

**A PHYSICS SHOW PERFORMED
BY STUDENTS FOR KIDS:
From Mechanics to Elementary Particle Physics**

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Physics students spend the early part of their training attending physics and mathematics lectures, solving problem sets and experimenting in laboratory courses. The program is typically intensive and fairly rigid. They have little opportunity to follow their own curiosity or apply their knowledge. There have been many attempts to address this deficiency specifically through outreach activities [1]-[23]. For example since 1984, Clint Sprott (University of Wisconsin) hosts a physics show entitled “The Wonders of Physics”. Dressed up as a circus director and assisted by students, Prof. Sprott presents entertaining and educating experiments to a regularly packed auditorium of all age groups [5]. This was in turn inspired by the “Chemistry is Fun” presentations of Basam Shakhshiri (University of Wisconsin), where the students are also involved [6].

Having myself witnessed these activities as a graduate student, I launched a similar activity together with Michael Kortmann in Bonn, in 2001. The idea was to give a group of undergraduates (about 20-25) from every incoming class (about 180) the opportunity to put on a physics show for kids aged 10 and older. The essential point of this initiative is that the *students* develop and perform the show themselves; it is entirely in their control. The students have full access to our collection of demonstration experiments, and are assisted and advised by Michael Kortmann, who is in charge of the equipment. They can thus follow their own curiosity, choosing the experiments they find interesting or build new ones based on their own ideas.

The show is an unique opportunity for the students to apply their knowledge at an early stage of their studies by teaching kids in a dramatic environment. The show has been a resounding success with the public, with a regularly packed auditorium (520 seats). For us however, the Bonn Physikshow [25] is foremost an educational tool addressed at our physics students [26], and it is our goal to maximize their benefit. A first sign of success, is the enthusiasm and energy with which the students participate. They spend hours of their free-time understanding the experiments and devising explanations for children. It is also an excellent mechanism to get the students developing and working on their own physics ideas. This includes designing and building new experiments from scratch. Furthermore, they learn to work as a team on all aspects of the project, including the organisational

and theatrical aspects. And of course they learn valuable public presentation (of science) skills, which will be very useful in their later careers. The Physikshow seems to greatly increase the enjoyment in their own physics education.

A further measure of success, is the enjoyment they develop for the public presentation of science. Having now run the Physikshow for five years, we have a pool of about 50 students who are active after *their* show. They have developed further outreach activities, such as a special 30min show for the semi-annual university science night and most recently an all-day physics demonstration table at a family fun-fair in the local parks. They have also joined the author in visiting local schools and putting on a show in the Deutsche Museum, Bonn. It is difficult to measure the resulting academic success for lack of a proper control sample. However, of the undergraduate students of the first Physikshow (2002) about three quarters are now working on their Ph.D. in physics or astronomy. Very recently one student who had been very active in the Physikshow has accepted a job offer from a company which builds and sells physics demonstration equipment.

In January, the older students and I recruit the new students in the main second year lecture course. We talk about our activities and collect the e-mail addresses of the interested students. We then use these to schedule a first meeting. Before the first show in 2002, I taught the second-years myself, so the students were very familiar with me. In recent years, many of the incoming students had heard of the Physikshow from older students or had attended a performance while in high-school. About 30 students attend the first meeting. Thus recruitment has not been a problem.

Together with students from previous years, Michael Kortmann and I attend the initial meetings. We pass on our experience and give the main idea of how the show is set up. Starting in March, the students largely organize the meetings themselves. They decide on a main theme for the show and select the experiments. They also design the new T-shirts and make the movies (see below). The last 10 days before the first show, the students rehearse daily. This is necessarily off-term time, since the rehearsals take place in the main physics lecture hall. It is also during the school year, so the kids can attend. During the rehearsals the students are assisted mainly by students from previous years, but also myself. All together we develop the text, the jokes etc., and advise on how to speak before a large audience. This is a collaborative creative effort. Furthermore, Michael Kortmann gives extensive technical assistance.

There are three performances in September and a repeat with three more at the end of February. One performance is always for school classes on a week day in the morning, and two are on the weekend for the general public. More recently, we have added a fourth show each time due to the high demand from school classes. The show lasts two hours, including a 20 minute intermission, when the children can try out and have a close look at experiments. There are two MC's (one woman and one man) to guide the audience through the show. Two important ingredients were introduced by the students in the first year.

(i) Short (< 90 sec) home-made entertaining movies to introduce the various physics topics (e.g. mechanics, magnetism, low-temperatures) into which the show is divided. Over the years these have become quite elaborate. They can be viewed at [25]. (ii) The experiments are accompanied by up-beat music, which creates an energetic atmosphere. For this we must pay license fees, about \$120/show.

Since January, 2007, we have put the introductory films, and films of experiments on YouTube (search words: *Physikshow*, *Bonn*). The most successful shows a boat out of aluminum foil floating in an aquarium filled with sulphur hexafluoride, Fig. 1, which now has over half a million viewings. Another film, shows a Newton pendulum, followed by four test car crashes, all to Beethoven's 9th symphony.

This is the basic structure of the show into which the students have introduced a tremendous variety. The first two years, it was similar to Prof. Sprott's: a series of experiments were presented and explained. In the third year, the students developed a question and answer scheme, between the two MCs. This created a better flow and also improved the explanations, since the students had to imagine questions the kids might have. In the fourth year, the students built a "time-travel machine" out of an old telephone booth and a smoke machine, and visited the Stone Age, Aristotle, Newton, *etc.* asking questions directly of the greats. Last year the students staged the entire physics show as a large computer game, where they had to solve various physics problems to advance to higher levels. For the movies, the two protagonists wandered through a virtual landscape to advance to the next level, see [25].

Over the years the students have built quite a few experiments themselves. It started with a simple apparatus to let pickles and other fruit glow in an electric current. Later, these included a hover craft with a chair and a vacuum cleaner engine, a superconducting train, the "Polar express", which is shown in Figs. 2 and 3, and a large tank to simulate a tsunami wave. The students also built a large box ($\sim 2\text{ m}^3$) which produces large smoke rings which travel through the entire lecture hall. Last year, two students built a large Tesla-transformer at home from simple materials you can buy in a hardware store.

There are many challenges involved in setting up such a show. It is difficult to produce a new show with a new group of students every year. For myself, it is also difficult to have the same motivational level each year, as well as to find enough time next to my regular teaching and research. I try to delegate as much as possible to the students, but a significant amount of work remains. For those starting a similar activity, one should take this into account particularly in the first two years. It is also possible to scale down the size of the show and the number of performances. In summary, it should be stressed that the students participate voluntarily and for no credit. The main initiative for the design and implementation of the shows comes from the students. Also since it is their show, they can fully identify with it and are highly motivated. It is thus in my opinion important to give the students the freedom to develop the show as far as possible themselves. This is

the main lesson I would like to convey.

The Physikshow has mainly involved classical physics occasionally with some quantum effects. However, when the particle physics laboratory CERN turned 50 in 2004, the first year group had sufficiently advanced in their studies that we could put on an elementary particle physics and cosmology show addressed at high-school students. We intend to repeat this 2008 for the launch of the LHC at CERN.

In March, 2006, we were honored that the Deutsche Museum, in München, invited us to put on three shows in the distinguished Ehrensaal, something like a hall of fame of German science and technology. This was an exciting opportunity for the students and our first big away game. It was also a logistical challenge to get the experiments to München at a reasonable cost. The performances were very well received and the Museum has suggested inviting us every two years.

The basic idea of the physics show also carries over to high-school physics. Two local high-schools have independently put on shows for their fellow students and their parents: the Kollegium Josephinum, and the Gesamtschule, Hennef [27]. We are currently jointly developing a show with a third school, the Amos Comenius Gymnasium. See also [10].

In October, 2006, in honor of the tremendous amount of effort the students have put into the physics show, they received the Alumni Prize of the University of Bonn for student initiatives: EUR 1000.

Over the years there have been many exciting articles on physics and science outreach activities, see for example [1]-[22]. For an interesting early project initiated by the US Naval Academy, which lead to many subsequent activities see [1]. Some shows are mainly in-house [2]-[11], like our's, whereas others emphasize going on-the-road [12]-[22]. I would like to draw particular attention to the previous endeavours which relied on a strong participation of the university or high school students [5, 10, 11, 14, 16, 18, 19, 20], *i.e.* where students taught other students. These are in character most similar to our work. I would also like to point out two interesting European activities, which might not be familiar in the United States. Rino [23] is a road show on low-temperature physics run entirely by students from Leiden University, Netherlands, which is organised like a company, and which tries to reach a large number of Dutch high-schools. Fysikshow Aarhus [24] is a national organisation run by the Danish physics students with the goal to be able to reach every high school in Denmark. I would be very happy to hear about other activities.

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- [23] See the website: www.physics.leidenuniv.nl/RINO/
- [24] See the website: www.fysikshow.dk/aarhus
- [25] For more information see our website: www.fysikshow.uni-bonn.de, where we have links to many photos and the movies. The movies are also all on YouTube.
- [26] In Germany, physics students only have physics and mathematics courses, as well as a minor, *e.g.* chemistry. After three years this is considered equivalent to an American bachelor degree. Furthermore, through an additional year of high-school and military service they are on average 1.5 years older.
- [27] For more information see: www.ge-hennef.de/foefo/begabung_physikusse.htm



Fig. 1 Aluminium boat floating on sulphur hexafluoride

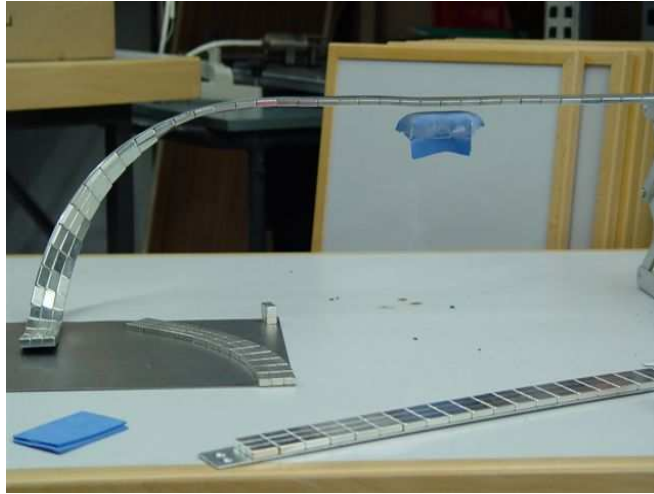


Fig 2. Superconducting train, construction phase, with a blue suspended “train”.

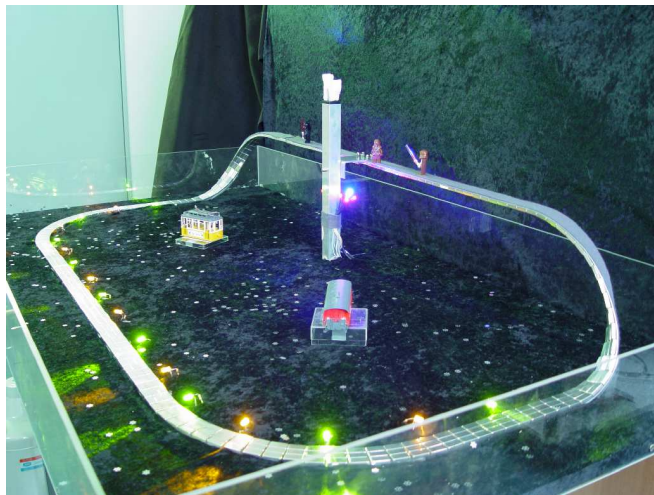


Fig. 3 Superconducting train set with lighting and gondola trains.