

## **Teaching science and technology using African and European illustrations drawn from everyday life**

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### **Abstract**

This paper describes evidence that interested members of the public can acquire increased insights and awareness of science and technology if they experience relatively informal lessons containing stimulating science and technology practical exemplars and illustrations drawn from everyday public life situations. At UCT we have developed many successful teaching methods and techniques, using numerous supplementary real life examples, for the specific purpose of bringing science and technology textbook principles to the public, and students, and vice versa. These resources include: (1) an annual four day field camp; (2) model construction using discarded household materials; (3) case studies of scientific moral dilemmas in the public domain; (4) creation of analogies using terminology from other areas of academic disciplines; (5) technology syllabus creation using from a single item of public hardware; and (6) visits to public sites and departments to study and teach applications of scientific and technological textbook principles in other disciplines.

### **Paper**

#### **INTRODUCTION**

One of the most important ways in which the teaching of science and technology can be improved in South Africa and Lesotho is by "introducing more real life skills into science, such as technical, trade, industrial, commercial, manufacturing, marketing and technological skills" [1]. This was one of the top-ranked views of 539 respondents in twelve diverse groups of surveyed lecturers, teachers and students in science and technology education from 1995 to 1999. They were asked to choose from 15-20 possible courses of action recommended in the recently published academic literature and government reports. In subsequent years, the author further corroborated this conclusion after the survey was repeated in another developing country, Turkey, in the year 2000.

The results of these surveys suggest that the teaching of science and technology might be more closely linked to skills and examples already existing in the public domains of trade, industry, marketing and manufacturing, particularly when the textbooks and resource materials available in schools are limited in scope.

This paper therefore describes and illustrates some of the successful teaching methods and techniques, using numerous real life examples, developed at the University of Cape Town for students, for schools and for the wider public. We use local and broader South African contexts, on a regular basis, to show how textbook principles of science and technology can be perceived, disclosed and interpreted in a wide range of examples that are conveniently available in the public domain. Our science students also share their suggestions, ideas, interpretations and explanations with members of the public at their own actual work sites - such as a brick making factory, a conservation area or an iron museum.

## BACKGROUND

Various technology curriculum reforms have continued through recent years. In the United States, for example, Jones has described how broader topics - such as economics, aesthetics, ethics and international issues - have been incorporated into the engineering curriculum [2]. In Australia courses such as communication skills, management, the political decision-making process, and environmental topics have been highlighted [4]. The multi-disciplinary nature of engineering has been emphasised in India, with focus on preparation for global engineering and the international market place [5]. In South Africa, innovation, entrepreneurship and research for a competitive industry are being promoted [6], and in Latvia a new system and programme has been worked out for food engineers - technologists to satisfy new demands from the food industry [7]. In Sri Lanka the conservation of fuel wood resources has been linked with plant process efficiency and sustainable development [8], and the design of high performance sports equipment in France has proved to be one benefit from recent East-West co-operation in engineering education [9].

It is against this background of science, engineering and technology curriculum evolution and development that our educational and methodological successes are now presented and described. They are set in the context of pedagogy in the teaching of technology [10], and the introduction of Outcomes-based Education in South Africa [11], and the need to share scientific knowledge with members of the public in informal settings.

## FIVE EFFECTIVE TEACHING STRATEGIES FOR BRINGING SCIENCE AND TECHNOLOGY TEXTBOOK PRINCIPLES TO LIFE IN THE PUBLIC DOMAIN

The following instructional strategies have been evolved and refined at the University of Cape Town in our science/technology teacher-training programmes. Their purpose is to bring textbook principles and applications of physics, etc. to reality during lectures, practical sessions, workshops and field trips involving the public. Dozens of individual real-life examples and illustrations are presented below, and many of these are recorded in the photographs referred to in Appendix 1.

(a) A camp lasting three or four days is held each year in an African wildlife nature reserve for our science, engineering and technology postgraduates who wish to teach or lecture. Numerous illustrations of principles of physics, chemistry and technology are pointed out in nature, and are identified and handled by each student. These are then shared with interested members of the public, on site, as opportunities arise in natural situations.

For example, a diffraction grating will be recognised and interpreted in the wing scales of a living butterfly; a natural thermocouple effect may be seen and examined in the bark of a fire-resistant plant after a local veld fire; principles of assembly

and alignment of telescopes are taught for sky studies at night; live starfish, octopus and mussels are used to feel and calculate suction pressures; the hydrostatic mechanisms used by a giraffe to prevent fainting, as it raises its head quickly, are explained; bushman paintings on rocks are used to introduce studies in the effects of water erosion on soluble and insoluble ingredients (blood, wood ash, etc.) in the ancient works of art; the jaw bones of a snake can be used to illustrate lever and joint systems for swallowing large prey; the photo-effects of sunlight on fynbos reeds used in thatching cause students to puzzle for possible explanations; the structural adaptations used by plants to sway in the wind without buckling and blocking the free-flow of fluids are pointed out; and so also are the numerous technically efficient adaptations of a wide diversity of plants to hot and dry and windy conditions identified and appreciated.

At the end of each day in the field, students are required to consolidate what they have learned by creating revision techniques. For example, they may script mock trials; make string models; invent quiz games; construct concept maps of their sensory experiences; generate formulae - e.g. of the two bob pendulum principle they observed in the outdoors earlier in the day; etc.

They are then encouraged to share their knowledge and insights in stimulating and attractive ways with the science-shy public, and with their fellow humanities-oriented students in formal or non-formal settings.

(b) Each year students are given an exercise using thrown-away household materials of their choice. They are required to construct and demonstrate any simple model, or overhead projector effect, to illustrate a scientific or engineering principle from their prescribed textbook.

For example, one student may use discarded perspex off-cuts to construct a model, with round beads of different sizes, to explain diffusion processes; another student may use moving balloons and pins to illustrate the effect of a "catalyst" on the speeded up release of energy, and balloons; a third student may use the balloons and sticks of wood to model muscle and bone lever systems in combination; inflated rubber gloves may be used to model the retraction of a snail's antennae; an old swimming pool hose pipe may be swung to generate base notes and resonance overtones in the air, or distorted to show how the cartilage rings in the human windpipe (trachea) hold it open under externally applied pressure; the smooth action of a lubricated skeletal ball and socket joint can be demonstrated with a laboratory round-bottomed flask, Vaseline, cellophane and the sectional base of an old plastic bottle of Coke; string and furniture can be used to simulate motion in a simple electric circuit; discarded polystyrene paper cups and string can be cut to form the modelled action of an insect's leg joint; a kitchen cheese grater can be used to show the rasping action of the thousands of radula on a snail's tongue; bottle tops and sponge discs can be used to make a model of the human spinal column; models of the structures of muscle cells can be constructed

with a stocking, toilet roll tubes, straws and pipe cleaners; blue and red wool and stocking can be wound into the shape of a kidney's glomerulus; earthquake damage can be simulated on the overhead projector with discarded hollow cardboard boxes; an old Zulu kraal (dome hut), spear and cooking pot may be used to demonstrate the action of Rutherford's scattering of alpha particles by atoms; and so on.

After trying out their constructed models on members of the public, each student is also required to submit a half-page report pointing out the limitations of his or her model. The students also suggest how their demonstrations or simulations could be technically improved, using feedback generated from the public's attempts to understand them.

(c) Once a year all students are set to work, in small groups, on at least one business/engineering case study involving basic arithmetic calculations and moral dilemmas.

E.g. one successful case study debate in the public domain which we use is entitled "Should we start a new coal mine in our local African wildlife sanctuary? In teams, for and against, work out the costs from the initial data provided".

(d) Once a year, students from other specialised academic departments are invited to spend an hour, in small groups, inventing analogies with science-engineering-technology graduate students.

For example, selected principles of hydrology might be re-stated using, instead, terminology from economics and accountancy such as "income", "debit", "credit", "inflation", "overdraft", "bankrupt", "summons", "arrest" etc. to describe the flow patterns of turbulent water molecules. For some engineering students the learning of scientific principles can become more personally meaningful in such novel and different contexts suggested and explained by visiting post-graduate students from other faculties. These, in turn, are encouraged to learn more about how science and technology actually work.

(e) In another exercise, students may be given a soup spoon to observe in as much detail as possible. They are then invited to create headings and sub-headings for the content of an entire science or technology case study mini-curriculum based on what they are able to see, feel, hear, devise and apply, using the solitary soup spoon.

Some observations are straightforward, such as the shiny concave and convex metal surfaces of the spoon forming a rear view mirror or a heat focus; other ideas evolve more subtly.

(f) One hour on-campus visits are arranged each year to action-based workshops in other faculties.

Invited guest lecturers explain and demonstrate many relevant applications of physics or technology during trips to the University of Cape Town's own opera rehearsals; ballet classes; sports medicine experiments on volunteer cyclists in laboratories; demonstrations with African music percussion instruments during lectures; etc., in the buildings occupied by these

other faculties. Also, many quotations in the plays of William Shakespeare and in classical and modern poetry use engineering or technology imagery, and use basic principles of physics, chemistry and applied mathematics in their similes and metaphors. These examples serve to set up two-way communications between science-prone students and the science-shy public; for example, the botanical characteristics of herbs mentioned in the Bible.

## EVALUATION OF THE MATERIALS

(a) The field camps have been held annually for more than 20 years on the virtually unanimous recommendation of the students of each successive year, and individual members of the wider public. In their written comments, invariably the students have evaluated it academically and professionally as "the highlight of their year" of study, with its emphasis on sharing personal educational values, commitments, challenges, inspiration, environmental priorities and two-way interactions with members of the wider public. In turn, local people say each year how much they look forward to the annual visits by the University of Cape Town students because, in their own words, "We learn so many new things from the UCT science teachers."

(b) Twenty-six of the demonstration materials were evaluated by a volunteer sample of 31 tutors for in-service courses for teachers. They were asked to rate each demonstrated working model, resource or idea as "excellent", "good", "possibly useful" or "not applicable/ not liked". Most of the 26 evaluators were working in historically disadvantaged educational settings.

The moving cardboard germinating seed model, created in conjunction with a participating member of the public, received the following scores: 25 "excellent"; 5 "good" and 1 "possibly useful".

The compound eye straw model scored 19 "excellent"; 10 "good" and 1 "possibly useful".

The string and gauze and metal washer model of parachute seed dispersal, also created in collaboration with a member of the public, scored 15; 14 and 2 respectively.

The car tail pipe and cotton wool pollution demonstration scored 15; 10 and 4 respectively.

The presentation that received the lowest rating was the use of one million dots on a long scroll of paper to illustrate the number of clay particles existing in a small test tube containing a soil sample. This idea was rated: 5 "excellent"; 11 "good"; 13 "possibly useful" and 2 "I do not like it/ not applicable".

Another evaluation of the resources and materials occurred after suggestions arising from the first evaluation had been incorporated into the models, demonstrations, ideas and instructional materials. This second evaluation, conducted with a sample of 39 primary teachers-in-training, produced a wider range of rated responses to most of the assessed materials. The usefulness of some of the advocated resource materials would depend on the particular educational contexts in which those

particular teachers would subsequently engage.

(c) - (f) The entire year programme has also been evaluated summatively. Many favourable qualitative comments and requests for additional copies of the materials have been received. The programme (a) to (f) was evaluated as a whole prior to several local, national and international awards of recognition being conferred by various professional associations in recent years.

## CONCLUSION

This paper has suggested and illustrated successful examples of training that might be offered to teachers of technology in an Outcomes-based Education mode [11] and to scientists who love teaching and sharing their work with the public. Creativity and imagination are an important ingredient in this educational programme.

It may be fitting to end by quoting the words of Richard Pring, so fitting for imparting an understanding of science to members of the public;-

“There is a knowledge which is distinctive of teaching - the knowledge of how to put across complex subjects in a form which is intelligible to learners of different ages and abilities. I am constantly amazed at how teachers are able to distil the substance of a complex matter creatively and imaginatively and make it intelligible in a practical and meaningful way. That is the essence of good teaching. It is practical skill gained from experience, reflection and effort ... It should be central to the training of teachers.” [12]

For decades we have found that these sentiments have been echoed in the enthusiastic public responses given to the science and technology insights and ideas we have reciprocated with interested lay people. These instances of sharing have occurred naturally in situations of work and leisure - in the real life, public domain - as they have crossed our mutual paths of experience outside the normal classroom. In turn, fresh insights and ideas supplied by interested members of the general public have served to generate the production of many of our successful and novel science teaching resources and ideas.

We owe the wider public a debt of gratitude.

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## APPENDIX

The paper will be presented with a poster displaying examples of the science and technology models, the teaching resources, photographs and responses of members of the public.

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