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Guide
Prof

Teaching Technology through Design

Special Project, June 2000

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Approval Sheet

The Special Project entitled "Teaching Technology through Design", done by 'Aurobinda Narayan Pradhan' is approved for partial fulfilment of the award of the degree in Masters of Design in Visual Communication.

Guide:
(Prof. K. Munshi)

Acknowledgement:

I am grateful to my Guide Prof. K. Munshi for his patient guidance throughout the project.

Mrs. Chandorkar, Science teacher, Powai English medium school for her invaluable feedback on technology education.

My classmates for all their help in terms of data and discussion.

International technology association for the bunch of related research paper on technology education.

Heartfelt Thanks

Introduction

Why Teach Technology?

With the rapid pace of technological change in our society, we are often overwhelmed by the sheer volume of new technology. However, technology is not just a collection of tools and machines; it is a way of thinking and a way of living. We hardly consider the impact of technology on our lives, but it does change the facts! To make the most of the opportunities that technology offers, we need to understand it. So here are some important facts about technology.

Science is to probe
Technology is to invent
Design is to fit

Simply saying "**Technology is human innovation in action**"
(Quoted from -The International Technology Education Association (ITEA)

Introduction

Why Teach Technology?

With the increasing impact of technology on the society, we are almost submerged in a technological environment. However technology, in various forms have become so much a part of us that, we hardly consider the living environment to be technical... but that doesnot cange the facts!

To make the most out of a "Technological Environment" we must use technology more intelligently. and to do so we must be technically literate!

So here is a reason as to why should technology be learnt... and more importantly " why technology be taught".

The Objectives of Teaching Technology

- * Technology as being closely linked to 'real-life' and vocational preparation.
- * Technology as empowering for the pupils. That is giving the pupil a go... giving them a feeling of technology first.

Scope

The scope of this project is vast. Considering the wide nature of potential pupils, starting from elementary school kids to uneducated layman, technology education can follow various types of guidelines and mediums.

However considering our concern to create a technologically literate society we better catch the society young. Such a move will develop technologically responsible users and consumers and in turn a technologically sound society.

Here the focus of technology education should be to make young people sensitive and skillful to look critically at technology and products they are using everyday.

BUT HOW?

This project is a critical analysis of present ways of technology education at school level education system. A few real life case studies backed by few case studies as found on internet are considered for analysis.

Depending upon the analysis, a link to the role of design in developing such an education system is discussed.

Technology education in Schools

The general practice of technology education in today's scenario depends upon the followings

- * Books
- * Educational Handwork
- * Computers
- * Web/Internet
- * Multimedia

Books

The book level technology education fails to address the need to teach technology. It is more of describing the concepts of science and its application in a technological environment. A close look at it shows, it tries to tell the working of a technology without addressing the need and its importance in our immediate surrounding.

Powai English Medium School
Reference: Mrs. Chandorkar, Science
teacher



Technology education in Schools

Educational Handwork

Problem-1: Teaching the technology behind a Solar Cooker

Book level Learnings:

Solar cooker works by the concept of trapping the solar heat inside an enclosed body. The pupils were told how the reflectors work in optimising the solar heat. Again how the teflon coated bowl retains the heat and ultimately how the solar cooker manages to attain the desired heat to cook a certain quantity of food!

However a lot was left to the imagination of the pupil. The problem remained unaddressed.

So in order to give the pupil a feel of technology behind the solar cooker, with the constraint of materials and understanding of students a totally different approach was considered.

Approach:

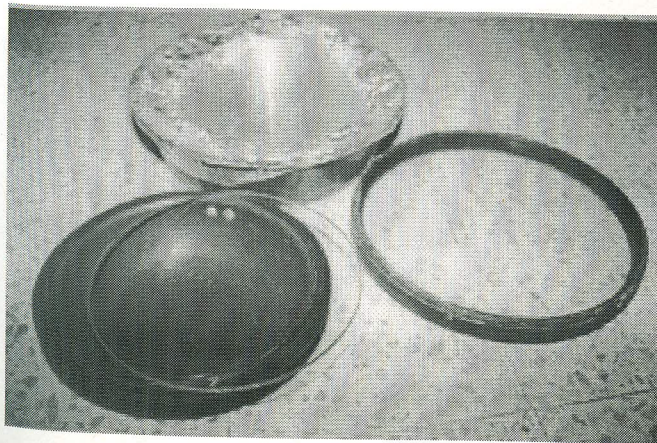
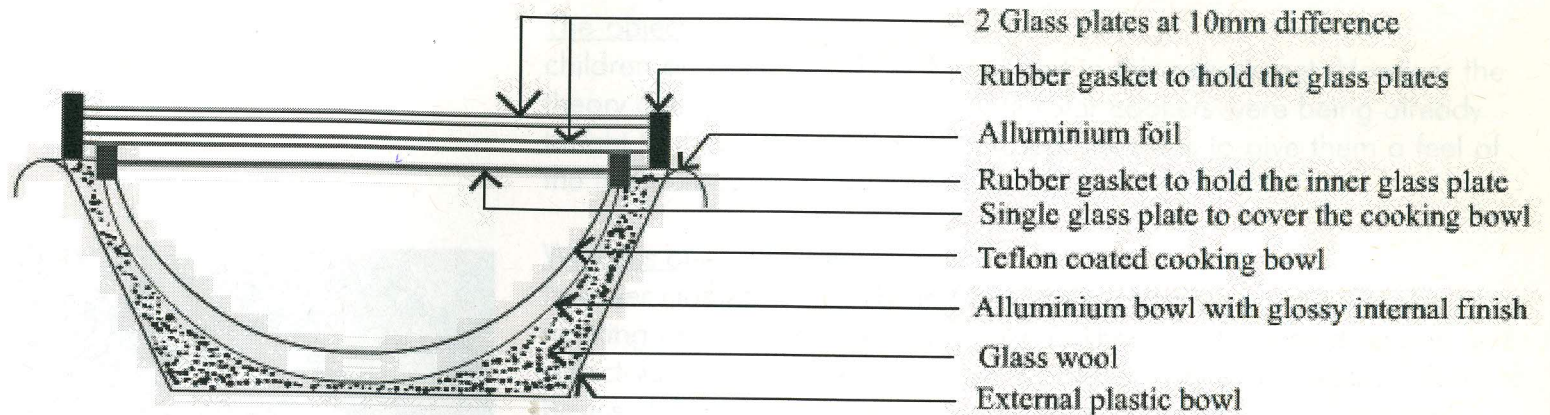
1. Consultation with an Industrial Designer
2. Developement of a sketch with a brief.
3. Assisting the students in understanding the sketch and the principles on which it will work
4. Asking the students to transform the sketched idea to a real product

Assistance was given in terms of finance and necessary instructions to carry out a practical and executionable solution.

Technology education in Schools

Educational Handwork

Problem-1: Teaching the technology behind a Solar Cooker



Materials:

Very simple and objects of day to day life are used to build the cooker. For example a couple of metal bowls- one with reflective inner surface and another with inner teflon coating, a larger plastic bowl, three circular pieces of plate glass, two rubber gaskets, some alluminium foil and some glass wool were all that required.

Analysis:

Use of day to day material. So easy availability of cheap raw materials. Least technical detail yet effective use of the principles of the relevant technology.

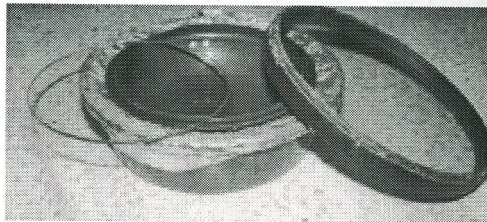
Technology education in Schools

Educational Handwork

Problem-1: Teaching the technology behind a Solar Cooker

The objective:

children of age group 12-14 took part in this experiment. However the theory and working of conventional solar cookers were being already taught to them, the challenge in this project was to give them a feel of the technology.



Why this one is different:

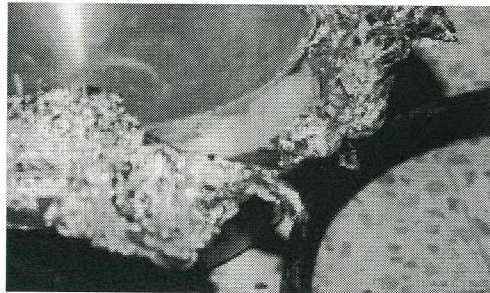
In lower classes the pupils had been theoretically taught the making and working of conventional solar cookers. That is, with slanted mirrors and reflectors to get the desired result. But the one they built was cut down to basics. The materials used were simple and easy to get. Again the modularness of the design allows one to create a product with larger capacity.

Problem solving approach developed by children:

Here the whole learning is more instruction driven. All technicalities being pre-planned, the children have only one choice, to execute the instructions.

Their creativity came into play when few execution problems came into picture.

- * Finding plate glasses of appropriate thickness to fit the available rubber gasket
- * Finding a way to cover the glass wool stuffed between the outer bowl and the inner bowl



The riddle of reducing the heat loss, solved by the pupils.

Technology education in Schools

Educational Handwork

Problem-1: Teaching the technology behind a Solar Cooker

Expected learnings

- * How the solar cooker works
- * How the principles of heat and solar energy act together to cook food.
- * How to realise a technology in product form
- * How to solve technical problems to achieve the desired goal.

Actual learnings:

- * Realising technology in product form
- * Solving execution problems in achieving the desired goal

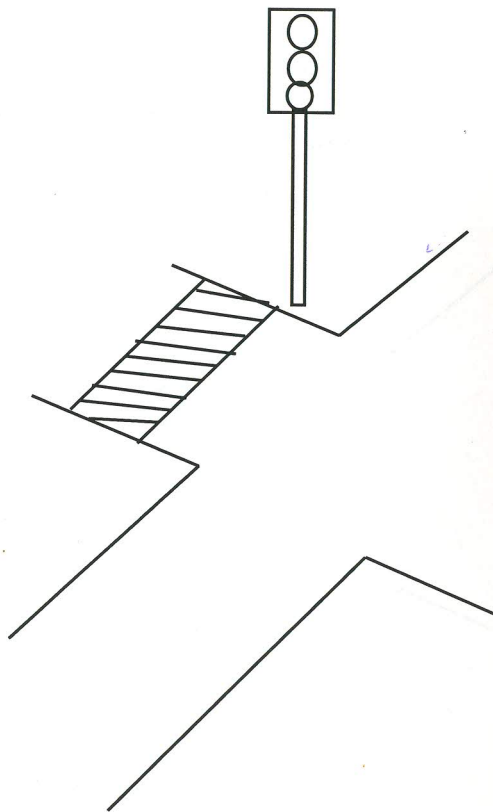
Analysis:

If seen from a different perspective we might conclude that such a teaching method gives little scope to explore and find the solution to a particular technological problem!

Such an approach may be termed as "Copying teaching method", where a particular idea is being conveyed to the student and their task is to execute the idea. All the exploration lies in execution rather than finding a solution.

Even in this case, the teacher found a creative way to make the children find a few solutions to certain technical problems. For instance asking them to find a way to lessen the heat loss between the inner bowl and out bowl.

Though in a crude manner, children found the solution. They used glass wool to fill the gap and suggested some sort of covering to bind all three layers together. Definitely a better way to learn the technology....



Technology education in Schools

Educational Handwork

Problem-2: Tickling the creative side of the children in finding a technology related problem area and finding a solution to it.

Approach:

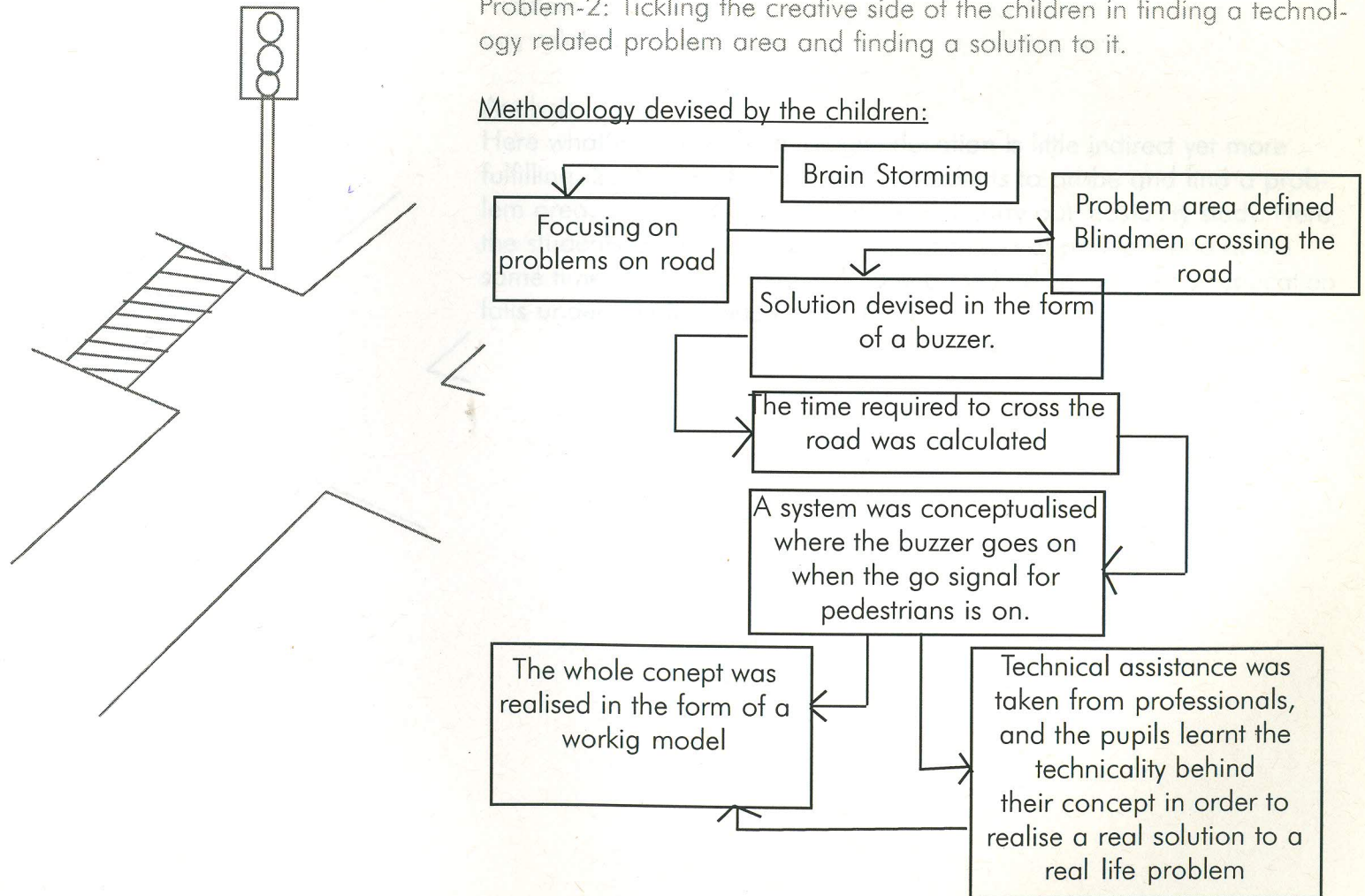
1. Children of age group 12-14 were asked to find out an interesting daily life problem area where they can contribute in developing some technology related solution.
2. Children found the problem in the road. The problem that blindmen find it difficult to cross the zebra crossing is what interested them most.
3. They prepared a brief of the problem
4. Brain stormed as to what should be the solution
5. Came out with a mutually agreed upon solution
6. Consulted the teacher
7. Found out the technical feasibility of their solution
8. Realised the solution in the form of a prototype

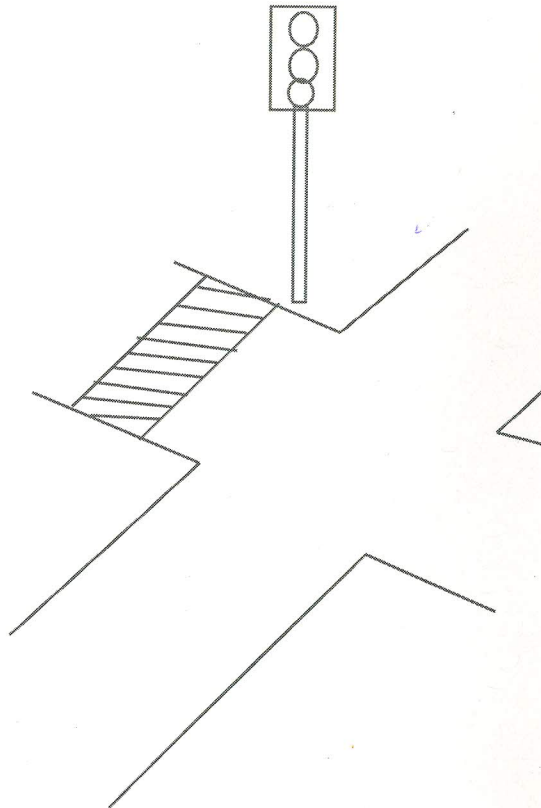
Technology education in Schools

Educational Handwork

Problem-2: Tickling the creative side of the children in finding a technology related problem area and finding a solution to it.

Methodology devised by the children:





Technology education in Schools

Educational Handwork

Problem-2: Tickling the creative side of the children in finding a technology related problem area and finding a solution to it.

Analysis:

Here what we see is, technology education is little indirect yet more fulfilling. Such a method allows the students to probe and find a problem area, come out with a solution and carry out feasibility study. Here the students are responsible for identification of problem and at the same time for the solution too! Such a method of technology education falls under "Design teaching method".

Technology education in Schools

Educational Handwork

Problem-3: Teaching the technology of "Waste water Purification".

Approach:

1. Built a model of land with a well filled with dirty water.
2. Found a link between the underground dirty water and the Industrial pollution
3. Developed a model to see how the waste water from industries can be purified and used
4. Ultimately what they got is a first hand experience on how the "technology behind waste water purification works".

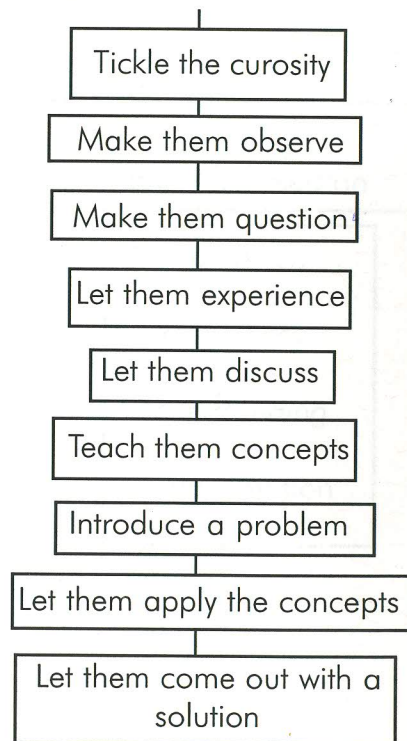
Technology education in Schools

Educational Handwork

Problem-3: Teaching the technology of "Waste water Purification".

Analysis:

Here again the children were made to think but text book and teacher assistance was a constant source of reference. The learning was based on "seeing what has been taught". A "see to believe" approach. Though this might as well fall into the 'copying teaching method', the experience is more at developing an attitude towards verifying what has been learnt in classroom teaching.



Technology education in Schools

Technology education approach in few schools

Homi Bhabha Institute of Science and Education

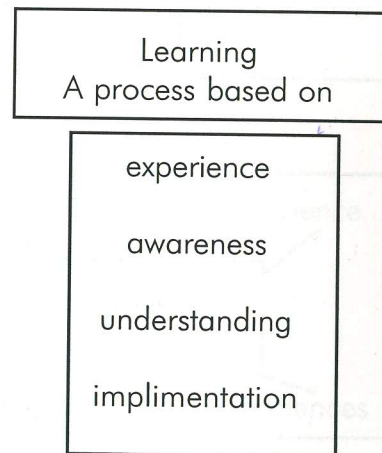
The strength of this institute lies in it's experimental attitude towards teaching. Follows the teaching principles that are observed in their basic education curriculum.

The teaching principles:

1. Children are by nature curious and observant.
2. They learn about the world by watching, asking questions, and trying to make sense of what they experience.
3. Technology education shoud aim to encourage these natural tendencies. Hence ask more questions.
4. Lend an opportunity to involve the class in the observations and discussions.
5. The aim of science and technology education should be to introduce concepts and ways of thinking that will help students interpret their experiences of natural world.

Analysis:

Did we see a broader and methodical approach towards technology education? an approach that makes the children think, relate and come out with undestanding technology and related subjects!



Institute of Science Education

Reference: Rajive Vartak

Approach

Vartak, the director of ISE has very specific outlook towards science and technology education.

1. ISE conducts workshop making science and technology a part of everyday life.
2. The main objective of these workshop is cognitive development.
3. It is believed in ISE that learning should be a process based on experience.
4. Students discuss problems among themselves and arrive at logical solutions based on argument and experiences.

Vartak feels that most effective education is possible only by the method of exploration and discovery.

Analysis:

First awareness. second Understanding and third implimentation is what seems to be followed in such a teaching strategy.

1. Trial

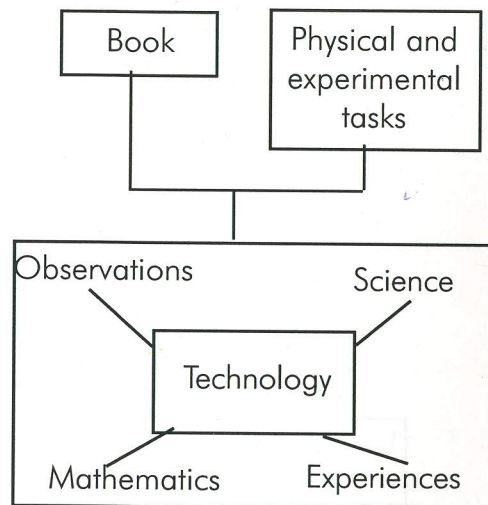
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2. Teach

3. Check

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Godrej Primary School

Approach:

1. Book based teaching supported by physical and experimental tasks.
2. Teaching involves integrating all subjects to teach any subject related to science.
3. Such a strategy allows the student to relate the scientific phenomenon to the world around, hence developing wider view points to apply scientific concepts to innovation.

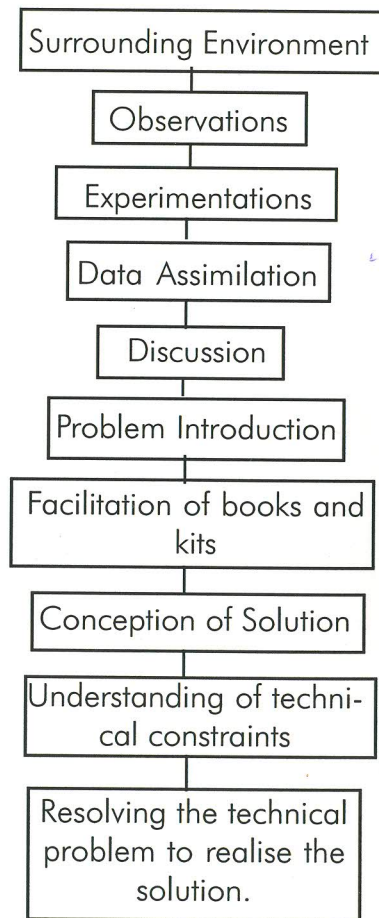
Eclavya (a non-profit voluntary organisation)

Works in several districts in Madhya Pradesh Through field centers in Harda, Hoshangabad, Piparia and Bhopal.

main area of innovation, in school education, publication of educational literature on science.

Approach:

1. Tries to redress the over emphasised content and tries to give emphasis on methodology.
2. Teaching through experiments and field trips
3. Children arrive at laws and concepts through a process of observation, experimentation, data assimilation, tabulation and group discussions.



4. attempts are made to tailor part of the content around the environment and life of the student.

5. Children perform experiments in small group hence enhancing communication and allowing the teacher to communicate with them easily.

6. The role of the teacher is modified into facilitating of performances of experiments, conducting of group discussions etc. to arrive at an understanding and experimenting skills through open book and practical examinations.

Analysis:

Apart from developing a link between the real life situation and observations and experimentation, interpersonal communication seems to be a major plus point in science and technology education.

Technology education through new media computers/Internet

The Internet has already revolutionised the education system by reaching a vast audience. Technology education has also been effected by it. The fact that internet as a technology in itself is being accepted as a normal part of day to day life, (without any formal education to many) proves that self exploration with little guidance can lead one to enslave a technology.

Apart from being a technology in itself, internet has also provided ample space for the growth of other technology by easy information transfer and quick user based experimentation.

The new K-12 internet education system has a wider audience. With sound interface and friendly navigational feature with real time interaction with teachers around the world, K-12 education system is becoming very popular.

Technology education through new media computers/Internet

Technology education through open ended educational sites:

Reference:

www.longman.awl.com/photosource

www.geocities.cm/baja/820s/robotenter.htm

www.members.xoom.com/dpscher

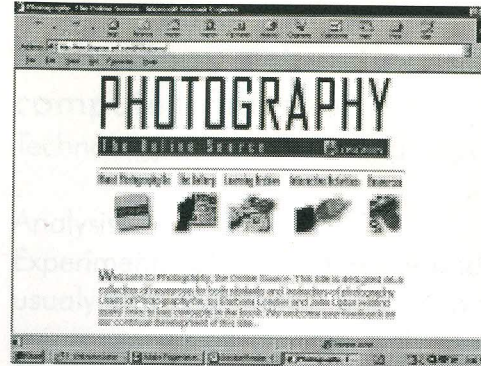
There are few sites those help perform experiments at home/ schools. These are simple experiments found in books, explanation of which is provided online. The observations and results of these experiments are shared with other students.

The information on the experiment, the procedure is given step by step with text, images, animations and videos.

The student performs his experiment in his lab/home with the material that are commonly available. If assistance or guidance is necessary, it is mentioned in the parents and teachers sections. Tips on assistance and care against accidents are also explained.

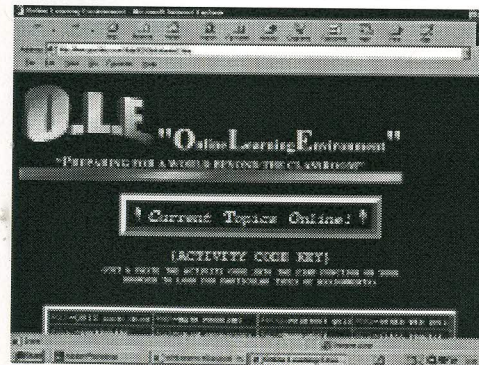
The observations of the experiments are shared on a common forum and the variations are drafted. Their observations are also graded.

A student is expected to draw conclusions from the theory learnt, the experiments performed and the observation bank accumulated. This conclusion if correct, the student is rewarded.



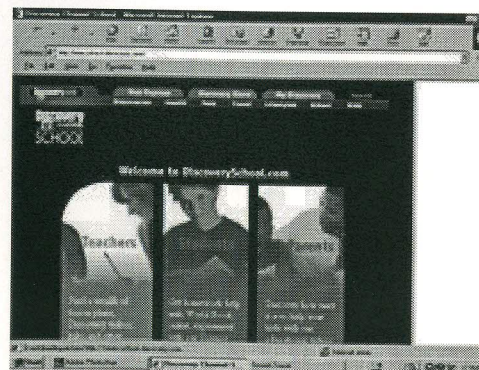
www.longman.awl.com/photosource

The technique of photography is no more inaccessible to layman. Even a kid can access the net and with a little guidance might as well learn to explore the various techniques behind photography



www.geocities.com/Baja/8205/robotenter.htm

This particular site gives links to various sites describing various technologies. Starting from environmental technologies to high tech robotics, the site allows one to go through the experience of understanding the desired technology.



www.school.discovery.com

A warehouse of different experiments and guidelines for teachers and students, discovery.com renders a wide range of education methodology.

Technology education through new media computers/Internet

Technology education through open ended educational sites

Analysis:

Experiments related to science and technology based education are usually from text books, which explain the basic concepts. The experiments are usually simple, with simple material as raw materials. The outcome is recorded. Incentives, such as scores, passwords, games etc are there for the students to perform the experiment sincerely.

A further extension is simulations of complex experiments cut down to the basics. Here Internet plays a medium of effective communication to get all teachers and students round the world to try out certain methodology to teach technology.

Such cases are followed.

Technology education at "National Science Foundation, Virginia, USA

Teaching the technology of communication

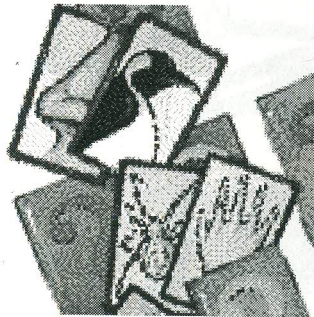
(<http://www.nsf.gov/od/lpa/nstw/teach/activity/english.htm#one>)

Follows a very interesting education system floated by NSF, USA in 1997 Teaching Activities are being presented as a series of six units. Each unit contains two to three activities, resources, and its own community outreach sections. These are designed to be undertaken in a sequence, but can stand alone as independent units.

Though the units are designed for specific age groups ranging from 5-14, most can also be adopted for use with younger or older children.

1: Naturally

Children will model and explore various natural (non- technological) methods of animal communication, each involving the senses of sight, sound, touch, or smell. These activities also introduce the concept (expanded in Units 3 and 4) of vibration as the foundation of all sound.



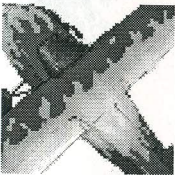
With codes



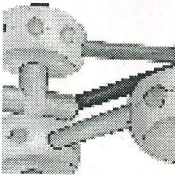
With wires



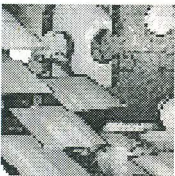
Through radio waves



Through networks
]



Into space



2: With codes

By sending distress signals from the Titanic, cracking coded song lyrics, and creating an egg-carton "binary decoder" children explore the many ways we use codes to communicate.

3: With wires

Youngsters will learn what makes electro- magnetic communication possible by constructing a rudimentary telephone and speaker out of ordinary materials.

4: Through radio waves

Youngsters will learn about radio communications and the electromagnetic spectrum by producing their own radio waves--and then figuring out how they did it.

5: Through networks

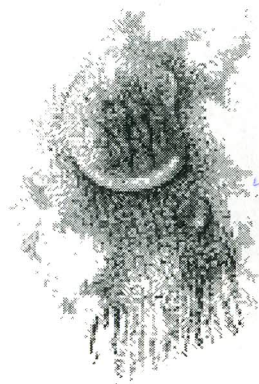
By building a ping-pong ball communication network and sending messages in binary code, children explore the basic components of all telecommunications links: input, transport, switch and output.

6: Into space

Youngsters will learn how we decode messages sent to us from space, such as from the Hubble Space Telescope, and then use problem-solving skills to interpret a simulated message from a civilization orbiting a distant star.

Analysis:

As we see from the above experiments there is a gradual learning process that has been followed. It's a distant cry from the general way of teaching technology behind communication. Here strength is being given to the very understanding of communication itself, which is gradually replaced by the complex issues related to the very technology.



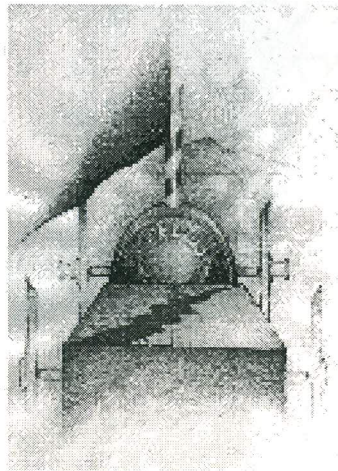
In 1996 National Science Foundation, USA had came out with a different kind of approach to teach various facades of technology. Follows brief of the whole project.

Nice Threads:

Children design fair tests while finding various degrees of absorbency of fabrics and fibers. They then learn not only the natural characteristics of several fibers, but also the matter of variables and their control. Finally, they apply the results of their fair tests in designing a headband for use in the 1996 Olympics.

Analysis:

Understanding the material, controlled use of it's characteristics and variables, and finally application of the understanding in designing a real life product.

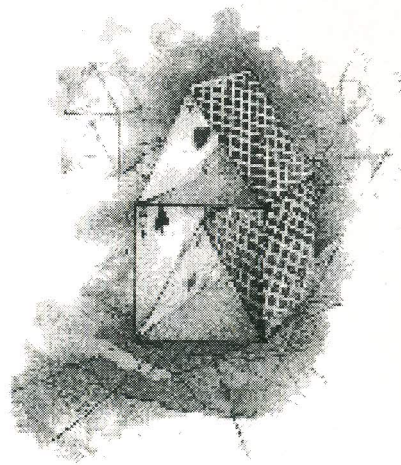
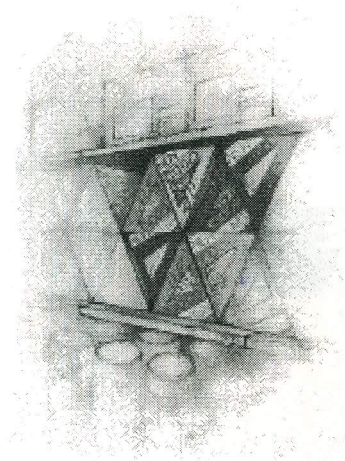


Designing for Speed:

Youngsters design a wind-powered vehicle for their own enjoyment in this activity. They also experience the process used by scientists and engineers in testing estimates and assumptions throughout several procedures and controls in creating a product.

Analysis:

Understanding the technology behind wind powered vehicles through enjoyment and applying the understanding in creating the product.



Designing for Consumers:

Through collaboration in a development process, students use market research, mathematics and communication arts skills in devising both a nutritious snack mix and attractive, economical, and environmentally sound packaging.

Analysis:

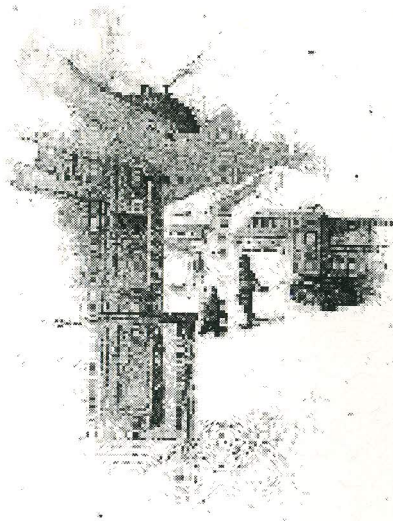
Should we call this marketing technology? However to create attractive, economical and most of all environmentally sound packaging, the children had to go through the rigorous process of understanding the environmental issues and the appropriate methodology and technology that must be followed to create the final product.

Designing for Adversity:

How do earthquakes damage structures? Groups of young people explore structural design by constructing houses that can withstand simulated earthquakes. Through this series of activities, participants gain hands-on understanding of earthquakes, ground types, and materials science and engineering.

Analysis:

Hands on construction technology, hands on understanding the forces and principles working behind an earth quake. Defining the problem area. Finding related influential factors and developing ways to counteract the earthquakes. An explorative way to learn the construction technology!



Designing for Community:

While designing a research community under the constraints of extreme cold and isolation, students learn about life in the Antarctic, where the temperature averages -13°C (8°F) and the sun doesn't shine for months at a time. Teams of young investigators research and plan specific aspects of a research station while complementing other teams' research and plans.

Analysis:

Learning the power of technology over the climatic constraints. Investigating the existing environment, planning a favourable environment. Applying the understanding in deciding upon specific aspects of required environment.

Observations:

-There are broadly two approaches followed for technology education

1. Making products using prescribed drawings or plans. (copying teaching method)
2. Students invent, design and make products themselves. (design teaching method)

-Technology education involves

1. Designing, developing and utilising technological systems
2. Cognitive, manipulative and effective learning strategies
3. Applying technological knowledge and processes to real world experiences using up-to-date resources.
4. Working individually as well as in a team to solve problems.

-The goals of teaching technology, as envisaged, is to enhance

1. Creativity
2. Problem solving skills
3. Social skills
4. Work life
5. Environmental education
6. Enterprise education

-The dimensions of technology literacy, as envisaged

1. Utilisation of technology
2. Evaluation of technology
3. appreciation of technology

Analysis

Technology education as seen in text books has little to do with the real life implementation by the reader. It's mostly dependent upon the pupil whether he is interested in trying out some experiments or not.

As we saw in the Solar cooker experiment, Pupil learnt the technology by trying to find a solution to certain execution problems. Had they been given the space to think and find a solution to use solar energy for cooking food, the whole experience surely would have been different!

For example finding the solution to the heat escape issue actually made them think. As per the science teacher, it was a thrill for them to find that their solution is actually the one the teacher had in mind!

Again in the second case where the pupils designed a Buzzer for the benefit of blindmen crossing the road... actually what they learnt is the technology that works behind the buzzer. But with a serious attitude towards finding a solution to a serious problem in their immediate environment.

Here the learning is more wholistic and complete.

As we see from the experiments conducted at ITEA, all of them are finally leading the pupil to learn the technology behind say a radio, a radar, a Morse code... (ref. page-26-27) or the technique behind choosing appropriate material for a particular function (ref. Nice thread, page 28), or say the technique of constructing an earthquakeproof house!

What was different in all these experiments was the pupils were directly involved in the process of learning the technology by designing a methodology and finally coming out with a technically sound product. With much better awareness towards the need and scope of a particular technology.

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The Key Questions

Whatever approach we might take in teaching technology, we must be able to judge the impact of both the approaches separately (namely copying teaching and design teaching approach)

Say for example-

- * What students are able to think and do after the instruction, namely what kind of mental schema does technology education creates?
- * Do they able to create conceptual schemas of the technological concepts that they are taught?
- * Do the technology education develop transferable thinking skills and general problem solving strategy?

In Search of the Appropriate Method

Teaching technology through copying teaching method

Analysis:

Though this is a widely accepted method of technology education. There are some loop holes. Actually what happens is pupils are generally confident when work is closely directed by the teacher, but less so when working independently to their own plans. Such cases induce little awareness of how their work will develop in the later stages of their projects. Since their work is dependent upon instructions, thinking skills remain immature.

Teaching technology through design teaching method

Analysis:

This method allows the pupil to alternate between Design, Construction, Testing and Inquiry and reflective activities to help them learn a variety of concepts. It lets them think, communicate, develop the sense of aesthetics and understanding of technology.

Conclusion

As we see from the given examples and related experiences as mentioned by the teachers and as experienced by the pupils, there is certainly an advantage in design teaching method. The creative experiences backed by the understanding of the whole process of conceiving a technology based problem to reaching a particular solution is what seems to leave a lasting impression on the pupil.

Few Suggestions

Based on the studies and analysis, follows few suggestions as how to make technology education most effective.

Pupils should be given opportunities to critically evaluate technological products and should be encouraged to consider alternative ways of addressing needs and opportunities other than making products. It is important that such a thing is linked with pupil's own designing and making so that their creative activities and thinking goes side by side.

Keeping in mind the goals of technology education following points may be followed for creation of an effective teaching module:

- * Assignments should focus on designing and making of products with respect to different contexts and materials.
- * Practical tasks should target at development and practise of particular skills and knowledge.
- * Activities should be targetted at investigation and evaluation of familiar products and application.

Clearly the focus should not be on merely instructing the pupil to build a product, rather the focus should be on inducing a sense of curocity in them. A curocity that builds in them the power to judge, evaluate and finally helps them finding aesthetically appealing, technically sound and appropriate solutions to demanding probems of the society. A curiosity that tickles the creative genius... that lays path to innovation... an innovation that works.....

“Technology is Human Innovation at Work”

What Teachers can do

Given what is known about young children's learning and about their amazing competence to express their visions of themselves and their world, how can the classroom be modified to best support children's emerging creativity?

TIME. Creativity does not follow the clock. Children need extended, unhurried time to explore and do their best work. They should not be artificially rotated, that is, asked to move to a different learning center or activity when they are still productively engaged and motivated by a piece of creative work.

SPACE. Children need a place to leave unfinished work to continue the next day, and a space that inspires them to do their best work. A barren, drab environment is not conducive to creative work. Rather, children's work is fostered by a space that has natural light, harmonious colors, comfortable and child-sized areas, examples of their own and others' work (not only their classmates, but as appropriate, also their teachers' and selected adult artists), and inviting materials.

MATERIALS. Without spending great amounts of money, teachers can organize wonderful collections of resource materials that might be bought, found, or recycled. These materials can include paper goods of all kinds; writing and drawing tools; materials for constructions and collages, such as buttons, stones, shells, beads, and seeds; and sculpting materials, such as play dough, goop, clay, and shaving cream. These materials are used most productively and imaginatively by children when they themselves have helped select, organize, sort, and arrange them.

CLIMATE. The classroom atmosphere should reflect the adults' encouragement and acceptance of mistakes, risk-taking, innovation, and uniqueness, along with a certain amount of mess, noise, and freedom. This is not a matter of chaos, or of tight control, but instead something in between. In order to create such a climate, teachers must give themselves permission to try artistic activity themselves, even when they have not been so fortunate as to have had formal art training or to feel they are naturally "good at art." Through workshops, adult education classes, or teamwork with an art teacher or parent, classroom teachers can gain the confidence for, and experience the pleasure of, venturing some distance down the road of self-expression in a medium in which they did not know they could be successful. Their skill will then translate into the work with the children.

OCCASIONS. Children's best and most exciting work involves an intense or arousing encounter between themselves and their inner or outer world. Teachers provide the occasions for these adventures. Children find it hard to be creative without any concrete inspiration. Instead, they prefer to draw on the direct evidence of their senses or memories. These memories can become more vivid and accessible through the teacher's provocations and preparations. For example, teachers can encourage children to represent their knowledge and ideas before and after they have watched an absorbing show, taken a field trip, or observed and discussed an interesting plant or animal brought into class. Teachers can put up a mirror or photos of the children in the art area, so children can study their faces as they draw their self-portrait. Teachers can offer children the opportunity to check what they have drawn against an original model and then let them revise and improve upon their first representation.

A Scheme to Teach the Technology Behind an ordinary Camera

Introduction: Based upon our study, analysis and understanding of design as the most effective medium of technology education, we can actually develop some schemes to teach complex technologies.

The most effective technology education shall be one, where the learner defines the usage, defines why such a technology is required, develops an insight into the scientific principles and finally explores the technology in his own innovative way!

Problem: To teach the technology behind an ordinary camera

Target Learner: School children of age 10-12

Guidelines:

1. Learning should go through a creative process, where they design a camera based upon their understanding of camera technology
2. The scientific principles must be made clear
3. Learning should be gradual
4. Learning should be fun
5. Materials should be easily available and should be safe to use
6. References and metaphors from day to day life should be used to simplify the complexities of technology

The Teaching Process

The whole process is to be divided into a number of units. To find out how many units, we must figure out the scope of teaching!

- * The origin of camera, it's most ancient form
- * The principles of a camera eg. Reflection, Refraction, Nature of light, Light control, Image formation, Image capture etc

Concern: Considering the young learners, the depth of technology education should be to a point from where they can extend their own exploration.

- * It is expected that the above theories concerning principles working behind a camera be taught in class room.
- * The technology is to be taught by hand on experience by the method of design!

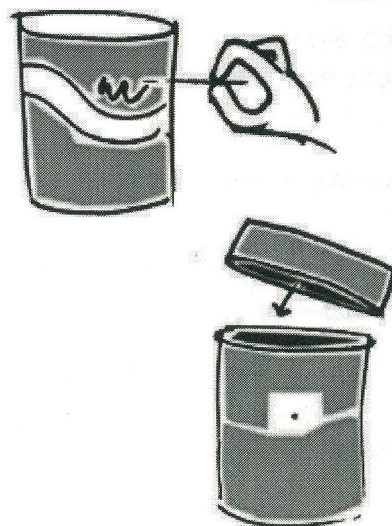
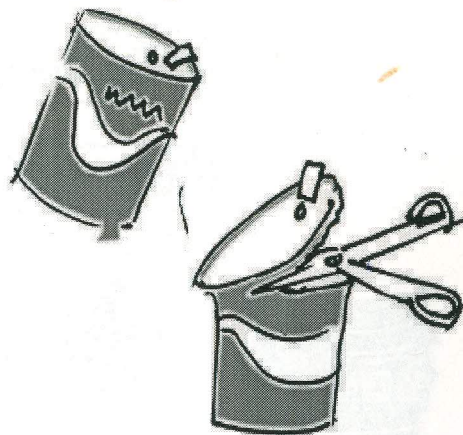
- The basic of camera technology education may start with the pinhole camera along with the facility to capture a picture through it!
- A good practical idea of how photographs are developed, need to be a part of the above exercise.
- Then the teaching focus can shift to use of lens in cameras and the difference it makes in taking a picture.
- Finally some idea about the exposure time and quality of acquired images should allow the children to get an overall idea of camera techniques with enough scope for self exploration.

Here a scheme to teach the first two techniques are developed.

Instructions to make a camera out of a drinking can

Materials Required

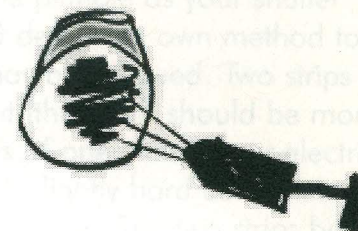
- * an aluminum soft-drink can
- * old scissors to cut the aluminum with (please don't use good scissors for this!)
- * flat black spray paint (not the glossy black kind)
- * dark, preferably black, contact paper to cover the lid of the camera: any color will work, however, since the lid will be spray painted black
- * a #16 bead-threading needle (used to make the pinhole in the aluminum). (If can't find a #16 needle, look for a #15 or #14 beading needle instead)
- * a manila file folder
- * plastic (electrical) tape
- * light cardboard, such as the side of a breakfast cereal box
- * a ruler to measure the paper shutter parts
- * an Exacto knife or one-sided razor blade to cut the hole in the oatmeal box. Please be careful when cutting!
- * emery cloth or very, very fine sandpaper
- * two strong rubber bands to hold on the lid while outdoors taking pictures



The process of making the camera:

Getting started

1. Take the can
2. Cut the top off using the pair of scissors.
3. Spray inside with matt black paint
4. Now we need to make a hole on the side of the can

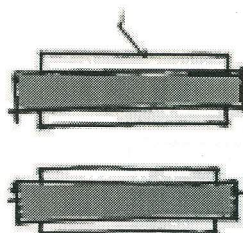


Making the pinhole

5. Before making the hole file the area in which we are going to put the hole down to make the metal as thin as possible.
6. Take the fine needle and gently create an indentation by smoothly turning the pin - do not go through and make a hole.
7. Use very fine sandpaper on the inside to gently smooth away the indentation and create the hole. (For children we can go for a larger hole which will decrease the exposure times.)

Making the camera light tight

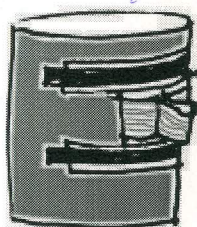
8. Make up a cover for the top of the can using cardboard and black insulation tape. Additional rubber bands can be used for better effect. At this stage childrens might as well be asked to devise their own solution



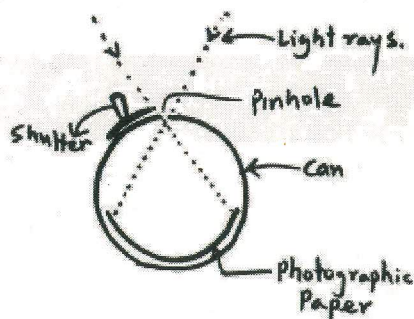
Prepare shutter guides as per instruction



A simple effective shutter



The pin hole camera with the shutter



Installing a shutter

9. Use a piece of black insulation tap over the pinhole as your shutter (and lens cap!). The student may be asked to devise his own method to create a shutter. Else the following method may be followed. Two strips of equal length from the manila envelope be cut (the width should be more than that of possessed electric tape). Two strips of one inch longer electric tape be cut and pasted as shown in picture. A slightly hard card sheet be cut and fold as shown. This should act as the shutter. The two strips be pasted on the can and the shutter be slid in between. Now we are ready with a slidable shutter!

Loading paper negative

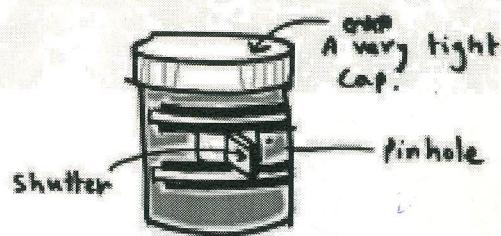
10. Load with either 5x4 paper or film. Paper is suggested for children. It's important to show the children the nature of photography paper by exposing some to sunlight and showing the result. At the same time how to load the paper in the pin hole camera must be taught.

Learning technical tricks

11. If use paper try exposing (in bright sunlight) for 30 seconds Contact print the paper negative into a positive. (Here dark room techniques and use of chemicals are vital.)

13. Don't point the pinhole directly into the sun, that might over expose the photo sensitive paper.

15. Take a clean changing bag with you to reload the camera.



The Final Pinhole Camera

Making exposers

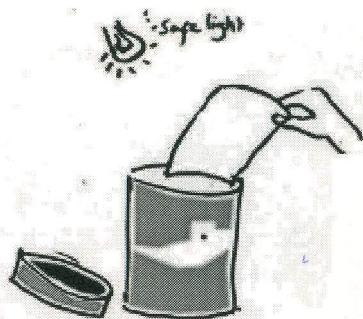
* This kind of camera takes about 20 seconds to take a normal exposers. It's a long time to hold the camera in hand. Even a slight movement will blur the photograph. So the camera should be put on some fixed position with some weight on it (to avoid to be blown away by wind!)

* To change the paper, we put the camera inside the changing bag and replace the paper. It will take a little time before we could master this. Lest we go back to the dark room and reload the camera.

Developing the negatives

Required materials

- three 5x7 developing trays
- developer (Kodak Dektol - comes in quart and larger sizes)
- stop bath (optional - clean water may be used instead) (Kodak Indicator Stop Bath or Acetic Acid)
- fixer (very important-Kodak Fixer is least expensive, comes in quart and larger sizes)
- sheet of plate glass large enough to cover 5 x 7 paper—must have edges ground so they are not sharp
- white light (a 15 watt bulb on a cord with a line switch is recommended. The room light can be used, but it is usually more difficult to control. Test it out first—you will probably want to use the 15w. bulb instead)
- clean towels
- recommended: plastic photographic chemical bottles to keep solutions in (sold at photo supply stores)

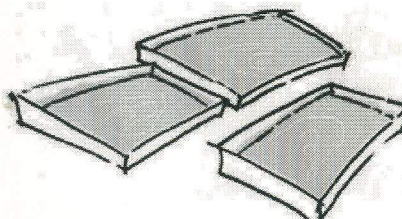


Take the exposed paper out of the camera under safe light

(These chemicals are common darkroom chemicals for black and white print developing. They are not toxic under normal use but ingestion is not recommended.)

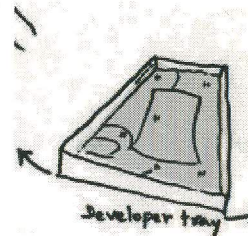
Negative to positive

* Under the safelight, remove the exposed film from the camera and place it in the developer tray. Gently rock the tray so that a wave of developer washes back and forth across the film. When it looks dark enough, pick the film up by one corner and let it drip for a few seconds. Then place it in the second tray, the stop bath (or water, if so desired.)

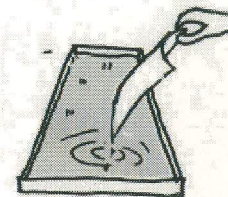


Get three trays and fill them separately with developer, fixer and Plain water respectively

* Again, rock the stop bath tray for about ten seconds (this is called "agitating"), lift up the negative and let it drip, then place it in the fixer tray. Agitate the fixer tray for at least two minutes. Fixing the image is very important: the fixer dissolves out any silver which hasn't turned black, so that years from now, the picture won't turn yellow or some other unwanted color. Sometimes improperly fixed photographs just fade out, as if they were bleached by time. After a minute of agitated fixing, it is OK to turn on the room light.



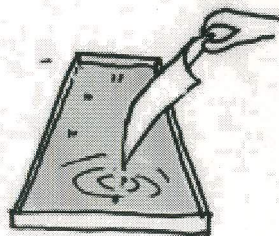
Put the paper in the developer tray. Agitate till the image appears.



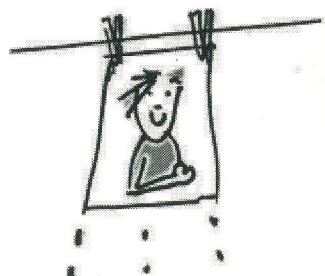
Take the paper out and let the chemical drip.



Put in stop bath for 10sec



Rinse in fresh water tray

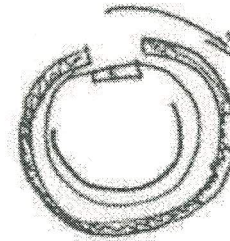
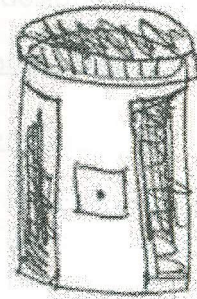


Let the image dry... Now the photograph ready!

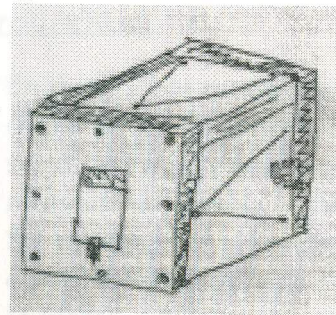
* The last "wet" processing step is to wash the photographic paper in clean, room temperature water for about four minutes. This step is very important, too, because if any fixer is left in the paper, it will act like a bleach and cause the photographic image to fade over time. Room temperature water is important because water which is too hot or too cold can damage the layers which make up the photographic paper. Last, pat the paper dry with paper towels or with a clean cloth towel and set the paper on a clean space where it will quickly dry.

Extension

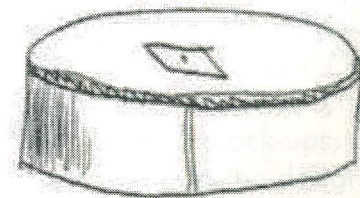
- * Children should be asked to design their own pin hole camera using variety of objects.
- * Some solutions which might give them some idea as to how to go about designing their own camera follows



A small yet effective camera can be built by using the plastic film role holder



Small card board boxes might as well come handy to tickle the creative genius in the kid



A simple chocolate box can also make an interesting camera.

Teaching the Technology behind a Glider

Developing a scheme

Suggested Materials:

Wind tunnel*
Balsa wood
Graph/drawing paper

Glue
Wax paper
Straight pins
Exacto-knives
Modeling clay
Card stock material
000 fine sandpaper
Ruler
Tape

Objective:

To design, build, test, and fly a glider.

Learner Group: Age group of 12-15

Prerequisites:

Principles of flight Understanding of how aerodynamics affects flight, what parts of the airplane control the aircraft as it moves through the air, and how these concepts affect the design of the aircraft Design specifications to include tolerances and performance standards

Introduction:

Engineers use models to test designs before building the actual airplane. In this activity the student will develop their ideas into a set of working plans included detailed blueprints, specifications, material list, and a technical report. They will build mock-ups, test the mock-up in a wind tunnel, make modifications to the designs, corrections to drawing, specifications and material list. Students will begin construction of the prototype (actual flying model). The final test will come when the prototype will compete

in a flying contest with classmates.

Suggested Teaching Procedures:

1. The teacher will review the principle of flight and discuss the design process used in aerospace technology. This process will consist of six basic stages.

Stage 1: Thumbnail sketch:

Quick sketches drawn by students to give them an idea of how the glider will look.

Stage 2: Rough sketch:

Sketches that show the glider from three views or profile.

Stage 3: Final drawings:

These drawings show the exact details of the size and shape of the glider. From these drawings, a material list will be developed. A rough draft of the technical report will be started to describe how the principles of flight have been considered in the design.

Stage 4: Prototype:

From the drawings and specifications a mock-up will be assembled to check design specifications. The mock-up may also be used to test the design in the wind tunnel.

Stage 5: Production:

The actual flying model will be built and flown competitively against the other airplanes produced by the students in class.

Stage 6: Technical Report:

The technical report should be based on the glider design and provide evidence that the student

has done research on the principals of flight as related to the design. Included in the technical report are the assembly instructions, description of the launch techniques, drawings and diagrams.

Evaluation:

This may be evaluated in a variety of ways. A suggested rubric follows:

1. Thumbnail Sketch
2. Rough Drawing
3. Final Drawing
4. Prototype
5. Production— Craftsmanship
6. Flight duration
7. Technical Report

Grades (low to high)

0 = nothing

1 = Thumbnail Sketch

2 = 1 + Rough drawing

3 = 1 + 2 + Final drawing

4 = 1 + 2 + 3 + Prototype Report

5 = 1 + 2 + 3 + 4 + Production Craftsmanship

6 = 1 + 2 + 3 + 4 + 5 + 6 + Technical Report

Teaching the Technology behind a Wind mill

Problem: To teach the technology behind a wind mill

Target learners: Age group 10-12

Guidelines:

1. The project should emphasise upon developing an understanding of the power of wind
2. The learning should be from the very basic wind instrument like a pinwheel to wind direction measuring device

Some concern

Wind is free. Wind is clean. If you live in an area where winds regularly blow at about 20 kilometres per hour, you can use the wind to make electricity. All you need is a modern windmill. Better yet, if you have enough land, you can set up a windmill farm using many windmills working together. Then you can generate enough wind to supply a village. One of the biggest windmills is found in California in a valley between large mountains. It consists of more than 4,000 windmills and it produces as much power as an average nuclear power plant. Right now windmill technology is rather expensive, but it is getting cheaper. In fact, electrical generation using wind is about five times cheaper today than it was in 1980.

Suggestions: Don't claim that wind energy is the solution to the world's energy problems. It is not. At best, scientists say it could supply only about 10 percent of the world's need next century. But that is very good,

because it could greatly reduce the pollution from greenhouse gases. Be prepared for criticism from other students, however. Windmill farms take a lot of land and they can be quite noisy. Point out, however, that the best places for windmill farms are often in remote areas with smaller populations. And engineers are working hard on the noise problem and they are having some success. Anyway, the windmill noise is not at dangerous levels.

The process

Make A Pinwheel

Everyone can make a pinwheel by following a few simple steps and using ordinary classroom materials. Remember, the more colorful, the more fun!

Make An Anemometer

Kids may find "anemometer" difficult to say, but they'll find an anemometer easy to make by following the instructions for this simple Dixie cup model.

Make A Wind Direction Indicator

Basically a simplified windsock, this indicator will very quickly have your students measuring the wind's direction.

Make a Wind Vane

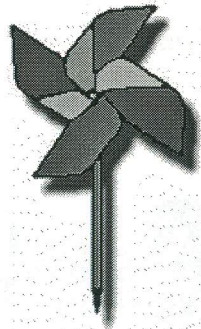
Commonly called a "weather vane," the wind vane indicates wind direction.

Exploring ways to make a working windmill

After a brief introduction to possibilities of a wind mill, the Children should be asked to explore the usability of a windmill and design one accordingly.

Materials

a pin
a square piece of construction
paper (about 8.5" x 8.5")
a sharpened pencil with an eraser
scissors



Designing a Pinwheel Wind collector

Procedure

Lay the square of paper flat on a table and draw a line diagonally from each corner to the opposite corner. Mark the center of the square where the two lines cross and punch a small hole through it with the pencil tip. Next, cut along each line stopping about an inch from the hole in the center of the square.

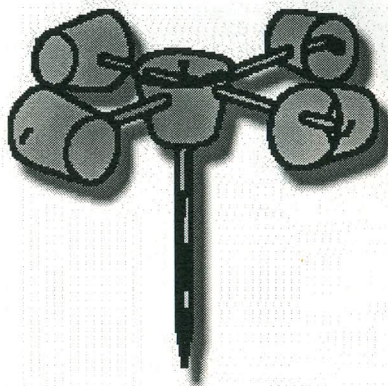
Take the pin and punch a hole in the top left corner of each of the four flaps. (No two holes should be next to each other.) Pick up a flap at a punched corner and carefully curve it over toward the center hole, securing it with the pin. Repeat this for the other flaps. When all four flaps are held by the pin, carefully lift the paper without letting the flaps unfurl. Lay the pencil flat on a table and carefully push the point of the pin into the side of the eraser.

Now your pinwheel is complete and ready to go. Pick up the pinwheel near the pencil point and let it catch the wind.

The students should discover that the pinwheel only spins when the wind hits its center. You now have a simple wind collector. The pinwheel is an example of a horizontal-axis active wind collector. It must be pointed into the wind in order to spin.

Materials

five 3 ounce paper Dixie cups
two straight plastic soda straws
a pin
scissors
paper punch
small stapler
sharp pencil with an eraser



Designing an anemometer

Procedure

Take four of the Dixie cups. Using the paper punch, punch one hole in each, about a half inch below the rim.

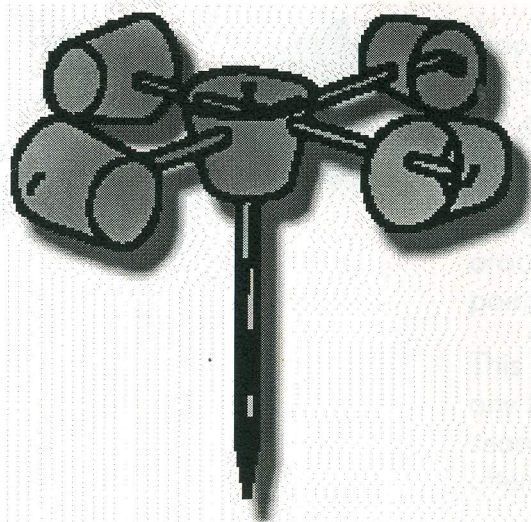
Take the fifth cup. Punch four equally spaced holes about a quarter inch below the rim. Then punch a hole in the center of the bottom of the cup.

Take one of the four cups and push a soda straw through the hole. Fold the end of the straw, and staple it to the side of the cup across from the hole. Repeat this procedure for another one-hole cup and the second straw.

Now slide one cup and straw assembly through two opposite holes in the cup with four holes. Push another one-hole cup onto the end of the straw just pushed through the four-hole cup. Bend the straw and staple it to the one-hole cup, making certain that the cup faces in the opposite direction from the first cup. Repeat this procedure using the other cup and straw assembly and the remaining one-hole cup.

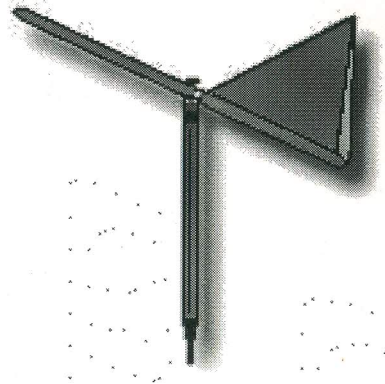
Align the four cups so that their open ends face in the same direction (clockwise or counterclockwise) around the center cup. Push the straight pin through the two straws where they intersect. Push the eraser end of the pencil through the bottom hole in the center cup. Push the pin into the end of the pencil eraser as far as it will go. Your anemometer is ready to use.

The anemometer is useful because it rotates at the same speed as the wind. This instrument is quite helpful in accurately determining wind speeds because it gives a direct measure of the speed of the wind. To find the wind speed, determine the number of revolutions per minute. Next calculate the circumference of the circle (in feet) made by the rotating paper cups. Multiply the revolutions per minute by the circumference of the circle (in feet per revolution), and you will have the velocity of the wind in feet per minute. The anemometer is an example of a vertical-axis wind collector. It need not be pointed into the wind to spin.



Materials

one straight plastic soda straw
one piece of construction paper
a pencil with an eraser tip
one straight pin
stapler
scissors



Wind Direction Indicator

Procedure

Cut one end off the piece of construction paper so that it is square. Fold one corner of the square over until it meets the opposite corner to form a large triangle.

Crease the fold and open the paper. Cut along the fold to make two triangles. Fold one triangle in half once again and crease it along the fold. Now place an open edge of this folded triangle over the soda straw with the point toward the center of the straw and the other open edge at the end of the straw.

Staple the tail to the straw. Next push the pin through the soda straw about one inch ahead of the front of the tail. Push the pin into the top of the eraser on the pencil. Your wind direction indicator is now ready to go.

Hold the wind direction indicator in the wind. It automatically turns around until the tail of the straw points away from the wind and the tip points into the wind.

This instrument is useful in determining where the wind is coming from at any time and in noting variations during the day or from season to season. Hold your wind direction indicator in the wind and notice how often the wind direction changes.

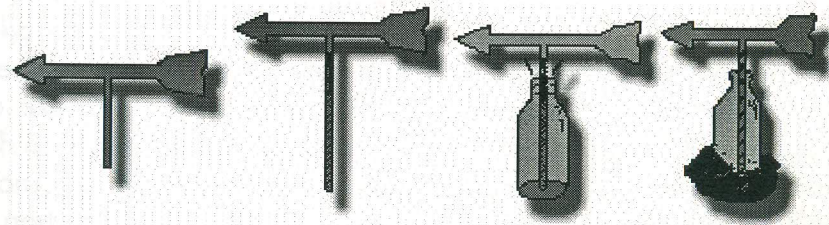
Materials
paper and pencil
scissors
cardboard
compass
plastic soft drink bottle
plastic drinking straw
shallow pan filled with rocks
felt marking pen

Designing a Wind Vane

Before You Start...

A weather vane is also called a wind vane. It is a tool for measuring wind direction. It spins on a rod and points in the direction from which the wind comes.

The weather vane is one of the oldest weather tools. The part of the vane that turns into the wind is usually shaped like an arrow. The other end is wide so it will catch the smallest breeze. The breeze turns the arrow until it catches both sides of the wide end equally. The arrow always points into the wind. The arrow tells you the direction from which the wind is coming.



Procedure

What is a weather vane? When have you seen weather vanes? Write down your answers. Draw a picture of a weather vane.

With the scissors, carefully cut an arrow with a tab from the tag board, as shown. Remember that scissors are sharp, so handle them carefully. Bend the tab slightly so the arrow turns easily when you put it in one end of the

straw. Put the other end of the straw in the bottle. Remove enough rocks from the pan to make room for the bottle. Pile the rocks back around the bottle so it won't be blown over. (See illustrations above.)

A compass always point north. Use your compass to find north, and then mark the four sides of the bottle E, W, N, and S with a felt pen.

Set your weather vane in a high place such as the top of a playhouse or a slide. Make sure it does not wobble or tilt, and that it catches the slightest breeze.

Watch your weather vane closely and then describe how it works. Test it on windy days and again when there is just a light breeze.

Background Information

A weather vane is a tool used to tell which direction the wind is coming from. Weather vanes are usually found on top of buildings so they will catch an open breeze. Look for them on top of barns, houses, weather stations, hardware stores, and other places that sell or use weather tools. The part of the vane that turns into the wind is usually shaped like an arrow. The other end is wide so it will catch the smallest breeze. Sometimes a metal rooster or other animal sits on top of the weather vane.

You have made a weather vane! If the wind is blowing from the south, the wind is usually warm. If the wind is blowing from the north, the wind is usually cooler.

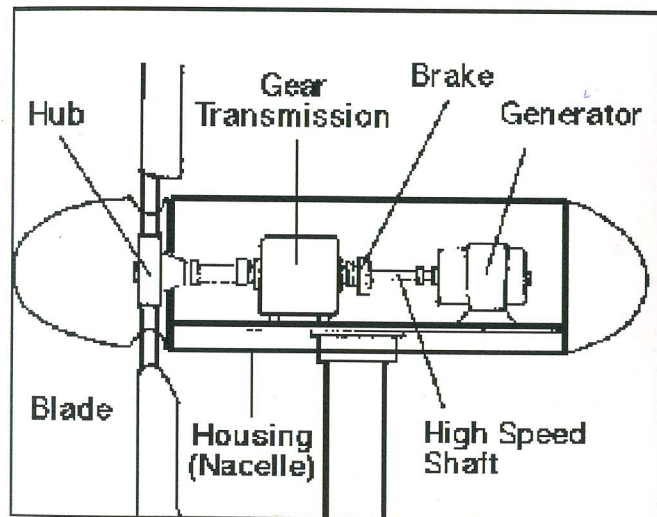
Some weather vanes have directional strips underneath the arrow to make it easier to read. Your markings on the bottle do the same thing.

The breeze turns the arrow on the weather vane until it catches both sides of the vane equally. The arrow always points into the wind.

It is easier to see how the energy from the wind moves your weather vane if it is up high and in an open area. You might also want to experiment by putting it on the ground.

A weather vane is one of the oldest weather tools. It is still used today to measure the direction of the wind. Weather vanes can only measure wind direction a few yards (meters) off the ground. Large, helium-filled weather balloons are used to measure winds high above the earth's surface. The balloons move with the same speed and direction as the wind.





Finally the electric energy generating windmill may be introduced with easily understandable sketch. Further exploration can lead the students to come out with their own version of windmill with multiple usage.

Designing a Windmill

I. Prior Knowledge

Students have, at this point, made many observations about the wind. Focus their attention on the ability of wind to make objects move. Because wind can do just that, it has kinetic energy or energy of movement. The faster the wind blows, the more kinetic energy it has. This energy is transferred when wind strikes an object, causing that object to move.

Ask students to list as many things as they can that are built precisely to catch the kinetic energy found in wind: sailboats, kites, windsocks, gliders, pinwheels, WINDMILLS. Have students discuss what it is they know about windmills and their capacity to catch atmospheric motion to make their blades spin. How many different types of windmill designs are familiar to them? You may want to have them draw their own conceptions of windmills in their journals.

II. Exploration

Windmills are designed to extract as much energy as possible from the wind. Windmills capture the energy of the wind when the wind moves the blades (or rotor) of the windmill. An effective windmill must therefore be designed to capture wind energy.

Children should be asked to come out with new ideas to utilise wind power.

With the developing understanding of windmill, the concept of electric generation and multiple use of wind power like pulling water etc. can be introduced.

Teaching the Technology behind a Speaker

Learner Group:

Age group of 13-15

Objectives:

To analyze electric and magnetic interactions in the physical world. To investigate the inter-relationships of science, technology, and society. To communicate results of scientific investigations in oral, written, and graphic form. To apply the principles of magnetism and electricity to build a speaker. Note: This laboratory should be conducted after the forces exerted by magnetic fields laboratory.

Prerequisites:

Magnetism
Electricity
Right hand rules
Sound
Introductory activities on magnetic properties

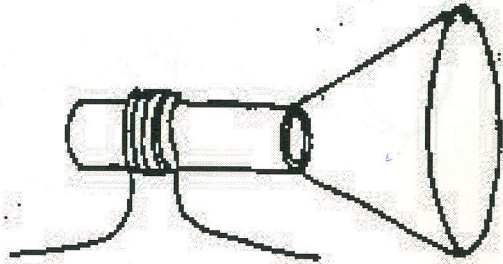
Introduction:

The interaction between electricity and magnetism allows society to use generators, motors, speakers, and microphones. Engineers use electricity flowing through coils of wire within a magnetic field to create the force needed to produce sound by pushing air with the cone of a speaker at a rate that our brains interpret as sound. This activity will allow students to build a functioning speaker.

Suggested Materials:

Coiling or magnet wire
Large horseshoe magnet or 2 strong bar magnets
Construction paper
Cardboard tube (from toilet paper)
Tape or quick drying glue
Rubber bands
Box (large shoe box) to mount speaker cone and magnet(s)
Signal generator
Oscilloscope
Small ceramic washer-shaped magnet

Suggested Teaching Procedures:



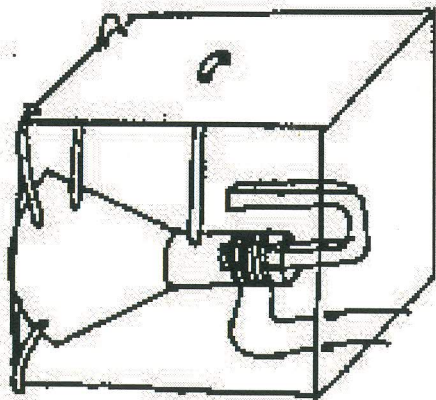
Students are divided into lab groups.

Fold construction paper to form a large cone. Use tape or glue to secure the seams of the cone.

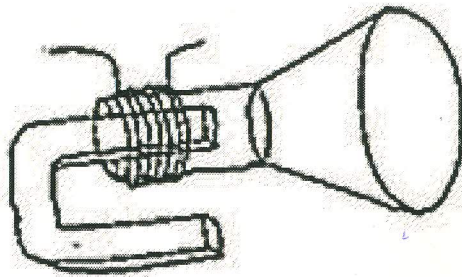
Wrap coiling wire around the cardboard tube. The wire loops should be wrapped tightly against each other to form a 1-1.5 inch coil.

Secure the loops of the coil with glue or tape. Each of the ends of the coil should extend about 4-6 inches. Strip the enamel insulation off each end.

The cardboard tube is then connected to the construction paper cone using glue or tape. Prior to combining the cone and tube, the tip of the cone should either be cut or folded towards the center of the cone. The cone/tube assembly should resemble the drawing below.



Next secure either the horseshoe magnet or the 2 bar magnets to the back center of the cardboard box. If using the 2 bar magnets, place them slightly apart to create a magnetic gap similar to the gap between the poles of a horseshoe magnet. The bar magnets should be aligned parallel to each other with opposite poles towards each other causing a force of attraction. Secure the magnet(s) with tape or glue.



Then place the cone/tube assembly over the magnet(s) so that one magnet (or one pole of the horseshoe magnet) is inside the coiled tube as shown.

The tube needs to be placed so that it surrounds the magnet inside it, but does not rub against it! Use tape or rubber bands "strings" (made by cutting rubber bands) to allow the cone/tube assembly to hang suspended in the cardboard box so that the tube surrounds the magnet without touching the magnet.

The speaker can be checked for "Quality Control" by connecting it to a signal generator. Place the speaker in front of a microphone which has a broad-range frequency response. Connect the microphone to an oscilloscope and monitor the signal coming from the speaker. Can the speaker respond to the entire range of audible frequencies? Have students prepare a specification sheet for their speaker.

How do you think the design of a speaker affects the range of frequencies to which it can respond? Would a large, more massive speaker be capable of the same response? Justify your answer.

Pose the question "Can you think of another type of speaker design?"

The emphasis here is to try to get the student to arrive at a design where the coil is stationary and the permanent magnet is attached to the end of the movable cone. In this design the permanent magnet moves in response to the coil. If students fail to arrive at this design alternative, you might suggest it to them. Students could then build the speaker and repeat steps 1-10 and then make a comparison between the two designs.

Evaluation:

Students successfully produced a speaker which produced sound from an electric signal produced by a signal generator.

Students successfully operated an oscilloscope to analyze the frequencies emitted by the signal generator.

Students produced a specification sheet for their speaker.

Students correctly answered questions regarding speaker design and frequency response as a function of mass.

Students can use appropriate rules to predict the direction of force on a current-bearing wire.

Extension:

The students could connect the speaker or a mini-amp made previously while studying electricity!

A small speaker can be made using one or two small circular magnets available from Radio Shack or Walmart. A very small cardboard or stiff paper tube must be constructed. The diameter of the tube should be 5 mm or less. The magnet can be secured to a small Styrofoam cup instead of the box. The cup can also serve to anchor the rubber bands supporting the paper cone (Dixie drink cup) which is attached to the tiny tube. The mini-speaker may be used as a microphone!

References

1. Bame, E.A. (1999). Personal and Social Impacts of Technology Education. PATT-9* Conference Netherland
2. Banks, F. of Open University. Barlex, D. of Brunel University(1999). "Noone forgets a good teacher!"- What do 'Good' Technology Teachers Know and How does What They Know Impact on Pupils' Learning. PATT-9 Conference
3. Barak, M. and Doppelt, Y. (1999). Pupils' Perspective on the Most Influential Characteristics and Major Outcomes of a Rich Technological Learning Environment. PATT-9 Conference
4. Tsuzuki, C., Miyakawa, H. and Nakashima, Y.(1999). A Fundamental Study on Fostering Creativity in Technology Education and Fostering Creativity in Productive Practices Using Two Teaching Subjects.PATT-9 Conference
5. Munshi, K. Science, Technology & Design- an Integral Approach to Education. IDC, IIT Bombay, India
6. Munshi, K. Dynamics of Design & Technology with an Indian Overview. IDC, IIT Bombay, India
7. www.longman.awl.com/photosource
8. www.geocities.com/Baja/8205/robotenter.htm
9. www.school.discovery.com
10. <http://glsmyth.freewebsites.com/Pinhole/Articles/History/PinholeHistory.htm>
11. <http://csmt.msstate.edu/lw/html/resources/glider.html>
12. <http://sln.fi.edu/tfi/units/energy/buildwindmill.html>