THE USE OF SCIENTIFIC TOYS AS A MEANS TO STIMULATE INTEREST AND UNDERSTANDING IN NATURAL SCIENCE

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ABSTRACT

An exhibition/workshop containing more than 200 "scientific toys" has been functioning for 8 years at Chalmers University of Technology, Sweden. With its new pedagogical methods it has been extremely successful in creating interest among young people for science and technology (7-20 years of age). Moreover, it has been very useful for teachers' training and for improving the public understanding of science in the society.

INDEX TERMS

Scientific toys, public understanding, teachers' training.

INTRODUCTION

It is now known trough numerous investigations [see e.g. 1] that the youth in the industrial world (in particular girls) to a large degree ignores natural science and technology. The situation is univocal: the youth has a confidence in scientists and technologists but does not want to engage itself in natural science and technology. The mentioned subjects are considered authoritarian and difficult. The state of affairs is considered (e.g. by the European Union) to be a serious threat to our society. The school and the mass media are often mentioned as the scapegoats for the situation. I judge that the universities also have a responsibility to improve the situation.

There are mainly three causes why the schools do not succeed in catching the interest of young people: i) The extensive course material leads to memory knowledge instead of understanding, ii) the content is too theoretical, and iii) the education process has a an intellectual image, where the emotional and social competence of the student cannot be developed.

More or less by chance I stepped upon a communication process, which turned out to be extremely fruitful and effective to improve the situation: the use of "scientific toys" as a means to communicate with not only young people, but also with teachers and the society in general. It should be immediately stressed that the toys themselves are only means and the result is completely dependent on *how* they are used in the context.

THE SCIENCE COMMUNICATION PROCESS

The present project started by an improvised exhibition of my small collection of physics toys at an international science exhibition in 1997 in Gothenburg, Sweden. An extensive investigation by a psychologist top ranked the activity in comparison with the other contributions. This success resulted in a permanent exhibition/workshop at Chalmers University. Now, 8 years later, evaluations univocal show that many of the problems mentioned in the introduction can be very successfully solved by the methods empirically developed at the exhibition/workshop.

The exhibition is housed in a 500 m^2 hall where about 200 scientific toys and experiments are presently set up. A web page is under development [2]. The toys have different origins:

i) advanced euipment bought from educational companies [x] and in shops,

ii) special, often world unique, apparatuses made at the university mechanical workshop

iii) objects fabricated by me using very simple tools

iv) everyday objects taken from my home (cups, wires,..).

It should be stressed that the activity differs very strongly from that occurring at conventional science centres. The toys are of course only tools; the success lies completely in the manner they are used. The instructor must be very competent in science and pedagogy and is the key point for the success (in our case a university professor is always the guide). Among the activities in connection with the centre can be mentioned.

i) visitors mingling around in the exhibition hall with the possibility for *individual* guiding

ii) open houses with shows, lectures, and demonstration for the public or specially invited categories (journalists, industry people, politicians…)

iii) lectures and demonstrations held in schools (toys then limited to 10-20 ones)

iv) toys are used in lectures in undergraduate and PhD courses at the university

v) teachers on all levels borrow toys and books

vi) the exhibition functions as a children's (7-15 years of age) workshop and a high school laboratory (15-19 years of age)

vi) academic research on the physics of the toys is carried out by university scientists [4].

In the present article I will mainly limit myself to activity i) and ii) above, which includes visits of school classes, teachers, open days for the public etc. At these visits I have only little ambition to teach the physics subject. The main aim is rather to create an entertaining atmosphere where the visitor feels comfortable and appreciate to play with the toys. The most important part is the *individual* interaction between the guide and the visitor, where the subject, performance, scientific level etc can be adjusted to the specific visitor. Many visitors would feel quite uncomfortable being confronted with advanced scientific instruments and equipment, which therefore are completely absent in the hall. Most fields of daily physics ("the world around us": mechanics, electricity, magnetism,…..) are demonstrated and tried by the visitors themselves. Experiments with extensive text and push buttons (as at science centres) as well as computers are completely lacking.

Sometimes one specific toy can be used on all age and professional levels, from day care centre children to university professors, depending on how it is used. Just for purpose of illustrating this point let me take a few examples from mechanics demonstrations. Consider first a raw and a boiled egg. For practical reasons plastic eggs filled with water and toothpaste respectively are used. One can study e.g. rotations, rolling and more just for fun or on a high scientific level. Figure 1 illustrates three experiments on different levels.

 a) For young children a raw and a boiled egg are rotated on the floor. Which egg rotates fastest using the same push on each? Another experiment: rotate the raw egg, stop it and let it go. Why does it "start by itself"?

b) For high school or undergraduate students a raw and a boiled egg are rolled downhill. Even if the students have not yet studied the concept of moment of inertia in school it is easy to explain why the raw egg rolls fastest, because it is essentially only the shell, which is revolving.

c) A boiled egg is rotated fast on a table. It gets up and rotates on its top. The full theory is on approximately the PhD level. It can be explained by considering the torque given by the friction against the table, which is caused by the point of gravity rotating around the vertical axes through the contact point.

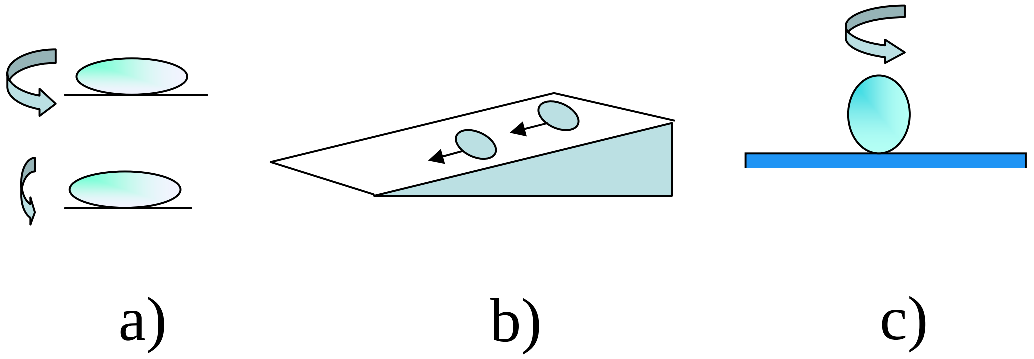

Figure 1.
a) A raw and a boiled egg are rotating on the floor after giving the same push to both. Which is rotating fastest?
b) A raw and a boiled egg are rolling down the same slope. Which one is rolling fastest?
c) A boiled egg is rotated quite fast on a table. Why does it get up on its top?

A second example from mechanics is the "Grandmother's cup", see figure 2. When the wire (with a weight) is dropped, the cup is not crashed on the floor as may be expected but the wire is winds up around the stick causing the cup to stop. For graduate students the concept of angular momentum is the key point in the analysis, while for a 12-year-old child, the frequency of pendulums with different lengths is an easier concept to use, which can be directly demonstrated visually.

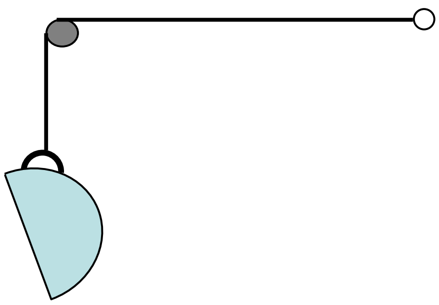

Figure 2. "Grandmother's cup". When the wire is released it winds up around the stick causing the cup not to fall down on the floor.

An important aspect of the two examples above is that they can be performed with things that are directly available in a home. It turns out in practice that a pupil in general gets very engaged by demonstrating these "tricks" for the family and maybe for the teacher and class in the school. It is in fact a very effective way of getting children interested in natural science by very simple means! I have constructed and collected 100's of such simple, amusing and instructive experiments, which does not only engage and entertain, but above all illustrate and help understanding the laws of nature in a very effective way.

The method to avoid mathematics in the starting phase of the communication has been successfully practiced by P.G. Hewitt, who coined the concept "Conceptual Physics" [5]. Another very important ingredient at the activities at the exhibition/workshop is "multiple intelligences"[6]. Howard Gardner viewed intelligence as "the capacity to solve problems or to fashion products that are valued in one or more cultural setting" and lists eight different ones (linguistic, musical,….). Thus it is important in the individual guiding to identify and use the special intelligences of the visitor.

An effective method for a good communication at a school lecture is to *start* with an amazing experiment (e.g. levitation, perpetuum mobile,,,.). The experiment will create curiosity of the student during the following (maybe theoretical) model treatment much more then at a conventional lecture where applications are discussed after the formal presentation. I think all lectures at all levels should be accompanied by experiments, especially using things from daily life. There is a myth that there is a difficulty in finding experiments in some subjects, e.g. in mathematics or history. As an example I show in figure 3 a simple experiment in general relativity demonstrating the equivalent principle by Einstein. How to easily get the ball in the cup? The solution is to drop the device and let it fall freely. Because the ball does not have a weight when falling it is sucked into the cup by the rubber spring.

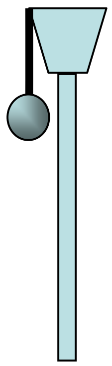

Figure 3.

Einstein's broom stick. When the stick is dropped the rubber band sucks the ball into the cup. This simple experiment illustrates deep thoughts, namely Einstein's equivalence principle, the base for general relativity.

EVALUATION

It is of course not enough to take statements from the guest book, course evaluations or similar as an indication of the success of the communication process. I could e.g. perform magic tricks and obtain a very high appreciation, but at the same time completely miss my goals. What are required are immediate professional written and oral questionnaires. Moreover, the long-term stability must be evaluated. As my activity has only proceeded for 8 years the latter aspect is yet not clear. The present project starts mainly with 12-year-old children. These are old enough to start communicate "scientifically" with and very open-minded. It will then take about 10 years before we see how lasting the results are.

There is no doubt however that the immediate impact of the methods of the present project is dramatic. It should be stressed that the visit contained indirectly a substantial part of "physics" rather than sensational experiments. I cite here some examples of preliminary evaluation results.

1.How many visitors thought *before* the visit that it was a good idea to make the visit: 78%

2. How many thought it was a good idea *after* the visit: 100%

The pupils were oriented before the visit that it had to do with natural sciences and in particular physics. The result indicates that the pupils found physics more interesting than they had expected.

3. Should the visit have lasted longer? 87%

4. Do you want to come for a new visit? 96%

The results indicate that the pupils enjoyed the visit and have a high interest enough to continue doing physics experiences.

5. Do you like the physics subject more after the visit? 75%

It is important here that "physics" is not mixed up with sensational experiments. The result includes an astonishingly high impact after just one-hour visit. It is of course important to check the long-term stability of this effect with and without renewed visits.

DISCUSSION

In a (yet unpublished) project I have studied the behaviour of children in conventional science centres. It turns out that if they are not guided (which often is the case) they do in general not understand what to do and what to learn at a specific station. This is partially due to the fact that they are not patient enough to read long text instructions and/or they cannot translate it into the intended actions. Moreover, many stations contain specially constructed equipment far from everyday objects. The set-up may appear strange, and sometimes even frightening, to the young visitor. Still another aspect is that because of many visitors and security reasons the objects must be robust not to be damaged. This strongly limits the selection of good hands-on-experiments. For instance, brittle glassware, open fire, handling of liquids, and much more cannot be used without supervision. It even occurs that equipments are situated in glass boxes and can only be operated via push-buttons.

The mentioned disadvantages at science centres are all avoided in the physics toys exhibition. Only small groups (typically 20 people) are allowed at a time (about one hour). A storage of duplicate toys, as well as a small workshop for repair, are available so that a toy can be immediately replaced or repaired in case of damage. The frustrating "out-of-order" situation seen in science centres does not occur in the physics toys exhibition.

CONCLUSION

The exhibition/workshop "Physics toys" has now being going on for 8 years. The result of the activity has been extremely successful what regards stimulation of the interest in science and technology among young people. The activity has also been very useful for public understanding of science and education of teachers.

ACKNOWLEDGEMENTS

I am very thankful to the Rector of Chalmers University of Technology, prof. Jan-Eric Sundgren, who allocated the exhibition hall for the physics toys activity. He has on the whole been very positive to the programme and by various means made it possible.

REFERENCES

1. See ee.g. Svein Sjoberg, "Science and Technology in Education", http://folk.uio.no/sveinsj/
2. http://www.fy.chalmers.se/physicstoys. The web pages are in Swedish (in English autumn 2005), but movies and pictures may be useful to a broad public.
3. Search the internet for shops of "physics toys" or similar. One example is http://www.teachersource.com/. Other sources can be found at http://www.e20.physik.tu-muenchen.de/~cucke/toylinke.htm
4. Examples of research on physics toys can be found at http://www.uni-muenster.de/Physik/DP/lit/spielzeug.html
5. See e.g. P.G. Hewitt, "Touch this!, Conceptual Physics for Everyone", ISBN 0-321-05162-9
6. See e.g. http://www.infed.org/thinkers/gardner.htm