II. SCIENCE CENTRES AND OTHER INFORMAL LEARNING OPPORTUNITIES

SCIENCE ON STAGE: THE EUROPEAN PLATFORM FOR SCIENCE TEACHERS

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INTRODUCTION

Science on stage is a pan European **teacher network** established in 2000 as Physics on Stage which grew into Science on Stage in 2005. It is a non-profit association since 2011 with administrative headquarters in Berlin. We believe that living out its motto "From teachers for teachers" makes Science on Stage unique in Europe. By inspiring science teachers we provide inspiration for our students, and therefore will make a difference in the supply of motivated scientists in the future. The ultimate goal of science on stage is to improve science teaching by encouraging creativity in science teaching, with teachers sharing ideas that have worked for them in the laboratory and classroom. Through this we shall encourage more school children to consider a career in science or engineering by spreading good teaching practice among Europe's science teachers.

Science on Stage has an expanding network of national committees (NSCs) in more than 25 european countries (1) who are responsible for selection national representatives for its festivals and promoting the good teaching ideas from these biannual festivals and consequently reaches about 100.000 teachers and teacher trainers each year. Each National Committee works independently following certain agreed guidelines common to all, is self funding from local industry, governments and educational institutions, and is supported from the Science on Stage office in Berlin.

Fig.1. Teachers sharing ideas at a recent Science on Stage Festival

Science on Stage has organised eight European festivals from 2000-2015, the latest being in London, and the next is planned to be held in Debrecen, Hungary in 2017.

We draw together teachers of school children of all ages to share experiences and work together on joint projects. We seek to promote science for young people via enthusiastic teachers and we encourage teachers as to their own value and promote high quality teaching, seeking to demonstrate the importance of STEM to children, to the public and to decision makers across Europe.

ORGANIZATION

Science on Stage is organized through an <u>executive board</u>

7 members, elected every 4 years by representatives of the National Science Committees. At the present time there are representatives from Cyprus, Czech Republic Germany, Spain, Sweden, Switzerland and UK. The board meets regularly in between festivals to plan and innovate for the future.

How does Science on Stage enable the international exchange from teachers for teachers?

Many people know of science on stage though its biannual festivals which are attended by delegates SELECTED by national Committees according to a quota system for each country depending on the number of inhabitants. We therefore maintain a high standard of presentation. Science on Stage festivals have taken place every 2 years at different venues throughout Europe bringing together up to 350 science teachers (primary to secondary level) from over 25 European countries. The national contacts can be found on www.science-on-stage.eu

Fig.2. Teachers at the recent Science on Stage Festival in London (2015)

FESTIVALS

Science on Stage Festivals showcase the work of the teachers with over 200 stalls showing a huge variety of projects from all STEM subjects. The Festivals are fully funded for participants by the host country and Science on Stage Europe, so teachers simply have to reach the venue. All else is provided for the 4 day festival. Follow-up activities are then encouraged across borders. All participants are selected through national events in each country. Each festival is carefully evaluated by recognized agencies, so that we can determine how successful the programmes have been. See the science on stage website for the most up to date information.

Evaluation

- 69% of the teachers attending said participation increased their motivation and joy in teaching
- 79% of participating teachers have incorporated ideas that were presented at Science on Stage into their own lessons

- 74% of teachers appreciated the opportunity to exchange experiences with cross border colleagues
- 50% of participating teachers have incorporated ideas from Science on Stage into teacher training events

(Reference: Evaluation Study carried out by Humboldt University Berlin)

The Science on Stage Festival is a platform for the exchange of **new ideas** and **concepts** in science teaching. The **follow-up-activities** ensure the development and sustainable spreading of these ideas and concepts.

<u>First we encourage sharing ideas within one's own country</u>

All participants are encouraged to take ideas from the festivals back home, to share
i) within their schools and localities
ii) through teacher training events and conferences
and we know that a massive 50% of participants use ideas in training events to share with others

<u>Then we encourage sharing ideas and working across Europe and beyond</u>

All participants are encouraged to make lasting friendships at the festivals which in turn lead to working relationships and sharing of fresh ideas. 50% of participants maintain 5-9 European contacts after festivals

INTERPLAY: MY OWN STORY

Fig.3. The author

I first encountered Science on Stage in 2005 when I was privilege to be selected by the UK National Science Committee to attend the Science on Stage Festival in Geneva. This was for me, like others, a great eye opener, to meet with so many like mined, enthusiastic teachers from a wide range of different backgrounds and countries. After the conference, where I presented some ideas on using magic to engage children, (that is magic that is based on scientific principles rather than deceit) I came home with my head buzzing with ideas.

Two years later the festival in Grenoble gave me the opportunity to represent the UK again and present a workshop "What Happens Next?" and meet up with colleagues from the previous festival. Several took up the idea, and we shared some ways in which the workshop could be extended.

Fig.4. Large and small balloons. When joined the smaller balloon inflated the larger one.

One such idea was the "Two balloon experiment" where a less inflated balloon will blow up, (surprisingly) a connected larger on. A discrepant event to many, Zuzana Jesková, a colleague from Slovakia, used this idea with her students, and together were able to publish an article in the journal Physics Education, "Balloons Revisited". I was able to visit Zuzana in Kosice, Slovakia and present the workshop there, and this led to further friendships, and even now, in 2015, a joint article published in Physics Education with a colleague of Zuzana. The workshop has since been presented in The Netherlands, Czech Republic, Poland, Ireland, Scotland, Belgium, Italy to my knowledge, and maybe other countries too, as the ideas now feature regularly in the journal of the Institute of Physics, Physics Education. Whilst I write the column, several colleagues from Science on Stage have been able to contribute.

Fig.5. The author with students at staff in Kosice, Slovakia.

More recently I was elected to be a member of the Science on Stage Executive and this has given me the privilege of serving the community more *widely, helping with decision making on matters of policy, and supporting new members of science on stage, We are a growing community and I fully expect that the 2017 festival will see the largest number of participating countries so far in Science on Stage's history.*

And finally I can honestly say I have friends and colleagues all over Europe now that I didn't have 10 years ago, a greater understanding of the different educational systems, and more than that a greater insight into the current situations around our continent and history of each nation.

In addition Science on Stage encourages its own follow-up projects alongside the education festivals.

Teacher training events and travel scholarships

Workshops with international festival projects take place in every Science on Stage country. Teachers can get scholarships for further exchange with their colleagues, to develop project ideas together.

Science on Stage Europe provides funds to encourage…

"**taking a workshop**" to another country

19 WORKSHOPS were formally funded across borders between 2013 and 2015, and others took place informally. Many workshops were repeated in home countries and participants used the ideas from workshops at the festivals to devise their own.

"working together on teacher initiated **joint projects**"

10 travel scholarships were formally funded between 2013 and 2015 and several more have already been instigated following the 2015 festival covering a huge range of topics. These enable teachers who participated in the festival to meet again and continue their work and to develop new projects.

Development of **teaching materials**

Groups of international teachers from Science on Stage develop teaching materials together. Results are published and spread Europe-wide; e.g. **Smartphones in Science Teaching** (2014). The latest pan European is a group of 20 teachers from 16 countries developing materials and a stage booklet on **„science and football"** sponsored by Science on Stage Germany due to be published in June 2016.

Some countries produce their own publications for European distribution both in print and on line For example the Irish Science on Stage team have produced 5 booklets ,

300 in each print run and now on line, detailing some of the demonstrations shown at the festivals. Free downloads can be accessed from http://www.scienceonstage.ie/ where videos of the experiments can also be seen.

In fact since the 2013 there have been over 85 publications in different journals etc. Check your own country's website to see those in your own language!

FUTURE FESTIVAL

Countries bid with each other in order to be selected to host the next festivals, and at the recent festival in London, Hungary was chosen to host the festival in 2017. It will take place in the beautiful city of Debrecen between June 29th and July 2nd 2017.

The festival will take place at the Kölcsey Convention Centre in Debrecen, organised by Science on Stage Hungary, the University of Debrecen and the MTA Atomki Institute in cooperation with Science on Stage Europe.

Fig.6. Debrecen cathedral

Meanwhile, **selection events** are taking place in all member countries; **follow up** meetings are happening across Europe; cross border exchanges are being planned; **significant internet cooperation** is ongoing every week; **joint papers** are being prepared and published; **good practice** is being shared, and all this from practicing teachers to other practicing teachers.

We know we are making a difference to STEM teaching across Europe and beyond.

BECOME PART OF THE INTERNATIONAL FAMILY

You can check the website at

www.science-on-stage.eu

Get in touch with Science on Stage in your country

Read our Newsletter via

www.science-on-stage.eu/newsletter

The European platform for science teachers

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The European Office in Berlin is mainly supported by the Federation of German Employers' Associations in the Metal and Electrical Engineering Industries (GESAMTMETALL) with its initiative think ING.

Member Countries of Science on Stage Europe (in population size order) are:

Germany, Turkey, UK, France, Italy, Spain, Poland, Romania, Netherlands, Greece, Belgium, Portugal, Czech Republic, Hungary, Sweden, Austria, Bulgaria, Switzerland, Denmark, Slovakia, Finland, Ireland, Slovenia, Cyprus, together with Canada, (special arrangement). Further European countries with membership pending and to be ratified. Ukraine, Macedonia, Latvia, Norway, Iceland.

DOUBTOLOGY (ABOUT COMMON SENSE, DOUBT AND CRITICAL THINKING)

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Throughout almost twenty years of experience running the Science Centre, I gradually realized that it is not a centre of science that I am running. Promotion of Science is just one of the tools used in order accomplish our main mission – inspiring curiosity and critical thinking.

Our society is facing a pandemic illness without a name but with clear symptoms of apathy in place of curiosity and learning, looking for easy but shallow ways of acquiring knowledge, no interest in seeking the answers to bothering questions, misinterpretation of dialog as being just two monologues, believing instead of having doubts, critical thinking, checking and proving…

There isn't a single country that would claim their educational system is perfect, or even that it is good. Experts are wondering when and where in the education process this curiosity is lost.

Curiosity is something every single human being is born with. Not only humans, many animals start their lives being curious. Curiosity is a driving force for the learning process. It is fuel for the trial and error process – learning by mistakes that are nothing more than personal learning experiences. Instead we have an educational system that despises mistakes rather than looks at them as a necessary learning optimisation method and encouraging them.

Imagine a curious child raising a hand in order to get the attention of the teacher and ask a question, pose a proposition or express a personal idea of the topic. This is one of the crucial moments that will define the future level of curiosity of the whole class.

There is a right and a wrong course of action. The teacher could respond with: “That’s a good question/idea! Let’s talk about it.” “I don’t know the answer. Does anyone have any ideas?” “Wow, great idea. What if we also take into account that …” “This is a question that also bothered great scientists at that time.” …

The other response (that demands less effort) might be: “Don’t interrupt the class!” “You should know that by now!” “What a crazy/stupid idea.” “We will talk about it later.” “We have already discussed this. Listen more carefully next time!” “Can someone please explain the idea to him/her. I am tired of repeating the same thing all over again and again.” …

One can guess which option is a “curiosity multiplier” and which is the “curiosity killer”. Both options directly signal to the curios person (but also to the whole class) the value of being curious, but one option is treating this curiosity as a virtue (the holy grail for creativity) while the other shows that the curiosity does not pay, that the curiosity is punished.

Curiosity is a very tangible substance that each teacher should nurture throughout life. It triggers the passion for learning and creativity. It is also important as a teacher to exercise the answer “I don’t know”. It is precious to admit the mistakes one makes while teaching (especially if the teacher is alerted to the mistake by some doubtful student). This shows that everyone makes mistakes. Moreover it gives the teacher the feedback that 1) students are curious, 2) that they do care what the teacher is communicating, 3) that they don’t just believe what they hear, 4) that they know to doubt and to think critically.

A good teacher is not a teacher at all. A good teacher is an inspirer that amplifies curiosity and encourages doubts and critical thinking. Inspired students will learn by themselves (Fig.1).

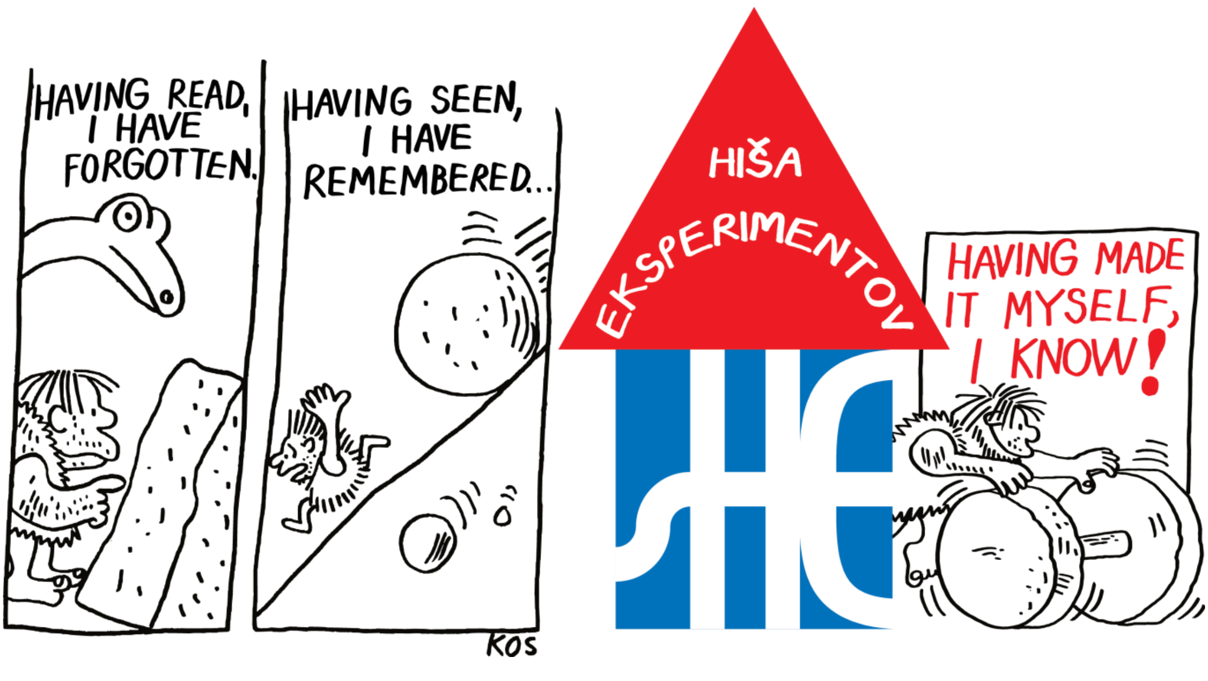

Fig.1. One can never learn from others’ mistakes, only from your own.

MAKING SCIENCE UNDERSTANDABLE AND MEANINGFUL: BRIDGING THE GAP BETWEEN FORMAL EDUCATION AND INFORMAL LEARNING

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INTRODUCTION

”Science education is not only a question of advancing technology or of demands for a scientifically qualified workforce, but is also a question of social goals. The aim is not solely to produce more scientists and technologists; it is also to produce a new generation of citizens who are scientifically literate and thus better prepared to function in a world that is increasingly influenced by science and technology” [1].

Learning and education can be defined both narrowly and broadly: they can occur either unconsciously or formally. One of the first to present this broader definition was in 1922 the German philosopher Krieck [2] who used the term "unreflektierte Erziehung" – “education by chance”. According to him, people also learn unconsciously through work, art, language and culture. The whole relationship between human beings is an educational one. Philosophically, informal education represents the ideas of freedom, in the spirit of Rousseau's tradition as manifested, for example, in the work of A.S. Neill.

Learning in informal contexts has often been regarded as the opposite of formal education. Even the names of the classic books – Deschooling Society by Ivan Illich [3] and The Unschooled Mind by Howard Gardner [4] – have been provocative. These books also contained harsh criticism of failures of schooling, which has alienated students from meaningful learning. Moreover, they argued that learning from informal sources was effective and motivating. These books have had a great effect on education and educational research.

Until the 1990s, informal learning solutions were often considered as unreachable ideals, or informal education was used only as a tool for criticising school or school reforms. To advance public understanding of science, new forms of education were actively sought. Learning does not take place only in the actual world of school but in the presented world of nature, parks, yards, science centres, gardens, and the media, as well as through the virtual worlds of the internet and social media.

Since the 1990s, however, informal education has become a widely accepted and integrated part of school systems. Despite this development, there has been less theoretical or empirical research in the informal sector. Recently, learning in informal contexts has become a more accepted part of science education.

A huge amount of information, especially about modern phenomena, is obtained in a personal way from family, friends, and peer groups. Furthermore, the roles of television, libraries, magazines, and newspapers are also essential. Museums and science centres have regularly had increased numbers of visitors during the last decades. Despite this development, there has been less theoretical or empirical research in the informal sector [5]. ICT- and web-based learning has totally changed the vision of formal education [6, 7].

The terminology of informal education is variable, due to, on the one hand, to the slight difficulties caused by differences in school systems and, on the other, some translation problems. One of the main difficulties is that pure informal learning refuses to be categorised, and the definitions are not needed until informal learning becomes institutionalised. Learning in informal contexts and open learning environments are the latest terminology in the field.

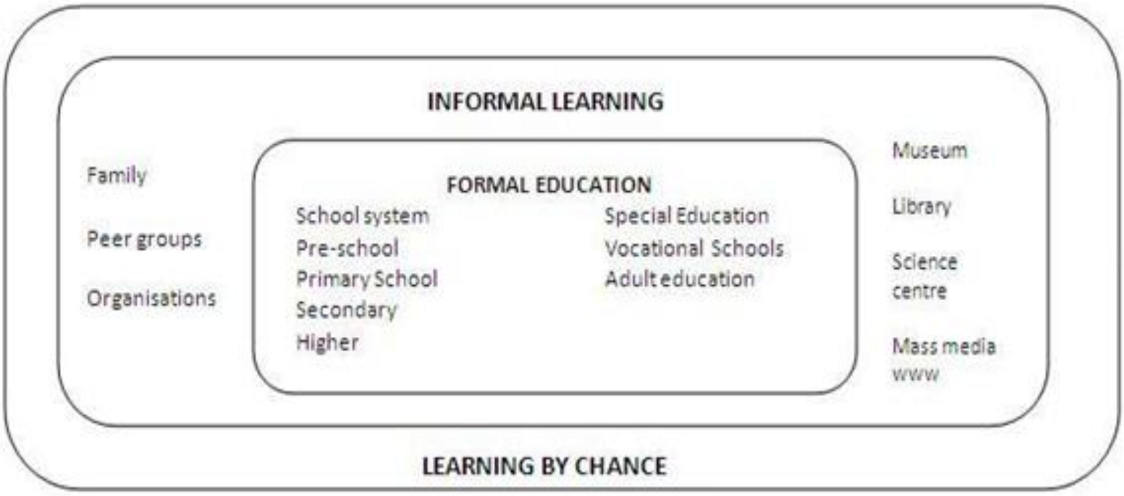

Fig.1. The relationship between the different kinds of education [8]

The relationship between the different kinds of education is shown in Fig.1, which is a combination from several sources. Originally it was the scheme for educational statistics in the UNESCO report Learning to Be – The Faure Report in 1968. It was used then for first time to show the forms of life-long education.

To promote public understanding of science, new forms of education are actively being sought. A huge amount of information, especially about modern phenomena, is obtained in a personal way from family, friends and peer groups. Furthermore, the roles of television, libraries, magazines and newspapers, and of course by ICT and web-based reality are essential. Informal learning has often been regarded as the opposite and criticism of formal education. However, since 2000s, informal education has become a widely accepted and integral part of school system.

The terminology of formal education and informal learning has been clearly defined in the literature for three decades now. The recent boom in informal learning has not changed the view on the terminological level. However, out-of-school education is yet another essential term. It means education that happens during school time and according to the curriculum, but uses settings and institutes outside the physical school building.

SCIENCE CENTRE PEDAGOGY

The numbers science centres – and their visitors – have increased regularly during the last decade. Most of these forms of education can be classified as informal learning, either focused on young people via informal, out-of-school education programmes or as clearly informal learning occurring totally outside any educational institutes for young people or adults. We have to head towards the evidence based education via teacher training. There is all too much anecdotes and every-day-experiences related to science education and informal learning. There has to be more reliable link between research communities and teacher training.

The role of informal learning is increasing in the modern societies – meaning the countries which are developing their societies by investing and creating opportunities for research, innovations, and education. The phenomenon is closely related to the growing impact of science and technology in our everyday lives. Lifelong learning needs new practical forms, and the formal education can learn something from the informal, open learning environments like the science centres.

Hands-on learning is the main pedagogical principle of the science centres. This classical “learning by doing” method is something that the science centres have been pioneering in Europe during the last decades. The multidiscipline contents of modern science centre exhibitions form a unique and reliable learning source. The most important results related to informal learning underline the role of intrinsic motivation and the learner's own activity, stimulated but not forced.

A science centre is a learning laboratory in two senses. First of all, it is a place where visitors can learn scientific ideas by themselves using interactive exhibit units. Secondly, it is a place where informal education can be studied in an open learning environment.

In the USA, the background to the expansion of modern science centres in 1960s was the Sputnik phenomenon. The crisis in national confidence that resulted from the successful launch of Sputnik had a knock-on effect on all education in the USA. The attitude towards the study and teaching of science dramatically changed. The educational system in the USA was totally reformed.

Exploratorium Science Centre started in San Francisco in 1968. In the 1970s and 1980s there was a period when nearly identical exhibitions were built by science centres just by copying exhibit units and whole exhibitions from other science centres. The main source for this was the ‘Exploratorium Cookbooks’, which were to a large extent published for this purpose. Many new institutes still utilise this concept for their main content which says much about the international nature of science and science centres.

However, the staff of science centres adapts their national and local features with their own ideas when choosing the content, design and programme ideas.

Frank Oppenheimer has been quoted as the creator of the science centre pedagogy. His criticism of the passive pedagogy of science education derives implicitly from John Dewey's ideas (1938) expressed in his thesis ‘learning by doing’. The same approach can be seen in contemporary developments in science centre pedagogy: The famous hands-on principle articulated by Oppenheimer is a corner-stone of the principle of interaction in modern science centres. What Dewey and modern science centre pedagogy share is the accent on motivation, free will and the learner's own activity, stimulated but not forced.

The growth of science centres since the 1990s is closely related to the developments of the information society. Communicating science to the public via different media is not only a matter of giving sufficient support for scientific research and academic education in society but also a process of giving citizens their basic democratic rights in relation to scientific information.

The continuing world-wide trend is for a broadening of the subject range of science centres and an increasingly interdisciplinary approach to exhibition themes. One non-trivial problem that has been raised in the discussion of the role of science centres and universities is related to the meaning of the word ‘science’. In English, science generally means the natural and physical sciences and is often limited to physics, chemistry and biology. However, in German, Swedish, Hungarian, or Finnish, the words ‘Wissenschaft’, ‘vetenskap’, tudomány, and ‘tiede’ include the humanities, history, psychology, social science and linguistics. The modern science centre must be able to present phenomena related to all academic research. Accordingly, the content of the leading science centres in Europe has been planned in an interdisciplinary way. The content of exhibitions is supported by a broad spectrum of temporary exhibition themes. Also the recent PISA-results are showing the importance of this relation and interaction between science and society.

Figure 2 presents the positions of a science centre in its relation to science, technology and education. It can be well used in order to explain and express the main goals of the European Commission Science with and for Society 2020 programme. It shows how these objectives are met through the cooperation between universities, science centres, schools, teacher education and school authorities. Science education is presented in at the point where science and education overlap. Science and technology meet in the area of research and development (R&D), within which academic research is used to develop industrial methods. Vocational education is at the intersection of technology and education.

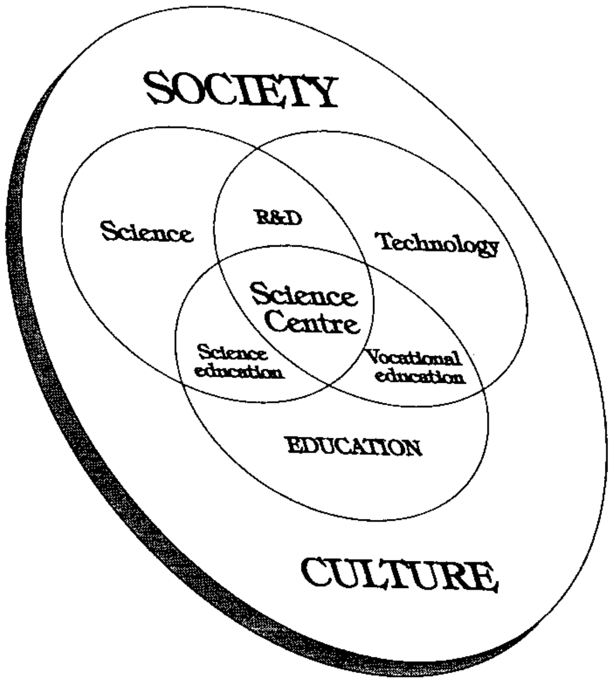

Fig.2. Education, Science and Technology in the context of Society & Culture [9, 7]

In the same figure, science centre is located where science, technology and education meet. According to this description, a science centre features all of these three fields. Any exhibition, event or educational activity like the science truck, combine these three elements and adapt them to the nature of the specific content.

Out-of school education often uses informal education sources for formal education. It forms a pedagogical link between formal education and informal learning. Science centre education is one form of out-of-school education [10].

The methods of informal learning have traditionally been used in, for example, the teaching of biology, geography learning, science education, museology solutions, and art education. To advance public understanding of science, new forms of education were actively sought [11]. Learning does not take place only in the actual world of school, but in the presented world of nature, parks, yards, science centres, gardens, and the media, as well as through the virtual worlds of the internet and social media [12]. There has been few activities related to mathematics education and learning in informal learning settings including science centre exhibitions [13,14]. The international mathematics happening BRIDGES arranged every second year is one of the few role models for this type of public understanding of mathematics exhibition and activities. Such results have been multiplied in the literature [10, 6]. However; science, technology and engineering have traditionally been tactile and become more and more visual, and many of the skills trained and taught are definitively not textual. Therefore, "here might be a mismatch between the structure of the knowledge and the structure of the print and language media traditionally used both impart and test that knowledge" [15].

Positive attitudes towards the science and technology and the motivation for science education are created at a young age both in the field of cognitive learning but also in the more affective sides of education. "Feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science of on society or scientists themselves" [16]. Attitudes have shown to be formed early, hard to change after elementary school. Because of this phenomenon, it is important to analyze and influence them before transition to middle school. The change of these false pre-concepts are especially difficult, if the attitudes have been formed more intuitively, automatically and on emotional basis than more consciously in process of time [17].

The big challenge is the fact, that the attitudes of girls already early ages become more negative towards science. Overall, students often tend to lose their interest by time. Therefore, analysing motivation, attitudes toward science and science education are essential in order to make predictions about whether and how the pupils will engage with science later in life and their career. It is essential not just for the individuals but also for society and the economy.

Recently some promising results have been reached in this area. How do science, technology, engineering, and mathematics attitudes vary by gender and motivation? Attractiveness of science exhibitions were carefully studied in six countries: Belgium, Estonia, Sweden, Latvia, Estonia, and Finland [18]. Science centres tend to give opportunities to hands-on experiences in an attractive learning environment. The study analysed attitudes, motivation and learning during a science exhibition visit, their relations to gender and future educational plans (N=1800 sixth-graders). Pupils' performance in a knowledge test improved after the visit. Autonomous motivation and attitudes towards science predicted situation motivation awakened in the science exhibition. Interestingly, the *scientist* attitude and the *societal* attitude were clearly separate dimensions. The third dimension was manifested in the *engineering* attitude typical for boys, who were keener on working with appliances, designing computer games and animations. *Scientist* and *societal* attitudes correlated positively and *engineering* attitude correlated negatively with the future educational plans of choosing the academic track in secondary education. The *societal* perspective on science was connected to above average achievement. In the follow-up test, these attitudes showed to be quite stable.

CONCLUSIONS

The main results of the science centre pedagogy can be stated as follows [19]:

1. Science centre education is still too much based on anecdotes and everyday knowledge.

2. Motivation is the main outcome of science centre pedagogy: how to move from situation motivation into intrinsic motivation!

3. Quality knowledge learning results can be achieved – but only by pre-lesson and/or post-materials in context of science centre visit.

4. The teachers must have courses related to science centre pedagogy to receive" cost-effective" learning results.

Also the European Commission's Rocard Report [20] has underlined the importance of this phenomenon. This report and other presentations describe the situation mostly in the pre-schools, primary and secondary schools while we also see the trends around the formal education. The role of learning in informal contexts is increasing in the modern societies – meaning the countries which are developing their societies by investing and creating opportunities for research, innovations, and education.

The digital technology and increasing computational complexity of daily practices are reorganizing our society. The quality of science education in primary and secondary schools is so rooted in the bright scientific history of Europe and so critical for its future that every effort should be made to remedy a far from optimal situation, such as that which we observe at the beginning of this 21st century. The European Union has all the necessary talents and tools to rebuild a strong educational system in science, able to communicate to every young person a taste for science, an understanding of its place in culture, and a vision of professional careers.

Science affects everyone's life. Thus, being scientifically literate is a civil right, and science education should promote accessibility to science by an attractive, inviting and not a too difficult pathway. However, both age and gender have to be taken into account. The modern movement for public understanding of science started from the Sputnik-phenomenon in late 1950s. Unfortunately, it seems that the humankind and the societies do react only after crises already have happened like the Tsernobyl accident, or are clearly treating like the Climate crisis. Scientific literate learners is one solution in the process of Science with and for Societies in 2020s.

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THE MAGIC TOWER OF EGER

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ABSTRACT

Programmes of the Magic Tower are housed in six different locations, which are the Magic Room, the Jedlik Ányos experimentarium (lecture-hall), the planetarium room, the astronomical museum, the panorama terrace, and the Camera Obscura. Having gained reputation, interest for certain programmes outside the building has increased. In the next sections, the work in the Magic Tower is presented by introducing each location one by one.

INTRODUCTION

The Lyceum of Eger was built between 1761 and 1785 as the home of a university. The key element of the building is the Specula or the Astronomical Tower (see Fig.1), where astronomical research took place after the construction. Later on, the Tower started functioning as an astronomical museum and the Eszterházy Károly College became its supporter. In 2006, the College broadened its museum activities with interactive experiments, experimental demonstrations, and planetarium shows [1]. Since then, the institute operates on four floors under the name Magic Tower. Its main tasks include the popularization of natural sciences, the scientific dissemination of knowledge, and turning young people's interest towards natural sciences within the confines of higher education.

Fig.1. Left panel: The Lyceum of Eger. Right panel: The Specula

Fig.2. Left panel: A staff member presents an exhibited device. Right panel: The Bermuda barrel at work. The black arrow shows the displacement of the toy ship

The Tower has about 24 000 visitors annually. Two third of them are primary and secondary school students, the rest are tourists. Students visit the Tower according to a pre-established schedule. Upon arrival, they are separated into parallel groups that explore the stations of the exposition in different order. The itinerary of each group includes about 20 minutes in the astronomical museum, 30-35 minutes in the Magic Room, 15 minutes in the Camera Obscura, 45 minutes in the planetarium room, 45 minutes in the experimentarium, and 20 minutes on the panorama terrace. The whole program takes almost four hours. Tourists spend less time, roughly 1 hour, in the Tower; they usually want to see only the museum, the panorama terrace, and the Camera Obscura. The guiding staff of the Tower consists of fourteen persons: nine college students, and four qualified members of the academic staff, all of them employed with part-time contracts.

THE MAGIC ROOM

The Magic Room houses more than 30 interactive experimental devices that help visitors to understand a wide scale of physical phenomena. These experimental stations do not only encourage hands-on experiments to teach the fundamental laws of physics in a playful and self-directed way, but they also give the visitors the opportunity to play scientific games. The method of demonstrations in the Magic Room is very different from those of secondary school. First, the professional staff describes the exhibited device and explains the law of nature behind its operation, then the visitors can try them themselves (see the left panel of Fig.2).

Our most popular experiments are the Bermuda barrel (see the right panel of Fig.2), the Lenz's law demonstrator (see the left panel of Fig.3.), and the hot air balloon (see the right panel of Fig.3). The Bermuda barrel is a transparent water tank with a floating toy ship (see the inset of Fig.2. right panel) whose average density is slightly less than that of water. At the very bottom of the tank, there is an aerator. When the aerator is turned on, the water becomes saturated with air bubbles, and its average density decreases to a smaller value than that of the ship. The ship goes to the bottom and stays there until the aerator stops. This phenomenon can possibly explain why ships get lost in the Bermuda Triangle.

The apparatus for demonstrating Lenz's law (Lenz cannon) can be seen in the left panel of Fig.3. It consists of an electromagnetic coil with an iron core, a switch, and a voltage source connected in series. Initially, an aluminium ring rests on the coil. When the switch is flipped on, the ring springs upward. The explanation is that the changing electric current in the coil generates a changing magnetic field in the core. This changing magnetic field induces voltage

Fig.3. Left panel: The Lenz cannon. Right panel: The hot air balloon is ready to start

and current in the aluminium ring. According to Lenz's law, the induced current will create a magnetic field in the direction opposite to the magnetic field in the core. Because of the opposite direction of these two fields, the core and the ring repel each other. In our case, the force between the "magnets" is strong enough to move the ring upward.

The hot air balloon presents the technology of the first successful human-carrying flight. The structure of the balloon is the same as usual: envelope, wicker basket, and hot air generator. The balloon can fly up to approximately 8 meters, but in this case, only the envelope flies. The basket with the hot air generator stays down, because the volume of the balloon is relatively small. The sideward movement of the envelope is prevented by a vertically extended metal wire. The scope of experiments in the Magic Room ranges from mechanical (e.g. hot air balloon, Bermuda barrel, Magdeburg hemispheres) through optical devices (e.g. laser blackboard, kaleidoscopes) to interesting features of electromagnetism (e.g. Lenz cannon). The operation of these devices gives delightful experience not only to children and students, but adult visitors as well.

JEDLIK ÁNYOS EXPERIMENTARIUM

The experimentarium is a classroom equipped with the most modern tools of educational technology where teachers of the Eszterházy Károly College give scientific lectures from fields of biology, physics, geography, mathematics, and chemistry (see Fig.4.). These lectures can be attended by classes of any primary or secondary school. The experimentarium also gives place to other programs, such as postgraduate courses for teachers, meetings of the local amateur astronomy club, and the Magic Tower Quiz, which is a scientific competition held yearly for primary school students of Heves County. The main aim of the competition is to popularize science subjects, although events are organized all year round in the Tower on poetry day, Saint Stephen's Day, and Advent Sundays. These programs are not typically scientific but science plays an important role in them.

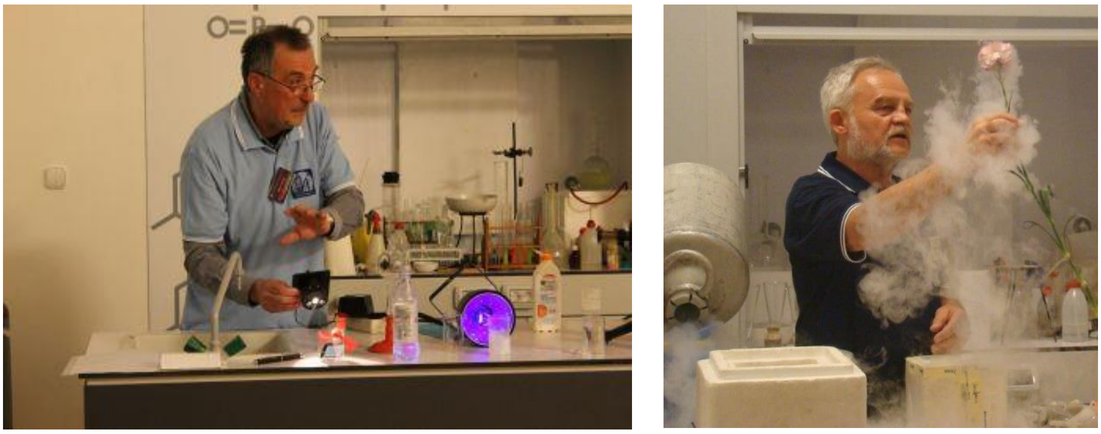

Fig.4. Experiments presented in the experimentarium. Left panel: The effect of ultraviolet radiation on a quinine solution. Right panel: The effect of liquid nitrogen on a rose

ASTRONOMICAL MUSEUM (SPECULA)

The Specula started its operation in 1776 as an observatory. It was equipped with the most modern astronomical instruments, which had been manufactured in workshops of London and Vienna. In the museum, you can see many instruments with the most different working principles: sundials, quadrants, reflecting and refracting telescopes (see the left panel of Fig.5), etc. A special sundial can be seen in right panel of Fig.5. It is a combination of a sundial, a cannon, and a burning glass. At noon, the glass concentrates the sunlight on the fuse of the cannon igniting the gunpowder and makes the cannon fire. Left panel of Fig.6. shows the great mural quadrant, which is an angle-measuring device. It is mounted on a wall oriented towards precisely the meridian. Astronomers used it to localize the position of a planet or a star. The special spectacularity of the museum is the Linea Meridionalis (see left panel of Fig.6.) or the Midday Line. The astronomical midday in Eger is marked by the moment when the shadow of a mark (see the inset of the picture) transits the Midday Line.

One of the specialties of the museum is that visitors get to see original instruments and devices at their original sites. In addition, the museum offers museum pedagogy programmes to visitors.

Fig.5. Left panel: Reflecting and refracting telescopes in the Astronomical Museum. Right panel: The sundial cannon, it can indicate noontime by a cannon-shot

Fig.6. Left panel: The great mural quadrant. Right panel: The Linea Meridionalis

PLANETARIUM

Our planetarium is equipped with a traditional planetarium projection apparatus. On the surface of the 6-meter-diameter hemisphere the copy of the starry sky can appear realistically. The planetarium programme shows the movements of stars and planets on the sky, and completes the astronomical knowledge of visitors. At the end of the show, they can ask the lecturer questions.

CAMERA OBSCURA, PANORAMA TERRACE

At the top of the tower there is the Camera Obscura architected by Miksa Hell (Maximilian Höll). Camera Obscura is a dark-room with a rotating periscope projecting the view of the city to a white, round-shaped, 266-cm-diameter table (see the left panel of Fig.7.). It is interesting because there are only two other similar instruments in the world. After the presentation, visitors can step out on the panorama terrace surrounding the building of Camera Obscura (see the right panel of Fig.7.), and can admire the beautiful panorama of Eger.

Fig.7. Left panel: The table of Camera Obscura. Right panel: The Camera Obscura surrounded by the Panorama Terrace

Fig.8. Left panel: Sun observation in Berekfürdő. Right panel: A water explosion experiment in a barrel with liquid nitrogen

The terrace is also the site of our telescopic observations and performances, which are connected to the activity of the local astronomy club as well. The Tower has three reflector and one refractor telescopes. During performances, staff members and amateur astronomers operate the telescopes and help the visitors to understand what they can see. Depending on the weather and the possibilities, the observed objects are planets, open clusters, galaxies, etc.

OUTDOOR PROGRAMMES

A couple of programmes can be taken to external sites. The staff members of the Tower are often invited as guest presenters by schools, organisations, and companies. These programmes are also very popular (see the panels of Fig.8.), the most popular one is the Astronomy Week in Berekfürdő [2].

CONCLUDING REMARKS

From the abovementioned aims of the Tower, the third one (young people's interest) is emphasised by social demand nowadays. Unfortunately, teaching of natural science subjects such as physics or chemistry in Hungary is in crisis, young people's interest is turning away from the field of natural sciences. Under such circumstances, institutes and organizations like the Magic Tower have a special opportunity and responsibility to do something in order to turn back this disadvantageous progress. This is the reason why currently our "target age-class" is the 15-18-year-old secondary school students. The numbers of invitations and visitors have been increasing recently, which implies the need for human resource development sooner or later.

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FROM FUN SCIENCE TO SEDUCTIVE SCIENCE*

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ABSTRACT

Science centres and museums have undergone a great evolution in recent decades although it seems that, lately, the science museum model has been somewhat stagnant. Since the radical changes of the mid-twentieth century, it has developed towards strategies in which visitor numbers take precedence over other considerations. Alongside a school science that still does not seem to attract a sufficient number of students to science, a trend has emerged with a focus on "fun science" in science centres and museums. We question this view and propose the idea of "seductive science" as an alternative to achieve long-term impact of museum visits, with an emphasis on scientific museology principles and inquiry based learning.

INTRODUCTION

In recent times, more and more science centres and museums are aligning themselves with the trend of presenting the visitor experience mostly as "fun", thus identifying the visit with a playful activity. A museum visit must certainly be unique and stimulating, but such an explicit identification with fun-related aspects can, in our view, leave out of the picture the wealth of other elements that a visit to a science centre or museum has to offer.

Let us first have a look at various factors that may have contributed to this trend:

- The focus on visitor numbers as a measure of success. It is indeed surprising that this is actually taking place in institutions that are meant to show how science works, with visitor numbers becoming, in practice, the only performance indicator of science centres and museums. Mission and vision statements always include a strong societal dimension, such as promoting uptake of science careers [1]. Naturally this should be also an important part of the evaluation of success, but we all know how scarce and difficult to obtain such evaluation data are (see for example [2] for one of the very few longitudinal studies available). As a consequence, there is the risk of just abandoning in practice the role of socio-cultural leadership science centres and museums can have within their communities and replace it with a focus on activities aimed at attracting ever growing visitor numbers. This is often done without the realm of museographic language, sometimes even under the disguise of bold experimenting with avant-garde museology.

- The use of business-style market studies. Institutions with a strong societal focus can certainly use market studies to gain a deeper knowledge of their public and so be able to ascertain what they can offer that is most appropriate. Unfortunately science centres and museums apply such studies in the same way businesses do – in order to learn about public demand and respond to it quickly. Paradoxically, one of the assets of science centres and museums is their ability to offer their audiences experiences previously unknown to them and for which clearly no demand will be detected via a direct and superficial market study.

• The identification of science centres and museums with leisure venues. Many members of the public identify science centres and museums as good leisure alternatives for a family day out keeping the children amused, rather than opportunities to share a creative museum experience. Whilst this approach by visitors is certainly welcome, it does not imply that museum managements have to share and cater for it as it is not aligned with the science communication aims and objectives they set themselves.

• The influence of "Braniac"-style TV shows. It may seem that science communication works well as a TV product, if one measures by the proliferation of programmes that have some degree of "science" in them, usually through spectacular science demonstrations that are fun and entertaining. Without questioning the good intentions of the producers of such shows, it has to be remembered that their main aim is not to communicate science, but to attract audiences measured by means of "shares".

• The influence of trends in schools. There is a current trend in schools which is concerned with ensuring –to a worrying degree— that pupils "feel good" and enjoy being in class, with the ulterior aim of preventing them from developing a distaste for learning, as it is proven that learning is strongly influenced by the learner's emotional state (cf. [3]). In this context, the main reason why many teachers take their classes to science centres and museums is for the pupils to have fun with science [4].

In summary, the demand both from school visits and family audiences seem to push science centres and museums to offer fun. Pairing science and fun can, however, bring about some unwanted consequences, as we will discuss in the next section.

FUN SCIENCE OR SEDUCTIVE SCIENCE?

Identifying science with fun can constitute a deceiving enticement towards science for the public, and in particular for prospective students of science careers, who constitute one of the main target audiences of a number of science communication channels, including science centres and museums.

The day-to-day work of a scientist hardly qualifies as "fun" if one looks at long lab hours, data analysis, or code programming, to mention but a few examples. A final year project supervised by one of us showed that those pursuing a career in science tend to distance themselves further and further from the concept of "fun" in science as they gather experience, and that there are numerous other adjectives they come up with to define science, such as fascinating, interesting, exciting, or important, for example [5]. In fact, assuming children will only do things they perceive to be fun could be considered a patronizing attitude towards them. Many children get involved in say, environmental or animal protection activities not because they think they are fun, but because they realize they are important [6]. However, repeatedly assuming they are only interested in fun could end up becoming a self-fulfilling prophecy.

Moreover, there is growing evidence that making science pleasant and fun for student does not go beyond improving their attitude towards science, as there is no correlation with decisions towards science careers, as reported in [7]. A recent broad study by Reach Advisors has shown that after a few years the most intense memory of a visit to a contemporary museum is often related to real objects of particular museographic value, even in the case of young visitors [8].

Focusing on fun during science centre and museum visits also leaves out of the picture educational considerations such as science centres and museums being ideal environments for constructivist, inquiry based learning [9], [10], [11]. Moreover, this can even have a backfiring effect in that it reinforces the idea that learning in class in inherently boring, the "fun" being outside the classroom.

Another often overlooked danger of the idea of "fun science" is that it dissuades scientists from getting involved in science communication, especially the most renowned and prestigious ones. In a day and age in which we are making a big effort to persuade the research community to get involved in public activities it is important to ensure they feel comfortable with it, and trivializing their work by portraying it as a show without substance certainly does not help.

TOWARDS SEDUCTIVE SCIENCE

We all know that another word for "fun" in English and other languages is "diversion", in one or other variant. In English the word "diversion" also kept the original Latin meaning of "turning away" from the intended path. This coincidence is a handy illustration of our view that overemphasising "fun" may "divert" or distract from the intended message about science, education or science centres and museums.

As mentioned earlier, there are many other adjectives that can be applied to science and which reflect much better what it represents: fascinating, exciting, thrilling… This is what "seduces" the scientists to make them willing to endure the hard and less gratifying aspects of research. They know that at the end of the process, obtaining results and drawing conclusions is an unmatched intellectual experience.

"Seducere" means in Latin "to attract" and this is exactly what should be strived to in science centres and museums – and in schools, too, we dare say—: to promote interest for science; to prevent the children's innate curiosity from fading off with time; to show pupils that a museum visit provides more questions rather than answers; to facilitate that excitement becomes fascination. To do so there are some fundamental elements a school visit should feature, which we list here with our experience and research as a basis, and without aiming to be exhaustive.

Collectively constructed science. The core of a science centre or museum is the exhibition. It should become the field where students in small groups collect data, where they observe nature, where the most exciting moments of encounter with the object or the phenomenon will take place. These data can then be analysed in the workshop rooms –their labs—, where they share ideas with their fellow students, and construct their own conclusions, which they can then communicate to the other members of their school or family group. Science is a collective human construction and in science centres and museums, there must be a constant interplay of doing, thinking and communicating, just as in real science, and as such, it is not necessary that everyone in the group does everything: there are different roles, and it is not about having done every single task, but rather about having gone through all intellectual stages and having taken part in the generation of new knowledge as a member of a team.

Science as a story. First, science needs to be portrayed as a human endeavour in constant change, embedded in culture, particularly in the culture of the visitors. To do so, science must be told as a story, scientific language has to become a narrative that links concepts with personal cultural experiences, almost like turning science into a new humanities discipline. Starting an activity as a story based in the use of different communication systems will help creating an emotional bond that can be referred to throughout its delivery.

Fig.1. Various children at the Museu Blau (Barcelona), attentively listening to a museum educator about a skull on display. Image: Museu de Ciències Naturals de Barcelona.

Science in dialogue with other disciplines. On the other hand, in a museum natural phenomena are presented out of their context. Objects displayed or exhibits that simulate natural processes need educational approaches which redefine their contexts and link them, again, to culture. This cannot be attained if science does not interact continuously with the other disciplines. Science may well be the central axis for a topic, but at the same level as, and in conversation with, other communication systems, the arts, mathematics, etc., so as to incorporate one of the key aspects of any scientific development: creativity, as reported in [12].

Consolidating learning. The museum is not a classroom, but the museum's assets can be developed to be an invaluable complement to classroom learning. In the science centres or museums we have little knowledge of how the teachers make links between the visit and the curriculum (or how the discussion will go on at home), as our contact time with visitors is brief and fleeting. Yet it is clear to us that, since two thirds of the visitors are not only looking for fun but for learning experiences, too, and 100% of teachers hope that learning will take place during the school visit to the museum [4], we must ensure this actually happens. The only way to achieve this is through a facilitated activity at the end of the visit in which participants have to apply their learning and the changes in the way they see reality that have taken place since they arrived. As we will mention below, the interplay of different communication systems and interdisciplinary dialogue will be key to this.

Calm Science. It easily follows from the previous points that, just like science itself, the whole process cannot be completed in haste. A visit to a science centre or museum has to be relaxed. Not only because science cannot be rushed, but simply because a high level of attention cannot be sustained for long periods of time, and it becomes necessary to alternate between moments of intense stimuli that require high levels of attention and other more relaxed ones that then allow to bring attention back to a high level. This implies that a museum visit, especially a school visit, needs to be as long as possible so as to include the necessary breaks. A whole morning would seem appropriate. But it is not only the delivery of the actual activity what matters, there are other relevant aspects that need to be taken care of:

a welcome at reception that is not rushed; moving through the exhibition floor quietly and without running; museum staff talking in a low voice; and everything that contributes to a calm atmosphere. This is radically different from the common scenario in which crowds of children shout and run around, press buttons without paying attention, etc., to the desperation of teachers, parents and museum staff.

Fig.2. Exhibition "Iriscendium: the soap bubbles lab” at the Engineering College of Tarragona. A fascinated child spends an extended period of time with full attention in order to make an iridescent giant soap bubble. Image: Ruth Dolado.

All this is certainly not easy. It definitely is not in the absence of a professional education team. It is not if we do not have educators instead of explainers and guides, if we leave these activities in hands of interns without much experience –internships are something quite different— and without resources at their disposal, if we rely on temporary workforces without continuity within roles. Highly knowledgeable educators are needed –visitors hope to meet experts to help them understand [4]—, trained both in the subject matters and in education, and prepared to deal with diverse audiences and adapt any part of the activity to changing audience needs, knowing that it is their only shot with these particular members of the public. We need educators that can cater for very different visitor groups, with radically different needs and unknown expectations.

We know that in the current economic climate, advocating such a working model may seem frivolous, but education is not, and there is a lot at stake. We know that we are not doing particularly well, that citizens do not feel involved in the issues of science and technology, that fewer and fewer young students want to become scientists. We need to act now.

Otherwise we will certainly contribute to the entertainment of the population, but without effecting any change in how they see science in the long run or in their ability to recognise the essence of what we call the scientific method. In such a scenario we do not need science centres or museums – theme parks and shopping malls will suffice.

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INSPIRING PUPILS TO STUDY PHYSICS AND ASTRONOMY AT THE SCIENCE CENTRE AT-BRISTOL, UK

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ABSTRACT

An investigation was carried out to collect evidence that science centres can have a positive effect on young children's formal education in Physics and Astronomy. We explored whether the science centre At-Bristol's exhibitions and planetarium show align with the current UK curriculum guidelines in Physics and Astronomy and the point of view of pupils, a science centre educator and a teacher on whether they can increase further uptake of these particular subjects later on. The evidence gathered showed a positive alignment between science centres and curricular content and that science centres are indeed considered an adequate and effective tool in supporting learning and inspiration for subjects such as Physics and Astronomy.

INTRODUCTION

A report in 2001 stated that 'in many developed countries of the world, science education is seen to be in crisis. Pupils' attitudes to school science decline progressively across the age range of secondary schooling, and declining numbers of students are choosing to study science at higher levels and as a career' [1]. This suggested the importance to ensure primary school children are kept sufficiently interested in the study of Science. Particularly in Physics and Astronomy is interest likely to decrease at secondary school level [2]. It has been suggested that this could be due to the subjects themselves or to lack of scientific knowledge and enthusiasm from teachers [3].

As a response to this reality, many changes have been made in recent years to how Science is taught across the UK and to the subjects covered. As many of the subjects covered in the key stage 2 (KS2) National Curriculum are statutory, it is important to ensure children are engaging with the right information inside and outside of the classroom. According to the UK's Department for Education the three main changes made to the primary school National Curriculum in 2014 were towards 'More focus on learning outside the classroom', 'New content areas to be covered' and 'More types of inquiry are to be specified' [4].

In 2014 the science centre At-Bristol had approximately 35,000 visitors attending educational workshops at the KS2 level, an increase of 5,000 visitors with respect to the previous year 2013 [5]. A suggested reason for the increase of visits to a science centre could be linked to the government guidelines encouraging more focused learning outside of the classroom in Science subjects.

Science centres are often used by schools to encourage a hands-on fun approach to learning, but are also as important in supporting formal education [6]. Recent studies show that with increased visits to science centres, young pupils' existing knowledge is reinforced, allowing them to discover subjects in more depth inside and outside of the curriculum. A report entitled ‘The Effect of Science Centres on Students' Attitudes towards Science’ concluded that ‘Science centres can be used by educators as an effective way of increasing students' attitudes towards science.’ [7].

On the other hand, a recent increase of students studying in Physics and Astronomy at the level of Higher Education has been reported. The Institute of Physics published these statistics in 2012 [8]:

- The total number of full-time students in the first year of first-degree physics courses increased by 25% between 2004/05 and 2009/10, from 3190 to 3975.
- In 2009/10, 51% of physics, 52% of astronomy, and 46% of chemistry fulltime first-year students are registered on enhanced first-degree courses compared to 19% of mathematics, 17% of electronic & electrical engineering, and less than 2% of biological science students.

It is important to establish what factors have contributed to the growth in interest in subjects such as Physics and Astronomy in order to be able to further promote and inspire young children into having an interest in these and other fields. If science centres are realistically creating exhibits and workshops that are aligned with the current Primary Science National Curriculum guidelines there should be clear evidence that they are a useful supporting tool for schools and families.

METHODS

Data were collected over a period of four months in a primary school and in the science centre At-Bristol.

First, quantitative content analysis methods were used to look at the amount of significant written content relating to Astronomy and Physics in the texts displayed on exhibits and in the planetarium show script at the Science Centre. Key words were identified and their counts compared to those in the KS2 National Curricular content. Irrelevant subject material, i.e. words that were not featured in the National Curriculum, was removed from summaries to simplify the detection of key words in the text.

Second, a classroom teacher asked a number of suitable questions to the year 3 pupils of Shield Road Primary School. Their responses were analysed and quantified regarding the pupils’ knowledge of Physics and Space Sciences.

Third, a structured interview was carried out on the Key Stage 2 classroom teacher; predetermined key questions were asked, with the aim of establishing an academic opinion on the subjects taught on the curriculum and what more can be done to encourage further study.

Finally, an unstructured interview was completed with an Education Officer at the science centre, At-Bristol to gain insight into the current relevant Physics and Astronomy learning tools at the centre and explore the opinions of a professional working in education outside of the classroom.

RESULTS

The current National Curriculum at upper and lower Key stage 2 has 14 compulsory Science modules that are to be covered in the classroom. Five of these modules are based on Physical Processes and Astronomy.

The frequencies of selected key words relating to Astronomy and Physics in the 5 relevant modules are shown in Table 1.

Table 1: Frequencies of key words in Physics and Astronomy in the KS2 National Curriculum

Astronomy:	**Total**
Earth	11
Sun	8
Moon	5
Solar System	5
Planets	4
Space	1

Physics:	**Total**
Light	28
Sound	11
Magnet	16
Force	9
Electricity	7
Gravity	1

Of an overall exhibit total of 164 in At-Bristol, 36 exhibits are directly related to Physics and Astronomy. This is 22% overall. Key words correlating with the Physics and Astronomy subjects covered in the KS2 National Curriculum were searched for in the exhibit texts as an indication of how many are related specifically to the National Curriculum at KS2 (Table 2).

Table 2: Physics and Astronomy key word frequencies in exhibit texts

Astronomy:	**Total**
Earth	22
Sun	9
Moon	2
Solar System	0
Planets	7
Space	20

Physics:	**Total**
Light	41
Sound	31
Magnet	21
Force	9
Electricity	11
Gravity	11

It can be seen that practically all the key words are covered with several occurrences in the exhibit texts.

From the transcript used in the show 'Exploring the Solar System' in the Planetarium of At-Bristol we identified the key words that align with the relevant National Curriculum content (Table 3).

Table 3: Physics and Astronomy key words in the planetarium show

Astronomy:	**Total**
Earth	39
Sun	28
Moon	16
Solar System	21
Planets	21
Space	6

Physics:	**Total**
Light	7
Sound	0
Magnet	0
Force	0
Electricity	0
Gravity	0

Whilst the absence of Physics key words is understandable given the topic of the show, a Chi-Squared test shows that the distribution of words in the National Curriculum relating to Astronomy is not significantly different from that of the planetarium show transcript (Chi-square= 0.95), the P-value of 0.97 suggesting that the two distributions are equivalent.

The KS2 Planetarium show transcript covered 75% of statutory requirement topics that pupils should be taught in the Earth and Space module at upper KS2, including:

- Describing the movement of the Earth and other planets relative to the Sun
- Describing the movement of the Moon relative to the Earth
- The Earth's rotation to explain day and night and the apparent movement of the Sun across the sky

Further, 50% of the non-statutory guided learning topics recommended in the Earth and Space module are also covered in more depth throughout the Planetarium show, including

- That the Sun is a star at the centre of our Solar System and that it has eight planets.
- A moon is a celestial body that orbits a planet (Earth has one, Jupiter has many)
- Pluto is now a dwarf planet

Responses to questions asked by the teacher at Shield Road Primary School to 30 KS2 pupils show that only one third have a knowledge of what Physics is, that two thirds have knowledge on Astronomy and Space that is not taught in school and that all would like to learn more about these topics. Also, two thirds have already had the opportunity to pursue this interest by visiting a Science Centre. (Fig.1).

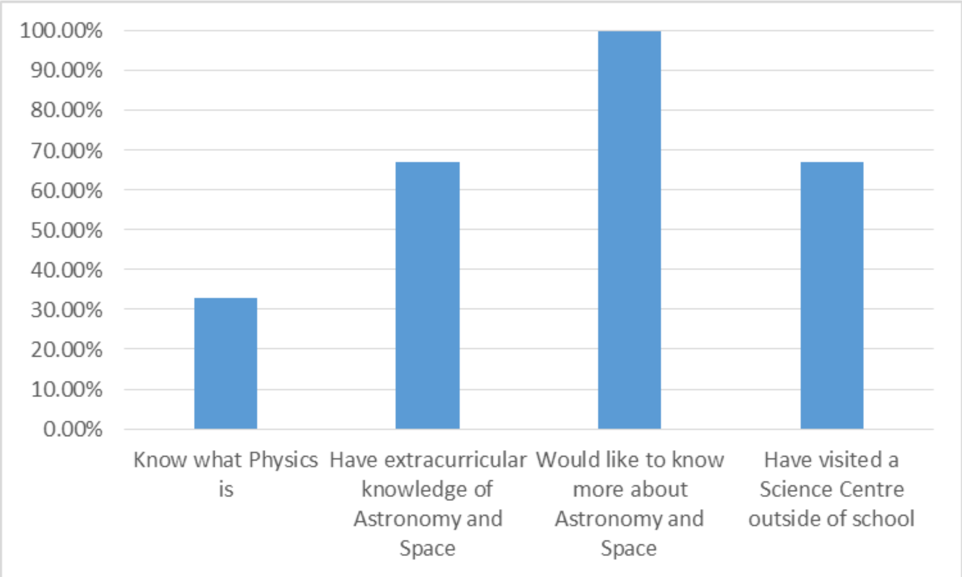

Fig.1: KS2 Pupils' responses to questions asked by the class teacher

The interview of the teacher showed that she and her colleagues agreed that the pupils would benefit from covering more topics in Physics/Space related subjects from a lower age, to give a better basis for the subjects and open up a potential interest even before upper KS2. Regarding interest in subjects that are not necessarily covered on the curriculum, especially in Science subjects such as Physics she pointed out the need for appropriate facilities such as science centres, museums and libraries, as it is sometimes difficult for parents to teach their children Physics based topics outside of the classroom as they are often not educated in these particular subjects themselves. Regarding school trips to At-Bristol and other opportunities to get hands-on with science, feedback was overwhelming and many pupils came out with solid knowledge of subjects they may not have been so confident in before, as well as expressing less of a dislike for subjects they labelled as 'boring' beforehand. So she would largely recommend more use of hands-on learning and encourage more trips.

The Education Officer of At-Bristol pointed out that Science Communication research suggests that if teaching and understanding of Science early in Primary Schools is sufficient then pupils are more likely to study the subject with confidence in later years. Ensuring pupils are getting the correct teaching is key, using Science Centres or other tools is sometimes necessary to support this. Visits to At-Bristol are designed to excite interest and build enthusiasm in Science as well as support learning in school. Many students have the opportunity to ask expert scientists questions that teachers do not cover and may not be able to answer in schools. It also gives students the chance to experience hands-on learning in laboratories and resources that are limited in schools. At-Bristol also encourages parents of children to come along and get involved with their children so they are able to engage about subjects that they can learn together when they have left the science centre.

DISCUSSION AND CONCLUSIONS

The evidence gathered shows a clear alignment between exhibits and planetarium shows at At-Bristol and the content taught on the Key Stage 2 National Curriculum, and that science centres are indeed perceived by pupils, teachers and science centre educators as an adequate and effective tool in supporting the content taught in school, particularly in difficult subjects such as Physics and Astronomy.

A study published in 2000 explores children’s ideas in science. It explains that children, even when very young, draw different scientific conclusions and each have personal ideas and concepts when studying Physics based subjects. The study states ‘students approach science in classes with previously acquired notions and these influence what is learnt from new experiences in a number of ways’. The study goes on to explain that students acquire information from several sources including texts and experimentation outside of class. It concludes that using supporting resources is paramount to ensure all levels of students attain a basic knowledge of Physics [9].

The views of the teacher and At-Bristol’s Education Officer are consistent with a recent study on primary school children’s developments in Astronomy concepts in the Planetarium. The results showed ‘significant improvement in knowledge of all areas of apparent celestial motion covered by the planetarium program’. As well as results demonstrating that ‘The value of both kinaesthetic learning techniques and the rich visual environment of the planetarium for improved understanding’ [10].

This is further supported for example by a longitudinal study entitled ‘Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre’ [11], which tested 10- and 11-year-old pupils from four schools regarding attitudes toward Science and Space before and after visiting the UK National Space Centre. The report concluded that nearly 20% of the pupils showed an increased desire to become scientists in the future and that immediately after the visit all pupils showed a more positive view on Space and a moderate increase in their views about the value of science in society. It also stated that the pupils that visited the centre ‘showed a positive advantage over the other children with regard to science enthusiasm and space interest’ and that ‘Two months later, they continued to be more positive about being future scientist’. Again evidence shows there is a clear positive change in young children’s attitudes toward science subjects when involving interactive and hands on learning spaces.

Although many improvements have been made to the science curricular content overall in recent years, this study suggests there is still a need for the inclusion of more Physics and Astronomy subjects at early primary school level to encourage future study in science based subjects, given that there is interest in such topics in KS2-aged pupils and that resources are available to schools and parents to support the pursuit of this interest.

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PROMOTING ENVIRONMENTAL PHYSICS ISSUES IN SCIENCE CENTRES AND AT SCIENCE EVENTS

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ABSTRACT

We consider that environmental physics issues could be interesting for students, but these topics are not included in the school curriculum. Organizing extracurricular physics events is of great importance as they present aspects that are related to everyday life and environment. We make an overview of experiments related to environmental physics displayed throughout different European science centres. We present experiments related to this topic performed during the annual event "Saturday of experiments" organized at the Babeş-Bolyai University – tsunamis, weather fronts, cyclones – and make suggestions for the possibility to display at science centres without the help of an animator.

INTRODUCTION

For students the process of learning physics is a very complex one, partly because of the abstract nature of many scientific concepts and of their mathematical representation. Topics of different curricula are related to simple physical models which in most of the cases do not relate to real-life situations. Because of their complexity, everyday life and environmental phenomena are difficult to be represented mathematically, so they are avoided in high school curricula. The other challenge of teaching these topics is to have an experiential approach to help better understanding. As for the moment we cannot have an influence on national educational policies, we try to summarise some informal learning activities to provide learning situations about our environment. Such informal learning activities are offered by science centres, different science events and student research projects. As an example of a science event we present the Saturday of experiments organized by the Faculty of Physics of the Babeş-Bolyai University and the EmpirX Association.

ENVIRONMENTAL PHYSICS IN SCIENCE CENTRES

Museums and science museums in special have a special educational role. In the case of museums the main motivational tools are intrinsic factors – such as curiosity, enjoyment in learning and mastery of challenge. Thus, learning in museums has a different character from that at schools, where extrinsic factors such as examinations, grades, approval of teachers are common motivators [1]. Mihaly Csikszentmihalyi has studied different intrinsically motivated activities [2]. He points out that this kind of learning is successful only when the challenge is close to but slightly greater than the skill level of the person and when feedback is immediate.

In the best museums, learning is a multisensory activity. Exhibits are visually exciting and most have a text to help explain the phenomena. But they also produce sounds and encourage touching. Because of this richness, museums and exhibits have the opportunity to connect with many different learning modes that people use.

We have made a short inventory – some of them by personal visits, some from the information provided by the scientific boards of the museums – of environmental physics exhibits in different European science museums. We have gathered information from the following ones: MUSE Trento, Italy, Phaeno Wolfsburg, Deutches Museum Munich, Germany, At-Bristol, Techniquest Cardiff, Wales, Science Museum London, UK, Technisches Museum Wien, Austria, NEMO Center, Amsterdam, Netherlands, Hiša Eksperimentov, Ljubljana, Csodák Palotája Budapest, Hungary. The playful atmosphere of science centres leads many people to think of them as places only for children. But "playing" is a serious matter in science education. It leads to the development of skills in observation and experimentation and the testing of ideas, and it provides an opportunity to independently discover order in nature.

Fig.1. Flow tank at Techniquest Cardiff [3]

We have found a diverse presentation of environmental physics related experiments, being hard to summarize them in one paper. Phenomena related to fluid dynamics have a special interest for us, as this is one of the topics which is avoided in our curriculum in high schools, not only in the Romanian educational system, but in the Hungarian as well. The most often presented phenomena are: turbulent and laminar flow, the Bermuda bubbles, vortices and tornados. The flow tank appears in many museums in the form of a tank of fluid with shiny mica crystals, inside which the visitor can move and rotate objects of different shapes with the help of a magnet, like the one shown in Fig.1. from Techniquest in Cardiff. With the help of these objects the visitor can experience the occurrence of turbulent flow and make connections with phenomena experienced in everyday life. In some cases turbulent flow is presented in connection with the atmospheric movements through a semi-spherical dome which can be rotated by the visitor (NEMO Center Amsterdam).

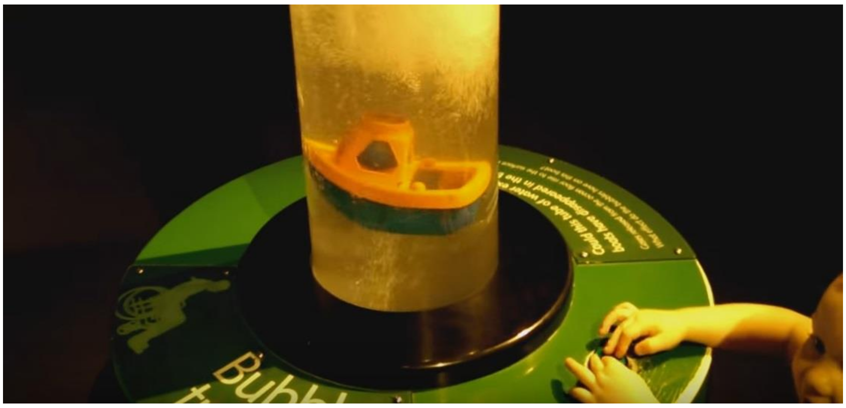

Fig.2. The Bermuda bubbles experiment in At-Bristol museum [4]

The mystery of the Bermuda triangle is a commonly known phenomenon where a number of aircrafts and ships are said to have disappeared under mysterious circumstances. We can argue about the accuracy of the data but our goal is just to find a possible explanation. Laboratory experiments have proven that bubbles can, indeed, sink a scale model ship by decreasing the density of the water [5]. Based on this, in many science museums the experiment is presented with the name: Bermuda bubbles, which consists of a large cylindrical tank filled with water and the visitor can adjust the amount of air released into from the bottom of the reservoir. The visitor can observe (Fig. 2.) how the model ship sinks to the bottom of the tank (At-Bristol). If the water is full of bubbles it is a much lighter fluid then ordinary water, so water full of bubbles cannot hold the ship.

SATURDAY OF EXPERIMENTS AT BABEŞ-BOLYAI UNIVERSITY

In our town, Cluj-Napoca, we do not have a functional science museum, but as one of the major cultural, academic and industrial centres of Romania there is a real need to have a science museum. We have tried to achieve something similar with the one-day event called *Saturday of experiments* which is organized once a year. It is organized by the Faculty of Physics at Babeş-Bolyai University in partnership with the EmpirX Association in the main building and the courtyard of the university every spring in April or May. In comparison with science centres it is a low budget event, as the exhibits are low-cost ones, they cannot be used individually, so each exhibit is presented by a guide. Even so, most of the exhibits are hands-on, thus the presence of an animator represents an advantage facing science centres, as the visitor has a person to ask his questions, to discuss the observed phenomena in detail, reaching a higher level of understanding. More than 60% of the visitors are high school students, as our aim is to keep their interest in physics alive. The animators are selected from among the students of the Physics Department, who are prepared in advance by their tutors, to present in pairs or teams a certain experiment and to reply to the visitors' questions. This is an excellent way to provide teaching practice for them. At each edition of the event, we present around 40-50 exhibits, many new ones as well, but there are some much enjoyed by the public, presented regularly. The visitor has free choice in both the experiments and the order of visit, similar to the science centres. We print out leaflets with the map of the event site and the location of each experiment. The event is with free entrance and it has become one of the main scientific events of the city, attracting more than 1000 visitors not only from Cluj County, but some schools are organizing trips for their students even from a distance of 300 km. The project *Saturday of experiments* was supported by grants from Bethlen Gábor Foundation, Cluj County Council and sponsorship from SKF Romania.

As first impression is always important, at the entrance to the event we project one of the main attractions of the day, like experiments with smoke rings or experiments with liquid nitrogen. Smoke rings are produced by a card box (about 80x80 cm base) with a hole of about 30 cm on the top. The bottom of the box is replaced by a membrane. The box is filled with smoke and rings are produced by hitting the membrane. We have used two boxes at the same time to observe the collision of the smoke rings, too. Liquid nitrogen is used for several experiments, like levitation of a magnet above a superconductor (Meissner effect), rapid freezing and crushing of different plants or placing inflated balloons into liquid nitrogen to observe the thermal contraction and expansion process of the air.

We have carried out a survey among the visitors about the most attractive exhibits in order to have a feedback of the event. Visitors were requested to complete a questionnaire at the end of their visit. They were asked to name the five most attractive exhibits. Among the most cited was the one called tsunami, which consists in a long water tank (dimension of the water tank: 297x12.8x35 cm), which is separated in two with a plexi glass. If at the beginning we make a difference of water level in the two sides, at the removal of the separator a soliton wave is formed which travels along the surface, as shown in Fig.3. A soliton is a wave-packet which maintains its shape while it propagates at a constant velocity. A remarkable quality of these solitary waves is that they collide with each other and yet preserve their shapes and speeds after the collision.

Fig.3. Soliton wave in a water tank, after the removal of the separator, presented at the Saturday of experiments event in 2015

In attracting talented students towards the study of physics, a significant role have the research projects realized by them. Inspired by the soliton waves, Vivien-Emőke Bartha and Botond Biró, students in Apáczai High School ran a project (simulation of known physical systems) using the experimental setup presented above to prove the relationship ($c = \sqrt{gH}$) between the travelling velocity of the soliton wave (c) and the depth of water before the separating glass is released (H), where g stands for the gravitational acceleration. They have found a very good correspondence between the theory and the measured data. They performed a two-dimensional computer simulation as well, which proved the formation of the soliton wave in such conditions [6]. In this project they were helped by a supervisor, a PhD student, Dávid Deritei, a former student of the high school. This project shows that science centres or science events may have long lasting influence on the interest in studying physics.

With the same setup we have presented weather fronts as well. For modelling the cold front we put cold water in the left side of the tank, and warm water into the right hand side (left panel of Fig. 4.). When releasing the separating glass, the water from the two sides mix together like in the right panel of Fig 4. The difference between cold and warm water can be highlighted by colouring the water in the left hand side. These experiments were inspired by the fruitful collaboration between the Physics Department of Babeş-Bolyai University and the Kármán Laboratory from ELTE University in Budapest. About similar experiments in this laboratory you can read in detail in the paper of Miklós Vincze: *Modelling climate change in the laboratory*, published in this same proceedings book of the conference.

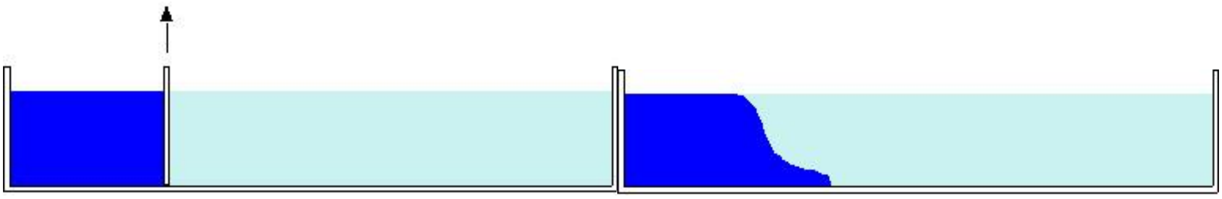

Fig.4. Left panel: Water tank separated in two by a glass with cold water in the left and warm in the right. Right panel: After removing the separator, the cold water moves similarly with the cold front [7]

Some atmospheric phenomena are intriguing, such as the von Kármán vortex street (Fig.5.). It is a repeated pattern of swirling vortices behind objects in a stream of a fluid. They appear on the two sides rotating in opposite direction and are caused by the unsteady separation of flow [8]. In order to save water, we use a cylindrical vessel with water on a rotating disc. We introduce the needle of a syringe that stands as an obstacle in the stream of water created by the rotation. The red ink released from the syringe is for visualizing the vortex street (left panel of Fig. 6). The syringe is moved slowly from the margin to the centre of the vessel, as the vortices can be seen for longer time. The von Kármán vortex street is visible behind the syringe as in the right panel of Fig. 6. Animators used to explain that vortex street is observable in our direct environment around a stone in a stream of water and could be tested with the help of some leaves dropped into the stream. Another example is the fluttering of a flag generated by the flagpole.

Fig.5. Landsat 7 satellite image in September 1999 above Selkirk Island, off South America. Credit: Bob Cahalan/NASA, USGS

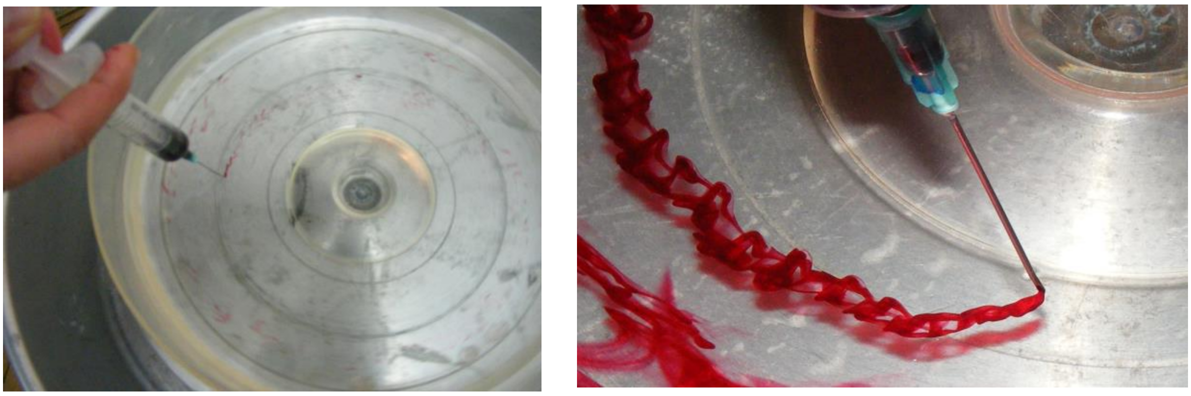

Fig.6. Left panel: rotating disc with cylindrical vessel with water, Right panel: von Kármán vortex street visible behind the syringe

According to our information, the latter two experiments presented above are not displayed in science museums, but because of their expressivity we propose them to be adapted in a hands-on manner. As for the case of the von Kármán vortex street experiment, the visitor could adjust the rotational velocity of the vessel, and to manoeuvre the syringe. With a robust construction, the experiment could be run safely even by a young student, in order to be displayed in a science museum.

CONCLUSIONS

Science museums have a diverse field of experiments, and in each case we have found a huge number of exhibits related to environmental physics: energy production and conversion, fluid dynamics, pollution, waste management. In this paper we presented only those related to fluid dynamics, as we think they are of great interest, because this topic is missing from the school curriculum, and related to it some new phenomena could be presented in science museums as hands-on experiments. We propose two experiments to be presented in this way: the tsunami and the von Kármán vortex street.

The *Saturday of experiments* science event has the following advantages: possibility for the visitor to ask questions about each exhibit, to have a discussion on the observed phenomena with a young scientist, it is a low budget event, the explanations can be adapted according to every age group and to the level of the individual knowledge. The event is a proper way to give the university students practice in both teaching and team building. Disadvantages of these events to the science centres: a lot of volunteers are needed, sometimes it is overcrowded at some exhibits, so some visitors could miss out some experiments, it is organized only once a year. The *Saturday of experiments* is a very good way to promote science in general and physics in particular, thus completing the formal educational tools and even leading to engage high school students in demanding research projects.

There are cases when science centres try to promote science in a more direct way. This is the case of Hiša Eksperimentov from Ljubljana, where each year a three-day long science festival is organized with a lot of volunteers engaged reaching outside the walls of the museum, and engaging the entire town centre into exciting science lectures, presentations and events. This way physics can reach the general public.

Science museums and science events as well, regard learning in a minimally guided approach, described under a variety of names: discovery learning, inquiry based learning or experiential learning. Formal education can use these methods only rarely, thus these events and institutions are excellent for deepening some existing structural competencies and knowledge [9].

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THE MOTIVATING ROLE OF THE FULL DAY EXPERIMENT PROGRAMME CALLED "PHYSICS SHOW" IN TEACHING PHYSICS AND CHEMISTRY

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ABSTRACT

Our school organized an experiment show day for the eighth time in 2015 where students demonstrated and explained experiments in physics and chemistry (in the last two years in biology, too) to their fellow students. In this article I will provide a short review of the history and organization of the full-day experiment programmes held for the public annually. I am going to report the way how the composition of the visitors, their number, and their opinion have developed during each programme. My accompanying students demonstrate a few physics and chemistry experiments chosen from the former show programmes, which can motivate learning physics and chemistry.

INTRODUCTION

In this article I am going to introduce our "Physics show". The show is a round-the-clock presentation of physics experiments. It takes place in our school, in Szent László ÁMK, in the city of Baja, usually in late April. The first show was held by students from the study group of physics in 2001. The renewed shows have continued since 2007 with attached chemistry and later biology experiments. The shows are organized year by year by study group and science workshop students with the help of their teachers.

THE PREPARATION FOR THE "SHOW"

After selecting the experiments, we choose the members of the groups for presentation. They practise in study groups, in science workshops, in the afternoons and sometimes in class if the experiment fits in the curriculum. We advertise the show in schools in town and in nearby villages, in newspaper ads, in the local radio and TV and on the Internet. Fig.1. shows the number of students carrying out experiments

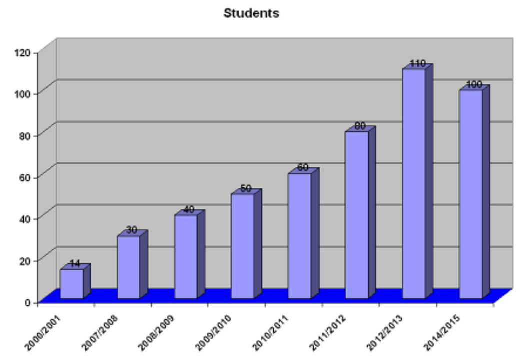

Fig.1. The very first show was held by only the study group students in 2001. Since 2007 volunteers also have been able to take part along with the study group students

VISITORS

The visitors of the show consist of our students, students from the schools in the area, their teachers, and children from the nursery school. We have very positive feedback. They expect to have it every year and encourage us to organize it again. Fig.2. shows the estimated numbers of the visitors of our show.

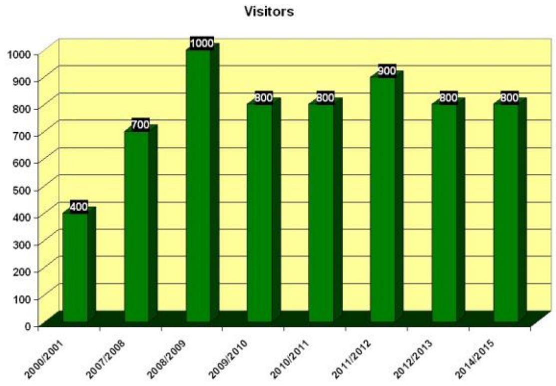

Fig.2. The estimated number of visitors based on preliminary registrations. In 2008 the show was held in two mornings

EXPERIMENTS

We selected experiments from books and from the internet. We have already demonstrated mechanics, electricity and magnetic phenomena, light and heat phenomena, nuclear physics together with chemical and biological phenomena. Fig.3. shows the increasing number of experiments in the shows. In 2001 on the anniversary of the discovery of the nucleus we carried out exactly 100 experiments [1].

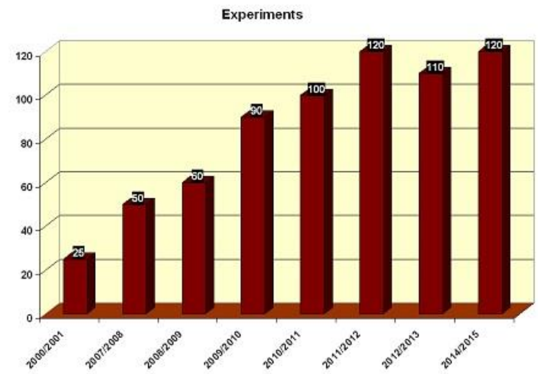

Fig.3. The increasing number of the physics show experiments

THE FIRST EXPERIMENT: ELEPHANT TOOTHPASTE

In this experiment, 30% or 35% hydrogen peroxide is mixed with some liquid soap, and then a catalyst is added (potassium iodide), to make the peroxide break down rapidly. As the peroxide breaks down, it releases a lot of oxygen. It results in a very showy outpouring of tiny soap bubbles. Hydrogen peroxide contains a lot of oxygen. The more concentrated the peroxide is, the more oxygen it releases. The oxygen gushing out is what makes the soap bubbles move. As the peroxide breaks down the soap that was mixed in will also combine with the water and turn into foam. A burning match reveals the presence the oxygen. Often some food colouring is added before the catalyst, which makes the resulting column of foam gushing out look even more like toothpaste. Fig.4. shows a student dropping a match into the foam [2, p.638].

Fig.4. A burning match began to glow dazzlingly because of the oxygen.

THE SECOND EXPERIMENT IS: HYDROGEN GUN

Our hydrogen gun is made from a plastic film box attached to a plastic tube. We filled the film box with air mixed with hydrogen. Hydrogen gas is produced by reacting an active metal, zinc (Zn), with hydrochloric acid (HCl). Having fixed the top, the compound is blown up with a sparkle made by a piezo-lighter. This exothermic reaction yields 286 kJ/mol of water formed. The rapid release of a considerable amount of energy causes the surrounding air to expand suddenly, resulting in a sharp explosion. The best 'pop' is usually achieved with a mixture containing 20 - 40 % by volume of hydrogen. Fig.5. shows the ignition of the mixture by a piezo-lighter [2, p.461.].

Fig.5. By pushing the piezo lighter Dóri starts the combustion of hydrogen-air mixture

THE THIRD EXPERIMENT: A LAMP FROM PENCIL REFILL

A thin pencil refill is placed between alligator clips fixed to a stand. It is connected to the power supply and the current is slowly increased. The thin graphite starts glowing due to the Joule-heat and then the carbon goes into reaction with the oxygen. At this time the pencil refill begins to glow dazzlingly. We cover it with a glass shade. The light goes out when the graphite burns away and cracks. Fig.6. shows the glowing refill when current flows through it [3].

Fig.6. The pencil refill starts glowing dazzlingly because of the Joule heat. The reaction between the carbon and the oxygen increases temperature

THE FOURTH EXPERIMENT: CONDUCTIVITY OF GLASS

Bulbs are set up in serial connection, one of them is broken and the tungsten filament is removed. This light bulb is heated in the closed circuit. When all the glass has melted permanently the other lights starts glowing again. Glass is in fact is a high viscosity liquid. During heating its viscosity decreases and it is able to flow (ductile over 600 ^{o}C). Cations can always be found in glass (Na^{+}, Ca^{2+}, Mg^{2+}) as well as anions (HCO_3^{-}, BO_3^{3-}), which are able to move due to the electric field resulting from an electric current. If it cools down, it will stop. Fig.7. shows heating the glass of the broken bulb and the other one beginning to glow [4].

Fig.7. Tünde heats the glass of the broken bulb to melt it

THE LAST EXPERIMENT: BURNING MONEY

Prepare a water-alcohol mixture by combining rubbing alcohol with of water. Make sure to stir the mixture thoroughly. We used 50 ml of 95% ethyl alcohol with 50 ml of water. Borrow a bank-note from your friend. Dip it into the mixture of water and rubbing alcohol making sure it is completely soaked. Remove it using the tongs - squeeze out any excess liquid. Hold one end of it with tongs and light the bottom of it. The bank-note will *seem to be* burning, but it should not burn (famous last words). When the flame is completely extinguished, it is safe to touch the money... you will find that the money is even cool to the touch. Alcohol burns with an almost invisible blue flame. One trick is to add a little table salt to the water-alcohol mixture to make the flame more visible. The water from the water-alcohol mixture absorbs much of the heat energy that is generated when you light the bank-note. If you reduce the amount of water in the mixture, the paper money is likely to be charred or even catch fire. Fig.8. indicates the girls burning my 5000 HUF [5].

Fig.8. My “bad” students are burning my bank-note, fortunately they are not able to

POSITIVE OUTCOMES

In our school only a few students want to take a final exam in physics. As a consequence, they show little interest towards the theoretical and calculation problems of the subject. These events arouse the students’ interest towards the phenomena and the experiments. During work they appear to be patient and try to be precise.

They are open to recognise interesting experiments found on the Internet. If necessary, they gear the given experiment to our facilities, to our appliances at hand. Their self-confidence grows when the experiment compiled and revised by themselves works. Even if it does not work, their endurance and creativity improve while correcting. Their communication also improves. They are proud to show and explain the experiment to the visitors, especially to their fellow students and teachers and do it in a very concentrated way.

They get better at experimenting and at manual skills. They become more patient, they get to the core more easily, sometimes even their aesthetic skills improve during the preparations and the presentation. They get more involved, certain rules and concepts get meaningful for them. Their skills in dealing with problems improve especially in solving practical difficulties. Their efficiency in learning academic curriculum gets better after they have relived the joy of understanding and carrying out an experiment. They enjoy showing and explaining experiments to visitors, their attitude towards the subject improves. Most of the visitors are students from our school who take in the explanations coming from their fellow students better than the usual teachers’ ones.

On the whole, the episodes of the physics “show” mean twice as much for the presenting and the visitor students as even a double-time longer physics lesson. During the consecutive weeks several of them would like to take part in the presentation, in the work of the study group and ask about the date of the next show.

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FIRE TORNADO

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ABSTRACT

The fire tornado is a special natural phenomenon that can be produced artificially, too. It is significant in the science centres because it is really spectacular and easy to show. Moreover, it models a large range of phenomena in physics, technology and chemistry. Therefore, it can be applied in experiments as well as in study groups. A popular device modelling the fire tornado has been developed by the Mobilis Science Center. The phenomenon can be presented in several ways. We can demonstrate the turbocharger, the gas turbine, the conditions of burning, and the chemistry of flame testing with it. A simplified explanation of the complex hydrodynamic processes taking place in a fire tornado will be also presented.

1. NATURAL PHENOMENON

Fire tornadoes are vertical fire whirls which can be observed in wildland, urban, and oil spill fires and volcanic eruptions. Fire whirls have also been called fire devils, fire tornadoes, and even firenadoes. Their size extends from 1 meter to 3 km in diameter. They can be observed easily due to the burning gases, ash and smoke. Fire whirls are rare but often devastating forms of fire which may occur for example when a stronger convection blows into a forest fire [1]. Due to the convection the fire is often transformed into a several meter high, rotating fire column. Fire whirls accelerate combustion, produce significant suction pressures and lifting forces, and can carry burning debris. Studying them is very important because of their great potential for damage when occurring in nature [2, 3]. The dynamics of the fire tornado is similar to other swirling atmospheric phenomena such as dust devils, waterspouts, and tornadoes [4]. Although fire tornadoes are rare and special natural phenomena, they can also be easily produced artificially. Fire whirls produced in laboratories are widely used for the investigation of the properties of the fire tornadoes [4-6]. Besides their scientific values, these whirls are very spectacular and therefore might be tools for motivating students for learning physics. In the following we are dealing mainly with these latter aspects of the phenomenon.

2. ARTIFICIAL FIRE TORNADO

Artificial fire tornadoes are very spectacular and therefore they are very popular experiments at physics demonstrations of Science Centres. Lots of films about them are available at Youtube [7] too. The phenomenon can be produced in several ways, it can demonstrate a lot of phenomena in physics and chemistry. The fire tornado can be easily demonstrated with the use of simple devices in the laboratory. We need a rotating disk, a small non-flammable bowl and acetone. (Any other easily flammable liquid is proper e.g. 96 % alcohol.)

Put a small bowl into the middle of a rotating disk. Fill it up with acetone (about 50 ml) then set it on fire. A slightly flickering flame of about 15-20 cm height appears. Starting to rotate the disk, nothing special happens. The height of the flame remains about only 15-20 cm. However, if the small fire column on the rotating disk is covered by a cylindrical wire mesh the flame will grow up and twist. Reversing the direction of the rotation the flame twists in opposite direction.

3. THE PHYSICS BEHIND

In spite of the popularity of the artificial fire tornadoes, their physical explanations available on the Internet are often insufficient and incorrect. The reason for this maybe is that the underlying physics is complex, the mathematical description of the phenomenon is not simple and the various approaches presented in the scientific literature are too sophisticated [5, 6]. However, in our opinion, taking into account the experienced properties of the artificially produced fire tornadoes a relatively simple approximate explanation can be given for them.

Our experiments - in accordance with the literature - have clearly shown that the development of a fire tornado needs a flame in which burning gases are ascending in a buoyant plume and the length of the flame can be increased by imposing rotation on this plume[1]. Keeping constant the rotation velocity and the burning rate a steady fire column is created. According to detailed investigations [3, 5] this hot column is rotating as a rigid body, therefore its azimuthal velocity increases proportionally with the radial distance measured from the centre of the whirl.

The phenomenon is analogous with the whirl coming to existence in rotating a water column (Fig.1.). Pour some water into a magnetic mixing bowl, scatter some tiny buoyant plastic granules onto the surface of the water and start to rotate the water. A conical whirl is appearing and is getting deeper and deeper, the tiny pieces are gathering on the side of the cone, some detach from the surface and move downward. Throwing more granules into the water, it can be seen that the pieces go closer to the axis of the whirl [8]. The water whirl corresponds to an upside-down fire tornado, where the tiny plastic pieces with low density correspond to the hot gases [9].

Fig.1. Water whirl Left panel: with plastic granules [photograph taken by the author in the von Karman Lab of ELTE]. Right panel: with coloured oil [10]

The two phenomena differ in the boundary conditions. While in the fire tornado the less dense warm air is flowing inward along a rigid ground, the whirl of the water column is generated in a cylindrical vessel of rigid wall. In the latter case the centrifugal force presses the water outward, which climbs on the wall of the cylinder and produces a conical surface. Therefore the height of the water is increasing with the increase of the radial distance and due to this a pressure gradient force rises, which balances the centrifugal force. The tiny plastic pieces are floating on the conical interface of the water and air. The tiny buoyant particles move in the water and in the air upward and downward, respectively.

The existence of the stable and steady rigid body-like rotation of the fire tornado can be supported by simple arguments. The reasoning can be accomplished either in inertial or in accelerating frames. The comparison of the two ways might be very instructive for secondary school students. In the frame rotating together with the flame

[1] According to our experiences at the beginning of the rotation the length of the flame increases with the increase of the angular velocity. However, reaching the angular velocity of 9 1/s, the fire column has not increased anymore; moreover it decreased a little, to the half of the height of the mesh. It means that a fire tornado has an optimal angular velocity to make the fire column be the highest.

column, the air particles are at rest due to the balance of the centrifugal and pressure gradient forces. With the notation of Fig.2. the forces acting on a cubic particle are:

$$F_{hidr.} - F_{cf} = 0$$

$$F_{hidr.} = p(r + \Delta r)\Delta r^2 - p(r)\Delta r^2 = \Delta p\, \Delta r^2$$

$$F_{cf} = \rho_{fluid} r \omega^2 \Delta r^3$$

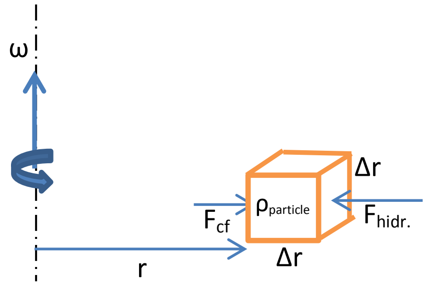

Fig.2. Air particle in the rotating flame column

It means that in the rotating fluid the pressure gradient is:

$$\frac{\Delta p}{\Delta r} = \rho_{fluid} r \omega^2$$

If there are density fluctuations in the flame and the density $\rho_{particle}$ of an air particle differs from that of its environment then a buoyant force acts on it. Due to this force the particle moves inwards (toward the centre of the rotation) if $\rho_{particle} < \rho_{fluid}$, otherwise if $\rho_{particle} > \rho_{fluid}$, it moves outwards. In the flame columns generally temperature fluctuations lead to the density fluctuations. Therefore as a consequence of the temperature fluctuations a secondary flow is generated in the flame column, hotter gas particles flow toward the rotation centre. This secondary flow strengthens the convection of the hot gas and lengthens the flame column. Due to the lengthening of the flame column its rotation is also accelerating. The effect is similar to the acceleration of rotation speed of figure skaters when they pull in their originally outstretched arms and decrease their rotational inertia.

A common misinterpretation of the phenomenon is based on Bernoulli's law. According to this explanation the pressure at the two sides of the mesh is different due to Bernoulli's law, therefore the air is flowing outwards at the mesh. This outflow is compensated by a descending flow along the mesh. This descending flow strengthens the upward motion of the air in the flame which - as a consequence of this - is lengthening and tightening. However, the Bernoulli-effect in this case is not strong enough to influence the flow largely. Because of the 1-mm thickness of the mesh and its relatively low azimuthal velocity air pressure difference is negligibly small between the two sides of the mesh.

A more correct interpretation may be the following: The inner surface of the cylindrical mesh drags the air so the flame starts to twist. The hot gases with small density flow up, as in a chimney, and they pull the flame up. The entrainment of the fresh air can occur only through the holes of the mesh.

4. THE APPLICATION OF THE FIRE TORNADO IN SCIENCE CENTERS

4.1. THE SOURCE OF THE IDEA

We have seen an artificial fire tornado for the first time at a demonstration performed by László Róbert Zsiros [11]. The video taken from it can be seen in his portal, szertar.com. His construction, the idea of which originated from Heureka Science Center in Finland differed from everybody's one.

Zsiros used a boxy shape trash can instead of the cylindrical wire mesh for covering the flame. This setup was also suitable to create a fire tornado.

2. SELF-DEVELOPED VERSION

In Hungary the Mobilis is the only Science Center which presents the fire tornado as an experiment in science-shows and roadshows as well. We have remade the model and it became safer, more spectacular and still portable.

The data of our self-constructed device are the following: the thickness of the wire of the cylindrical mesh is 1 mm, the diameter of the holes of the mesh is also 1 mm, and the centres of the holes are 3 mm far from each other. The diameter of the cylinder is 40 cm, its height is 1.1 m. The flame obviously grows up to the top of the cylinder.

Preparing the cylinder (Fig.3.). A flat highly perforated plate of 1 mm thickness was bended into a cylinder of 42 cm in diameter. The bending of the plate was to be made cautiously because during it high forces are arising in the plate. The edges of the plate were fastened by five screws.

Fixing the cylinder and the fuel bowl Three L shaped steal plates were fastened to the rotating disk leaving narrow gaps between the rim of the disk and the vertical part of the plates. The cylinder should be slipped into these gaps to fix it. The fuel bowl was fastened by three nails.

Safety conditions: The safety implementation is very important because most people are afraid of the experiment. After lighting up the acetone, refilling is dangerous and it is forbidden. The removing of the cylinder is also forbidden until all the fuel has burned out.

This self-made form has won a prize at an experiment innovation competition which was hosted by the OFI (Institute for Educational Research and Development) and the EvoPro Kft together [12]. These Institutes made a promise to develop a standardized production from this equipment which can be easily used for demonstrations at schools.

Fig.3. The self-developed fire tornado and the equipment

4.3. SCIENCE CENTER MODELS ABROAD

The Science Centre Singapore has got a 5-mhigh device. For this equipment - as it can be seen in the video [13] the air flow is ensured with strong blow. This form is very spectacular but it is not interactive. The construction is very complicated and not portable.

The Phaeno Science Center in Wolfsburg, Germany has got a more than 6-m-high equipment. This construction is one of the most popular experiments in Wolfsburg. The air flow is ensured by ventilators which suck up the air from the space above the fire column. [14]

There are fire tornadoes which work with upper ventilators in Poland at the Copernikus Science Center (Warsaw) and in England at The Magna Science Adventure Center (Rotherham) too. Each of these pieces of equipment is several meters in height and is not portable.

5. METHODOLOGICAL AND DIFFERENT MODELING OPPORTUNITIES

5.1. WHY DOES THE MOBILIS SCIENCE CENTER USE IT?

The Mobilis Science Center has a unique subject in experiments, it focuses on car-vehicle-transport. The other Hungarian Science Centers are dealing universally with natural sciences and they append some concrete natural or technical applications. The philosophy of the Mobilis is reverse. We show technologies from the vehicle industry appending natural science analogies and explanations. Mobilis is located in a 1200 m^2 building. We have got 70 interactive exhibition devices and present physics-laden science shows, roadshows. We have also led study groups. In science shows, we present and analyze, for example, the fire tornado.

5.2. UTILIZATION

The experiment models a reverse-acting gas turbine, where we can increase the burning by rotating the cylinder. The real gas turbines work in the other way. The burning engenders the rotation, for example in the case of the jet planes. It is similar to the turbocharger because it flows more air into the combustion chamber. A Science Center which focuses on the vehicle industry has to present these analogies as well.

It holds the opportunity of interactivity. It is suitable for a teacher-led demonstration, but only works in small groups; over seventh or eighth grade students can do it independently. The kids can do the cap filling and setting the fire, but putting up the cylinder is two people’s job. Doing the experiment needs an adult observer or a teacher. Scientific birthday can be held with it. There is a big demand for scientific birthday parties in our center. There the kids do experiments, they play and they can watch a special science show as well. The celebrated kid can rotate the candle on the cake, the fire tornado. It can be applied in chemistry lessons. We can recommend this experiment for chemistry lessons because we can demonstrate flame-dyeing. We can explain the conditions of burning. It can be applied in physics lessons. Hydrodynamics, convection, density, buoyancy, rotating movements can be explained with this experiment.

5.3. VERSIONS

Double flame. We put two fuel sources into the serving disk. One of them should be filled with acetone and the other with methanol with dissolved copper sulfate. After igniting the fuels green and yellow flames are growing up and twisting around each other. Flame-dyeing. Before pouring methanol into the fuel bowl, put some copper sulfate into it since the methanol dissolves the copper sulfate well. The copper ions will dye the flame to green. Without moving device. Instead of the cylindrical mesh a transparent, tight plastic sheet can be also used as enclosure of the tornado. As shown in Fig.4., a tangential gap should be left on the cylindrical sheet. The flowing gases of small density only get fresh air from this gap. The tangentially entrained gas turns the air inside the enclosure and the flame is twisted.

Turn-way sensitive. We make a cylinder from an expanded disc. Due to the shape of the holes, the effect of turning the disk to right and to left is not same. If it turns left, the air flows inwards and the burning is stronger, so the flame is lengthening. Reversing the rotation, the air flows out from the cylinder, the flame decreases to the third of its former length. 12 big ventilators turn the air. It needs 5 liters of acetone and a heat resistant pot. This experiment can he made only outdoors. The flame is twisting up to 4-5 m height (Fig.5.).

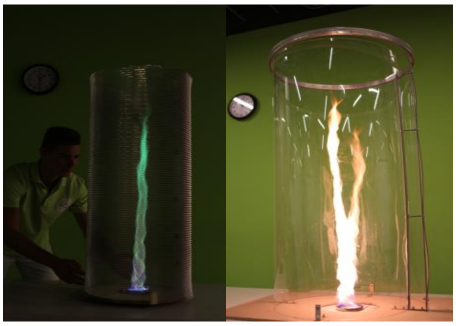

Fig.4. Left: flame-dyeing.
Right: without moving device

Fig.5. Left panel: The turn-way sensitive expanded disc. Right panel: with 12 ventilators

CONCLUSIONS

Natural sciences should be popularized in all possible places. We should go into the streets among those people who do not come to the science center and should explain them that science, physics is all around us and science can be exciting. All Science Centers have the task to teach the people in informal ways. The spectacular and extraordinary experiments raise attention; provide the possibility to give explanations in different depth and from different points of view. The Science Centre can help the teachers: gives ideas how to make simple devices. Moreover, it provides additional knowledge and special experiments that cannot be shown in a school.

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