may click on the left arrow to return to the previous card. If the user wishes to return to the "home card," he or she may click on the red sun icon in between the right and left arrows (see the bottom of Figure 4).
Instructional Design

All of the multimedia elements of the SES are currently employed by CAI designers. Multimedia special effects can add variety and excitement to the program. Moreover, text, graphics, sound, animation, and video segments can aid auditory and visual learners with conceptualization of new material.
Studies have demonstrated that multimedia technologies and CAI can link classroom instruction to real-world activities (Dyrli & Kennaman, 1995), motivate students to learn and increase creativity (Sakamoto, 1992, Sakamoto 1993, & Terrel, 1994), improve student satisfaction and participation (Templin, 1995), and improve test scores (Liao, 1992, & Templin, 1995).

The structure of the Solar Energy Software is rooted in constructivist learning theory, and employs current multimedia authoring techniques. Furthermore, the SES has been developed as an integral part of the SPC, which is a student-centered and project based unit. These two teaching strategies have been found to be effective instructional methodologies (Grauman, 1993, Keck, 1993; Wygoda & Cain, 1994).

Computer assisted instruction (CAI) is one way to create a student-centered learning atmosphere. Moreover, with hypermedia-linked elements of interactivity—the user can control the pace and amount of information being learned. The CAI design should help users to intuitively determine which information path to follow. Users can become overwhelmed at the amount of information available, or get lost in the labyrinth of a program’s structure. Software design should provide the user with an effective and user friendly navigational system. By providing the users with a simple means of controlling the program, a wide variety of stimuli, and access to a diverse learning environment, the SES functions as a constructivist application of CAI.

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Screen Design

SES was designed using accepted elements of computer screen layout. The following are graphical approaches to effective screen design:

* Neatly executed contrasts: Big/small, heavy/light, bright/dark, thin/thick, cheap/dear
* Simple and clean screens with lots of white space
* Eye-grabbers such as Initial Caps, or a single brightly colored object alone on a gray-scale screen
* Shadows and drop shadows in various shades
* Gradients
* Reversed graphics to emphasize important text or images
* Shaded objects and text in 2-D and 3-D (Vaughn, 1994, p. 404).

The author has attempted to use neatly executed contrasts, such as the ones shown in Figures 1, 2, and 3. Another example of contrasts is shown in Figure 1 where the white borders of the navigational “icon-buttons” stand out against the lightly colored background. In addition, Figures 2 and 3 use simplistically designed screens that utilize lots of white space. Graphics should be given special attention when developing multimedia software. They should be simple, displayed simultaneously with text, and should be emphasized with color (Heinich, et al., 1993). As shown in Figure 4, SES has attempted to follow these guidelines throughout the program.
In order to move the solar car from start to finish, you must answer a question correctly. As the questions flash inside this box, click on the correct answer (letter). You will have 3 minutes before the battery runs out. Click the right arrow to start.

How long would the sun have to shine in order to supply the world's energy needs for one year?

A) 15 Mins. B) 15 Hours C) 15 Days
In screen design, "each functional area should be identifiable by its location, its display characteristics (color, font, etc.) and its structure when feasible." (Venzky and Osin, 1991, p. 215). In Figures 5 and 6, the functional areas are clearly visible. In addition, the navigational interface at the bottom of these screen stand out against the green background. Furthermore, the text field—a rectangular bordered area for textual information—in these figures contains black instructions, which stand out against the white background. This familiar arrangement allows the user to immediately recognize the necessary information to proceed to the next level during the course of the instructional game. SES has attempted to maintain this consistency throughout the program.

Screen designers should also take into consideration such factors as: titles, instructions, and text. Titles should be short, concise, boldfaced, and centered at the top (Heinich, et al., 1993). Figures 1, 2, 3, 5 and 6 consistently illustrate this important pattern. Instructions should be short and concise, as shown in Figure 5. Equally important, is the software developer’s choice of fonts for textual information. For example, a computer program’s text should be left justified, use upper and lower case letters, contain no more than two or three different fonts, and a paragraph should be displayed on only one screen at a time (Heinich, et al., 1993). The SES follows screen design principles throughout the program as evidenced by Figures 1, 2, 3, 5, and 6.
Formative Evaluation

To assess the potential effectiveness of the Solar Power Curriculum, a questionnaire was developed to evaluate the ETE curricular unit and the solar energy CAI software (see Appendix G). The curriculum and software evaluations were completed by two middle school teachers and one high school teacher from three separate school sites. One of the evaluators is currently teaching technology education at a middle school that is located in a predominantly middle class neighborhood. The other middle school instructor teaches science, and his school is located in a mixed socioeconomic area. Another one of the respondents is a high school photography teacher, from a school that has a high percentage of students coming from middle class households.

In addition, the author administered the same software questionnaire to twenty-two of his seventh and eighth grade students. The author’s middle school is located in the same community as the high school teacher.

Solar Power Curriculum Evaluation

To evaluate the SPC, a questionnaire was mailed to each teacher, asking the respondents to list the strengths and weaknesses of the software and curriculum. The overall results of the curriculum questionnaires were favorable. Two out of three teachers felt that the cross curricular activities were strong points of the SPC. For example, one teacher reported that having each student present to an
audience is an effective way of reinforcing communication and language arts skills. Another teacher reported that the SPC "flows smoothly, is easy to follow, and that the students cannot progress on until the students have the teacher's initials...for quick assessment."

The author also appreciated the evaluators' honesty when it came to critiquing the SPC. Two out of three instructors wanted to see specific resources listed in the teacher's guide. One teacher reported that it may be difficult for the instructor to keep up with individual and group progress throughout the SPC. Finally, one of the technology teachers said it best when he stated: "it seems very workable, but I would have to try it out for areas of improvement."

**Results of Teachers' SES Evaluation**

In evaluating the SES, the respondents reported on the strengths and weaknesses of the software. Two out of three teachers reported that they liked the attention-getting graphics. One teacher stated that he liked the educational application of multimedia to CAI. This same teacher also thought that the instructional game reinforced the software's content. Another teacher said that the program was easy to navigate and simple to load into the computer's hard drive.

On the other hand, the evaluators also reported how the SES could be improved. For example, one evaluator reported that some of the text on the first two screens was missing. This was because the evaluator's computer system did not have the text fonts that were used for the first two screens.
One respondent said that he would like to see the "pop-out" feature of the instructional game deleted from the software. Another evaluator thought that some areas were too short, and he suggested that the history and introduction sections be lengthened. In addition, a different respondent said that the duration of the "solar power in space" slide show should be made longer. This was probably due to the speed of the computer. The author noted that this program runs at different speeds on different machines. One of the evaluators also suggested that the main screen should be arranged in some type of sequential arrangement.

**Results of the Students' SES Evaluation**

On May 3, 1996, the author administered the student SES software questionnaire—which was identical to the teacher's evaluation form—to his seventh and eighth grade students. While students were working through the SES, the author observed his students, who were working in groups of two students per computer. During the course of the student evaluations the author observed that the majority of the students worked through most of the sections and the computer screens/cards. However, it was unclear if most of the students read and studied the screens in detail.

Students appeared to be engaged while working through the SES. Moreover, most went to the appealing sections first, such as the satellite video, solar power animation, slide show, and instructional game. After these sections, the majority of users navigated through the introduction,
uses, and history sections. Almost all of the students were able to easily navigate through the SES.

Many of the students who used the SES went to the game section prior to the completion of the information sections. As expected, most of the users were frustrated when they clicked on an incorrect answer and were sent back to the main screen (home card) during the course of the game. One student remarked that the game format should be changed. He suggested that the user should be informed of an incorrect response, and then be allowed to proceed with the game. Overall, students liked the following aspects of the SES in rank order: quality graphics and pictures, music, sound, the slide show, the game, the information screens, the overall effect of the program, animation, and the video segment.

On the other hand, students were most critical of the following sections in rank order: the instructional game, the history section, introduction, movie, uses of solar power, and the animation. A few students felt that the SES lacked sufficient excitement. Two students reported that the SES was too easy. Additionally, two students reported that the program was “hard to figure out,” but they also stated that once they “got the hang of it, it was easy.”

Finally, the students made the following comments on the questionnaire. “The power in space is cool when you are showing the pictures,...I like it.” “There should be more options on the games.” Typical comments also included: “pretty cool” and “cool music on power in space.” Perhaps the most comprehensive student analysis of the SES is summed up by this quote: “I like the program, but I think
that you should make it more interesting.” It should be noted here that middle school students can be very critical, and they are used to fast-paced media such as television, video games, and contemporary movies.

**SES Revisions**

After reviewing the results from the student and teacher evaluations, the author made some revisions in the SES to reflect the evaluators’ suggestions, and to make the program more user friendly and effective. For example, the original font has been replaced with a standard font, so that the end users do not need an additional font to run the program. Furthermore, the “Solar Power in Space” slide show has been lengthened so that it will run slower on computers that have quicker processors. The main navigational screen: “Solar Navigator” has also been changed. This was due to a suggestion by one of the evaluating teachers, who said that he would like to see the program sections arranged in alphabetical order. The sections are now arranged clockwise in the following numbered sequence on the “Solar Navigator” screen: 1) Introduction, 2) History, 3) Uses, 4) Solar Power in Space, 5) Animation, 6) Satellite Video, and 7) Instructional Game (see Figure 1). However, the user is free to navigate any of these sections as he or she desires.
Finally, the format of the instructional game was changed due to the frustration of the students (and one of the teacher evaluators) so that the user is no longer automatically "booted out" of the game when he or she clicks on an incorrect response.

**Strengths of the SPC and SES**

The Solar Power Curriculum—and the accompanying SES package—offer middle school students an opportunity to experience "real-world" applications of the ETE power and energy performance standard. Through the SPC, students are taught about engineering skills, and environmental responsibility through the application of solar energy. It is the author's intent to engage ETE students with challenging and engaging learning activities that reinforce the academic core.

**Limitations of the SPC**

However, the author also recognizes the limitations of the SPC. If the SPC is to be adopted by other teachers, the author would need to provide inservices, and/or provide instructors with sufficient detail of how the ETE instructional delivery system works. In addition, designing and implementing a curriculum of this magnitude means time investment for both the planning and implementation phases.
Furthermore, due to time constraints, many overburdened teachers may fail to see the potential educational benefits for their students from the SPC.

Before the SPC can be undertaken, there must first be financial resources allocated to purchase consumable materials. The estimated cost to implement this project—at the time of publication—would be from $500.00 to $1,000.00. However, this may not be a problem for most ETE teachers, because many of these programs already collect a lab/materials fee from their students. Funding could also be allocated from supplemental sources as needed.

Once the funding has been allocated, the instructor must begin the time consuming planning and implementation phases. The ETE instructor must be willing to devote much time and energy to see the SPC carried out successfully. Time must be set aside to: plan, order materials, coordinate with academic core teachers, and to contact outside speakers/assistants.

In addition, teachers have to be effective facilitators in order to manage students once the SPC begins. This is because students may be working on different activities at different times, and students will need varying amounts of assistance. These problems could be lessened through cooperative learning, self paced instructions, supplying students with age-appropriate classroom materials, and by using outside volunteers.

Another potential shortfall of SPC is the problem of objective student assessment.
Meaningful student assessment can be achieved through authentic assessment techniques such as: student journals, meeting deadlines, portfolios, lab reports, and participation. Finally, students can also be assessed by requiring them to demonstrate mastery through presentations to their peers, the teacher, parents, academic core teachers, and community members.

**Strengths of the SPC**

The SPC contains a significant number of hands-on and project-based activities that can motivate students to achieve academic success. Student motivation can be improved through student collaboration, and by providing students with a rich learning environment containing many resources and instructional strategies.

The SPC also addresses career awareness, as evidenced by the career investigations requirement. Furthermore, the SPC can develop critical thinking and problem solving skills, that are necessary for today's workplace, while students design and test their vehicles. Finally, students can become aware of environmental education concepts such as sustainable energy development and the responsible use of technology.

The SES supports the overall goals of the SPC, by integrating CAI into the beginning of the curriculum. In addition, the SES requires relatively low system requirements.
To use the software, the author recommends using a color Macintosh computer with system 7.0 or higher, four megabytes of free RAM, and about three megabytes of hard disk storage. Moreover, this program can be freely distributed on a set of two floppy discs.

Recommendations

The author plans to implement the SPC during the 1996-97 school year. In addition, this curriculum should also be implemented at different school sites with different student populations. Before other teachers pilot this program, the author should provide a comprehensive list of instructional support materials, and possible vendors for consumable materials.

The supporting Solar Energy Software package should also be improved by reauthoring the program for IBM formatted computers. Finally, the software should be made more appealing to the end-users—middle school students—by adding more multimedia effects such as fast-paced animations and video clips, eye-catching graphics, and by improving the instructional game options. For future software development, SES could be produced on CD-ROM. With the CD format, the author could take advantage of higher storage capacity to add improved graphics, sound, animation, game options, and enhanced video.
Concluding Statement

The Solar Power Curriculum (SPC) has great potential as an exploring technology education (ETE) unit. The SPC can also meet many of the school restructuring mandates called for by educational reformists, who advocate the need to prepare today's students for the next century. At the same time, this curriculum can teach middle school students about the importance of efficient energy management. In addition, students can learn about how societies around the world can use technology responsibly through the utilization of solar energy. It is the author's intent to instill a sense of environmental awareness in the future generations of this global village.
Appendix A: Exploring Technology Education
Career Technical Performance Standards

Standard 1: Biotechnology
Students will understand the application of biology and technology. Students will demonstrate/explain methods of biotechnology in the investigation of living systems (e.g. agriculture, bio processing, health, medicine, environment).

Standard 2: Communication
Students will understand a variety of communication processes (e.g. audio, CAD, electronic, visual) and their importance in communications technology. Students will use different processes and media to communicate a message.

Standard 3: Construction
Students will understand a variety of construction processes (e.g. planning, framing, plumbing, writing, excavating) and their importance in construction technology. Students will build models/products incorporating these processes.

Standard 4: Machine and Tool Safety
Students will understand safe and appropriate use of tools and machines. Students will demonstrate the correct operation of tools and machines to form, separate, combine, and condition materials.
Standard 5: Production
Students will understand a variety of production processes (eg. research, tooling, casting, combining, conditioning) and their importance in production technology. Students will build models/products incorporating different processes.

Standard 6: Materials
Students will understand how raw materials (animal, mineral, vegetable, waste, management) are collected and processed to produce industrial materials (eg. composites, metals, wood products). Students will demonstrate/explain processes and testing used to produce and recycle common industrial materials.

Standard 7: Power and Energy
Students will understand sources and systems of power and energy (eg. electrical, simple machines, solar, thermal, water, wind). Students will build models/products incorporating different sources.

Standard 8: Transportation
Students will understand the applications of transportation technology to land, water, air, and space. Students will incorporate the technology into the design and construction of a model/functional vehicle.
Appendix B: Exploring Technology Education

Career Performance Standards

1: Personal Skills

Students will understand how personal skill development affects their employability. They will exhibit positive attitudes, self confidence, honesty, perseverance, and self discipline. They will manage time and balance priorities as well as demonstrate a capacity for increased learning.

2: Interpersonal Skills

Students will understand key concepts in group dynamics, conflict resolution, and negotiations. They will work cooperatively, share responsibilities, accept supervision and assume leadership roles. They will demonstrate cooperative working relationships across gender and cultural groups.

3: Thinking and Problem Solving Skills

Students will exhibit critical and creative thinking skills, logical reasoning, and problem solving. They will apply estimation, measurement, and calculation as appropriate. They will recognize problem situations; identify, locate, and organize needed information or data; and propose evaluate, and select from alternative solutions.
4: Communication Skills
Students will understand principles of effective communication. They will communicate both orally and in writing. They will listen attentively to instructions and request clarification or additional information as needed.

5: Occupational Safety
Students will understand occupational safety issues including the avoidance of physical hazards in the work environment. They will operate equipment safely so as not to endanger themselves or others. They will demonstrate proper handling of hazardous materials.
Problem Identification

Design and make a solar powered vehicle that will travel under its own power at the highest rate of speed possible.

Design Briefs

1) Design and make a model solar powered vehicle that will travel on a 25 foot test track.

2) The vehicle must travel under its own power without any human assistance.

3) Vehicles will be attached to a fishing line to keep them traveling in a straight line.

4) The vehicle's solar panel will be covered with a piece of cardboard to block out the sun until the car is signaled to start.

5) Vehicles will be timed from start to stop on the test track to determine the most efficient vehicle.
Technology Universal Systems Model: Input, Process, Output, Feedback

Input: Create a solar powered vehicle that will travel at the highest rate of speed possible.

Process: Using student selected materials and processes design and make a model solar powered vehicle.

Output: A working model of a solar powered vehicle.

Feedback: How well did the vehicle perform?

Student Division of Labor

1) Students will work together in teams of two students. If necessary, teams of three students may be formed at the discretion of the teacher.

2) Students are expected to contribute equally to the best of their abilities in order to complete the project on time.

Assessment

Students will receive an individual grade and a group grade for this unit. One half of each student’s grade will be an individual grade based on participation and effort, which will be earned from the requirements listed below.
The other half of the student’s grade will be a group grade, which will be earned by completing the group requirements listed below.

**Individual Grade**

1) Each student will keep a journal of individual daily participation, and group progress which will be recorded in the student’s log book. In addition, students will be required to keep all: journal entries, sketches, drawings, presentation outlines, notes, lab reports, written assignments, and time lines in a student portfolio. These requirements will account for 25% of the student’s final grade.

2) Students will be required to earn daily individual participation points. Students can earn up to twelve points per day for their contribution(s) to the group effort. If a student is absent, he or she will be required to make up his or her daily individual participation points and assignments by completing the missed work after school, or make-up work will be assigned by the teacher. These points will be recorded on an individual student time card. These requirements will account for 25% of the student’s final grade.
Group Grade

1) Each student will be required to present an oral report to the class outlining his or her contributions to their group’s overall success at regularly scheduled (weekly) design reviews. During these presentations, students are encouraged to share what they have learned—as well as successes and/or failures—with the class and the teacher. Listeners will also participate during design reviews through constructive criticism. Each student will have a chance to give comments and receive suggestions. These requirements will account for 25% of the student’s final grade.

2) As a culminating event, each group will be required to give a final presentation to the class, which must be written and rehearsed. These requirements will account for 25% of the student’s final grade.

Team Responsibilities

Research: To acquire information needed for various solutions to problems that are encountered throughout this unit, students may consult the following: books, handouts, texts, computer software and CD-ROMs, internet bulletin boards, parent’s, community members, outside experts, and guest speakers.
Note: Each of the requirements must be completed and checked off by the teacher in the order listed below, before each group can proceed to the next step.

Historical Perspective: Activities 1a, 1b, 2a, and 2b

1) First, take a pretest about the use of solar energy. Second, complete the 'Solar Energy' computer program to provide background information about solar energy. Finally, take the post test, which must be passed with 70% accuracy in order to proceed to the next requirement.

   Teacher's Initials _____

2) Write and submit a one to two page paper describing the development of solar power, how this project relates to other subject areas, and how the use of solar energy can have an effect on our society.

   Teacher's Initials _____
Engineering Analysis: Activity 3

1) Complete Experiment One: Drive Belts, to find out the most efficient type of belt transmission.

   Teacher’s Initials ____

2) Complete Experiment Two: Gear Transmission to find out the most efficient type of gear transmission.

   Teacher’s Initials ____

3) Complete Experiment Three: Transmission Investigation A, to figure out the correct ratio for a belt transmission.

   Teacher’s Initials ____

4) Complete Experiment Four: Transmission Investigation B, to figure out the correct ratio for a gear transmission.

   Teacher’s Initials ____

5) Complete Experiment Five: Friction Investigation, to find out how to reduce friction from wheels and axles.

   Teacher’s Initials ____
6) Complete Experiment Six: Aerodynamics Investigation A to observe the effects of aerodynamic drag.

   Teacher’s Initials ______

7) Complete Experiment Seven: Aerodynamics Investigation B, to determine the effects of aerodynamic drag created from cars with different frontal areas.

   Teacher’s Initials ______

Thumbnail Sketching: Activity 4a

1) Each student is required to make at least three thumbnail sketches. Thumbnail sketches are multiple solutions to the problem in the form of quick sketches.

2) Group members must decide on an idea to proceed with.

   Teacher’s Initials ______

Final Sketch and Design: Activities 4b and 4c

A final sketch must be produced with input from each group member. This needs to be a scaled working-drawing that includes dimensions and materials, and it should include as much detail as possible, (see example, but do not reproduce it). In addition, each student must complete at least one detail drawing of the component(s)
that they are responsible for designing and making. For example, one student can work on the chassis and transmission design, and another student can work on the solar cell and body design.

Teacher’s Initials ______

Careers: Activity 5

Each student in the group will be required to investigate a career from any field that is directly related to this unit. Examples of appropriate career fields may include: power and energy, engineering, utilities, and any related field (with the teacher’s permission). Each student will be required to complete a one to two page report about the career field of their choice. “The report will include information about the skills and experience necessary, physical and mental qualifications, locations and length of training programs, range of wages, geographic areas of possible employment, opportunities for advancement, and related career fields” (ETE Curriculum Changes, 1992, p. 128). The report will be submitted in writing, and must be presented orally for the group’s final presentation.

Teacher’s Initials ______
Prototype and Working Model: Activity 6a and 6b

1) Make a working prototype from the final sketch using the materials and resources available to you in the Technology Lab (see Team Responsibilities on page 3). The group has the option of bringing in additional materials from home, or materials may be purchased from different stores (see student handouts for more information). However, the group may not purchase or bring in from home the following items: solar panel, motor, or other type of power source (i.e. batteries). In addition, students may not spend more than ten dollars per group on outside materials (students may be asked to bring in receipts).

2) Group members are free to use any of the following resources in the Technology Lab to construct the vehicle: tools and machines, computer software (Junior Solar Sprints), reference books, handouts, texts, class notes, classmates, or the teacher.

3) Vehicles must be constructed in class, or after school during open lab time. Vehicles may not be taken home!

4) When the group is finished with the vehicle, the group may decide to modify it in order to increase performance (refer to handouts).
5) After the group is satisfied with their vehicle’s performance, complete Experiments Eight and Nine (see Appendix D): Theoretical Calculations for a Solar Car to figure out the vehicle’s power output and acceleration.

6) Prepare for final presentations by writing and rehearsing a speech that is no longer than five minutes in length, about your experiences during this unit. Give final presentation to the teacher and class.

Time Line

Week 1

Work to be completed

Solar Energy Software (including pre and post tests), historical perspective paper, complete experiments one through seven begin engineering analysis, and start technical sketches.

Dates: ________ through ________
Week 2

Work to be completed

Career investigation report, individual detail drawings, final sketch, design review, and begin prototypes.

Dates: __________ through __________

Week 3

Work to be completed

Prototype, fine tune vehicle, complete experiments eight and nine, design review, and outline for final presentation.

Dates: __________ through __________

Week 4

Work to be completed

Finish vehicle, complete Experiments Eight and Nine, solar vehicle competitions, write and rehearse for presentation, turn in student portfolios and final group presentations.

Dates: __________ through __________
APPENDIX D: Solar Power Curriculum Teacher’s Guide

Introduction

The Solar Power Curriculum (SPC) was developed from the Exploring Technology Education (ETE) Career-Technical Performance Standard number seven. This standard states: "Students will understand sources and systems of power and energy (e.g. electrical, simple machines, solar, thermal, water, wind). Students will build models/products incorporating different sources" (Exploring Technology Education Association, 1995). The SPC follows these recommendations, and it is approximately four-weeks in length.

During this unit, students learn about solar energy through hands-on activities that reinforce the academic core. Students are required to investigate solar energy as a viable power source, and to design a model solar-powered vehicle. This curriculum has been designed as a long term project-based unit. However, the SPC could easily be modified to fit a five to ten day student rotation in an ETE modular lab setting. In addition, the author would like to acknowledge the Junior Solar Sprints program for some of the student activities that are included in this unit.

Junior Solar Sprints is a program that offers middle school students an opportunity to design, build, and race solar powered vehicles on a local level. This program is sponsored by the Department of Energy (DOE), National
Renewable Energy Labs, and The Society for Automotive Engineers (SAE). For more information regarding Junior Solar Sprints, contact Dr. William Guentzler, SDSU (Tel. 619-594-5807). Originally, the SPC was to incorporate the Junior Solar Sprints program.

However, due to uncertainties regarding continued funding, or possible cancellation of Junior Solar Sprints, the author decided to create a framework that gives ETE teachers an alternative to this outstanding program. The SPC offers a low-cost method of emulating the Junior Solar Sprints program. For example, the solar vehicle kits can be put together for approximately five to ten dollars per vehicle. Contact Kelvin Electronics, Melville NY, (Tel. 516-756-1750), for bulk rates on solar cells, motors, gears and pulleys. Finally, the SPC introduces students to power and energy concepts, engineering techniques, environmental education, and cross-curricular instruction.

**Solar Power Curriculum Objectives**

The main goal of the Solar Power Curriculum is to develop an exploring technology education curricular unit, designed to teach middle school students about solar energy, through computer assisted instruction (CAI) and "hands-on" activities. Therefore, upon completion of the Solar Power Curriculum (SPC), the student(s) will be able to:

1. Describe the difference between renewable and non renewable energy.
2. Explain at least three different applications of solar power.
4. Describe two advantages and two disadvantages of utilizing solar power.
5. Identify several career options in this field.
6. Demonstrate communication skills through written and verbal expressions.

**Solar Power Curriculum Goals**

The SPC will allow students to achieve the following instructional goals:

* Meet exploring technology education curricular standards.
* Develop problem solving and collaborative skills
* See the relationship between technology education and the academic core.
* Acquire problem solving and collaborative skills
* Explore careers that may be of interest.
* Think about environmental responsibility.
* Learn how technology can be used responsibly.
* Recognize the need for alternative forms of energy.
* Realize that solar energy has great potential.
* Reinforce science and math curricula.
* Make the connection between the classroom and the "real world."

Recommendations for implementing the Solar Power Curriculum

In addition to the student syllabus, the following recommendations may be useful for implementing the SPC:

1) Students should work in groups of two or three.

2) Solar and renewable energies should be presented as part of an overall sustainable energy policy.

3) Videos about solar and renewable energies should be shown to reinforce class discussions.

4) A wide variety of student resources should be available throughout the unit.

5) Student resources should include: software, CD-ROMs, Junior Solar Sprints handouts, videos, tools, machines, and materials.

6) Schedule weekly design reviews, where students can share successes and failures, as well as receiving constructive feedback from the teacher and their classmates.
7) Students should have additional time available to them, so they can work on the requirements for this unit after school or during lunch time.

8) Students should be encouraged to share ideas and designs with their parents and other community members, but should not be allowed to take their vehicles home.

9) Ideally, outside experts from related fields such as engineers, utility workers and business people, should be invited to speak to and/or assist students while developing their vehicles.

**Student Assessment**

There are many ways of assessing students during the course of the curriculum. Authentic assessment through individual student portfolios can be an effective measure of student achievement. In addition, students can be held accountable for: deadlines, journals, working drawings/sketches, participation points, lab reports, written assignments, and student presentations (please see Student Syllabus for more information). As a culminating event, each group should give a final presentation to the class. This presentation should be written, rehearsed, and approved prior to the presentations. If possible, students could create multimedia presentations, that could be video-taped and taken home, or shown to interested audiences.
These presentations should also be evaluated by the teacher and students in the class. In order for this type of assessment to be successful, requirements should be negotiated ahead of time with the students.

Furthermore, the SPC offers a great opportunity for cross-curricular instruction with interested teachers. For example, in science students could conduct some of the required experiments, and/or investigate related theories (e.g. energy, simple machines, power transmission, etc.). In math, students could calculate: acceleration, MPH, and electrical power output.

Moreover, outside experts, teachers, administrators, district personnel, community members, and school board members could be invited to attend--and possibly evaluate--the final presentations. If this were not possible, these presentations could be video taped, and shared with the community at a later date. Interested audiences could also be invited to attend the final vehicle competitions at a school-wide assembly.
APPENDIX E: Solar Energy Software Pretest

Directions: Circle the correct answer (letter) to make the statement correct.

1. How long would the sun have to shine in order to supply the world’s energy needs for one year?
   A) 15 minutes       C) 15 hours
   B) 15 days

2. A passive solar system is one that:
   A) creates electricity       C) positions windows to take advantage of the sun’s heat
   B) lets the sun shine in

3. The Hubble Space Telescope uses solar panels to:
   A) power the spacecraft       C) talk to aliens
   B) keep the astronauts warm

4. A solar cell creates electricity by:
   A) changing light to heat       C) heating silicon atoms
   B) an exchange of electrons

5. Solar panels can be used to:
   A) send radio and TV signals       C) change sunlight into electricity
   B) reflect sunlight to boil water
6. Humans have built their shelters facing south for thousands of years to:
   A) view the sunrise  
   C) to grow more crops
   B) to keep their shelters warm

7. One advantage of solar power is:
   A) it is very cheap  
   C) that it is almost non-polluting
   B) one solar cell can make
       a large amount of electricity
APPENDIX F: Solar Power Curriculum Experiments

Experiment One: Drive Belts (The Everyday Science Book, 1985)

Topic Generalizations: Drive belts are a form of pulley system that can be used to turn wheels and gears.

Materials Needed: hammer, nails, board, rubber band, large spool and small spool.

Procedure:
1. Hammer two nails into a board far enough apart to lightly stretch the rubber band between them.

2. Place the small wooden spool over one nail and the larger spool over the other nail. The spools should turn freely.

3. Slip the rubber band around both spools so when one spool is turned the other moves.

4. Place a mark on the top edge of each spool.

5. Beginning at the mark, turn the large spool through one complete turn.

Conclusions:
- How many times did the small spool turn?
- In which direction did the spools turn?
- Does the length of the drive belt make a difference?
Experiment Two: Gear Transmission (The Everyday Science Book, 1985)

Topic Generalization: Gears can be used to transfer forces from one part of a machine to another part. With gears, the direction or speed of rotation of other objects can be changed.

Materials Needed: board and spools from Activity Four, hammer and nails, rubberband.

Procedure:
1. Drive another nail farther away from the large spool and move the small spool onto it.
2. The rubberband will now stretch tighter around both spools.
3. Turn the large spool around once again to see if the smaller spool turns the same distance as before.
4. Twist the rubberband so that it forms a cross between the spools.
5. Turn the larger spool again.

Conclusions:
How many times did the smaller spool turn?
In what direction did it turn?
Experiment Three: Transmission Investigation A: Effect of transmission ratio (Heafitz, 1994)

Topic Generalization: Building a car without any knowledge of the best transmission and ratio is very risky because the car will not perform to its full potential (if it moves at all). The following test setup uses a belt and pulley transmission but, the ratio of the pulley diameters applies to all of the other types of transmissions as well (gears, friction drive). Optimizing the transmission ratio in your car is critical for good performance.

Materials: Motor and 3V power source, one small pulley for motor shaft, three larger pulleys for output shaft (axle), shaft bearings, cardboard (or any suitable material) for chassis, rubber band or belt, hot glue, two shaft axles.

Procedure: Use the test transmission provided by your teacher. Mount the motor on a piece of stiff material (using hot glue, good tape, etc.) that is easy to grip or attach to the chassis. Use it to adjust the motor location and belt tension.

Things to try:
* Move the belt to different pulleys to see the results of different rations. See which ratios give the give the highest speed, and which make the shaft easiest to stop with your fingers.
* Try different bearings between the axles and the frame.

* Try adding or removing weight from the output shaft to see the effect of acceleration.
Experiment Four: Transmission Investigation B: Effect of wheel size (Heafitz, 1994)

Topic Generalization: Try different wheel sizes on a sample car and see how the performance varies (acceleration and speed). Wheel size is as important a factor in a car’s design as the transmission ratio; in fact, they are closely related.

Materials: Use the prototype car from the instructor, and different sizes of wheels.

Procedure: Try to calculate what distance your car travels per one revolution of the motor. The transmission ratio will tell you how many revolutions the wheel axles will turn per wheel rotation.

Things to Try:

* Experiment with this concept by varying the wheel diameter on your car.
* How much faster/slower does your car travel with large wheels?
* How much faster/slower does your car travel with small wheels?
* What is the best wheel arrangement for this car?
Experiment Five: Friction Investigation (Heafitz, 1994)

Topic Generalization: Friction is a resisting force between two materials that are in contact and moving past each other, in other words, the sticking force between two objects being rubbed together. In a solar car, the wheels and axles have friction when they turn with respect to the chassis. Minimizing this friction will let the wheels spin more freely as well as faster, resulting in a faster car.

To choose the best materials for axles and bearings (e.g. metal axle in a wood bearing, etc.), find samples of different materials and test the friction between them. This test will help determine at what angle a sample piece of material starts to slide. The steeper the hill, the more friction there is between the test piece and the material covering the slope. The more friction, the worse those materials are for bearings. Picking two materials that "run" well together will mean that less power will be used to overcome the friction and more will go towards driving the car faster.

Materials: Planks that can be lifted at one end, ruler, small objects made of various materials, lubricants such as oil, soap, graphite.

Things to Try:

* Put an object on the plank with no lubricants, and observe the results when your lift one side to move the object.
Record the distance between the table and top of the board when the object starts moving. Use the same procedure for the following tests.

* Put an object on the plank covered with oil, and observe the results.
* Put an object on the plank covered with soap, and observe the results.
* Put an object on the plank covered with graphite, and observe the results.
* Which surface provided the least resistance?
* Which object and surface provided the least resistance?
* How can this information help you determine the best materials for your axles and bearings?
Experiment Six: Aerodynamics Investigation A: What is aerodynamic drag? (Heafitz, 1994)

Topic Generalization: Aerodynamic drag or "wind resistance" is the resisting force that a moving object feels as it moves through air. You probably know that air consists of oxygen, nitrogen, carbon dioxide, and other gasses, so it is clear that air does have mass and is not "nothing." As an object moves through air it will experience a resisting force proportional to the object's speed and geometry. Since we want our cars to go as fast as possible, let's look into how to reduce the drag due to the physical dimensions of the car.

There are two primary physical characteristics responsible for aerodynamic drag on a moving vehicle. The first is the "frontal area" of the car, or the cross sectional size of the car as viewed head-on. The second is the shape of the car, or how "streamlined" it is.

If an object is relatively large and heavy, the friction forces are likely to far outweigh the aerodynamic forces unless the wind gets very strong. Most of us are not worried about our family's cars blowing away when they are in the driveway, but drag is a major factor in fuel efficiency when driving at highway speeds.

Aerodynamic drag can be demonstrated with an ordinary soda can. Since the soda can is lightweight and will slide easily on many hard surfaces, the friction forces on it will be low enough that we look at variations in the resistance from aerodynamic drag.
We can vary the car's shape while maintaining it's frontal area by using different lightweight shapes in the front of the can.

Materials: soda can, sheet of ordinary paper, scotch tape, two 1/2" diameter wooden dowel rods, 3' long

Things to try:
* Set up the dowels at a slight angle and place the soda can on them at one end. Blow on the end of the can and see if it moves.
* Now make a cone out of the paper, and tape it to the front of the can so it looks like a rocket with a pointed nose cone.
* Blow on the can with the nose cone again and see if it moves.
* What kind of resistance forces would this can feel if it were on a moving vehicle as compared to the flat can?
Experiment Seven: Aerodynamics Investigation B: Roll down test (Heafitz, 1994)

Topic Generalization: Roll-down tests are used by some automobile manufacturers, race car builders, and car testing organizations (among others) to test the aerodynamic drag of a car. The idea is to roll a car (with the engine turned off and out of gear) down a hill and see how far it rolls. A car with more drag (for example, a car with a parachute behind it) will roll to a stop faster (or after a shorter distance) than a streamlined low drag car.

Materials: ramp, one miniature car, different car profile shapes to put on the car using paper, blocks of wood, or styrofoam.

Things to try:
* Set up the ramp and release the car from the top. Record the distance that the car travels.
* Repeat with different frontal areas, keeping the car weight constant. Use one which has a very large frontal area.
* Try out different streamlined shapes as you did with the nose cone on the soda can. Be careful to keep the other variables constant.
* Why is it invalid to use different test cars?
* What other physical properties can affect the amount of distance traveled?
Appendix G: Solar Power Curriculum and Solar Energy Software Questionnaires

Present teaching assignment (Subject/Grade Level(s)): _______
Number of years teaching this subject: _______

Solar Power Curriculum

1. What I liked best about this curriculum: ______________________
   ______________________
   ______________________

2. What I liked least about this curriculum: ______________________
   ______________________
   ______________________

3. Suggestions on how this curriculum could be improved: ______
   ______________________
   ______________________

"Solar Energy" Solar Energy Software

1. What I liked best about this software: ______________________
   ______________________
   ______________________

2. What I liked least about this software: ______________________
   ______________________
   ______________________

3. Suggestions on how this software could be improved: ______
   ______________________
   ______________________

Comments: ______________________
   ______________________
   ______________________
Appendix H: Copyrighted References

1) The picture included in the "Uses" section of the Solar Energy Software that appears on screen two is from Technology shaping our world (p. 172), by J. Gradwell, M. Welch, & E. Martin, 1991, South Holland, IL: Goodhart-Wilcox. Copyright 1991 by Goodheart-Willcox.

2) The pictures included in the "Uses" section of the Solar Energy Software that appear on screens one, four, and five are from Living with technology (P. 369), by M. Hacker, & R. Barden, 1988, Albany, NY: Delmar Publishing Inc. Copyright 1989 by Delmar Publishing Inc.

3) The pictures included in the "Uses" section of the Solar Energy Software that appear on screens three and five are from How in the world (pp. 127 & 128), 1990, Pleasantville, NY: Reader's Digest Association Inc. Copyright 1990 by Reader's Digest Association Limited.

4) The video clip included in the "Movie" section of the Solar Energy Software is from Energy, power, and Transportation [video]. (Available from Agency for Instructional Technology, AIT, Box A, Bloomington, IN 47402-0120)

REFERENCES


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