PROCEEDINGS OF SCIENCE

New educational activity about CMS air pads for education labs at CERN Science Gateway

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CERN is currently preparing Science Gateway, a new facility for scientific education and outreach that will open in summer 2023. Besides inspirational exhibition spaces, science shows and online education activities, Science Gateway will feature educational labs for hands-on scientific experiments for diverse audiences from 5 years old. We provide an overview of the educational offer foreseen at Science Gateway including the hands-on labs, science shows and online education content. In the context of the new educational labs, a "Power of Air" hands-on activity involving 3D-printed hovercraft and toy balloons will be presented. This activity is designed to raise awareness of how engineers at CERN exploit the power of air to move 1000+ tonne detector slices by means of an air pad system.

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1. Introduction

In this contribution, we will first give an overview of CERN Science Gateway and its offer for visitors. We will then explain the design principles of the hands-on labs at CERN Science Gateway and present a new educational activity about air pads.

CERN is currently preparing Science Gateway [1], a new facility for scientific education and outreach that will open in summer 2023. The aspirations of the CERN Science Gateway project are to inspire visitors with the beauty and mysteries of science through positive enjoyable experiences while engaging with the science, discoveries, technologies, and people working at CERN.

Science Gateway will feature 3 new exhibitions *Discover CERN*, *Our Universe,* and *Quantum World*, which are designed to tell authentic stories through immersive, realistic, and inspiring scenography, real CERN objects, hands-on exhibits, multimedia, film, and art in collaboration with Arts at CERN.

Science Gateway will also offer a variety of educational activities: interactive science shows, online learning programmes, and hands-on labs. The science shows explore the stories of scientific discoveries in 30-45 mins and are tailored to an international audience and different age groups. Science shows are designed with a focus on surprising demonstrations and interactive storytelling. The online learning will include short and long videos with quiz questions, DIY experiments and material for educators. The material will be available in English and French, and the focus is on independent learning [2]. Finally, the educational labs will feature 2 modular spaces for 24 participants each, who will discover their inner scientists in 45-90 mins workshops, that are tailored according to age and have a focus on independent hands-on experimentation and teamwork.

Educational labs are a successful out-of-school learning experience and are increasingly being recognised worldwide as an essential part of STEM education [3]. For the last 8 years, CERN S'Cool LAB has welcomed over 40,000 visitors and has been shown to have positive effects for students' interest, self-concept and demonstrated to help close the gender gap [4]. The hands-on labs at Science Gateway will build on the S'Cool LAB legacy and strive to inspire the next generation.

2. Design principles of the hands-on labs

The educational goals of the hands-on labs at Science Gateway are (1) creating memorable impressions related to STEM (science, technology, engineering, and math), (2) fostering positive attitudes towards STEM professionals and STEM careers, (3)

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raising the awareness and understanding of nature of science and scientific methods, and (4) promoting the value of fundamental science. To achieve these goals, the development of educational activities is guided by the following design principles: authenticity, the Hands, Head and Heart approach, and "science is for me".

Authentic learning experiences significantly increase the effectiveness of out-of-school learning and enable learners to become practitioners of science [5]. A previous educational activity designed at CERN has shown that students' interest is noticeably greater if they find the experience intrinsic, personal with a sense of "realness" in relation to the world around them [6]. Context of educational activities matters when it comes to catching students' interest [7] and this is crucial since it plays an important role in students' course and career choices [8]. Moreover, interacting with scientists in out-of-school learning settings has a positive effect on students' learning and aspirations [9]. Thus, activities at CERN Science Gateway are designed to bring learners in contact with topics that are linked to CERN using authentic research equipment under guidance from volunteers from CERN's scientific community. CERN has the unique setting of being able to use authentic equipment and have a large volunteering community of scientists who will be involved in the design, delivery and operation of Science Gateway and interact with visitors. The labs strive to address the image of fundamental science and scientists and give lab participants real role models and have a positive impact on their career aspirations. For example, the educational labs at Science Gateway work in close collaboration with volunteers from the *CERN Women in Technology* group [10]. Science workshops led by female role models with relevant expertise facilitate science identification among early adolescent girls from diverse ethnic backgrounds [11].

The design principles of educational activities at CERN Science Gateway are underpinned by a **Hands, Head and Heart** approach, promoting a holistic meaningful learning experience [12]. It enables participants to actively take part in hands-on manipulations (Hands), cognitively through surprising observations and educational explanations (Head), and affectively through their positive experiences with volunteers (Heart).

Research shows that already at a young age many students (especially girls) hold the view that science is not "for them" [13]. However, even short interventions can boost learners' confidence in themselves [4]. Therefore, empowering people of all backgrounds to engage with the discoveries, the science, and the technologies at CERN might convince them that they can do more than they thought they could. Indeed, the most important aim is that participants of workshops leave with a feeling of ***science is for me***.

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3. New "Power of Air" educational activity about CMS air pads

In this last section, we present one example of a hands-on workshop that will be part of the offer at CERN Science Gateway while highlighting how the above-described design principles have been considered and embedded.

Engineering is often overlooked at school and not typically part of the curriculum [14] so there is an increasing need and place to include engineering hands-on activities in educational settings. Technology at CERN is multidisciplinary, spans a huge range and is constantly pushing the boundaries of what we consider possible. For instance, when the LHC was planned, cutting-edge magnet technology was not at the level required for it to operate and although promising benchmark tests had been performed it was essential for development to catch up with the challenge.

Among the most staggering and most complex machines used at CERN is the CMS detector, one of the four large particle detectors at the LHC, and the largest detector by weight in the world [15]. Various engineering advances were required to be made to assemble this detector, to lower its elements into an underground cavern and to open and close them for maintenance and upgrades. Individual slices weigh upwards of 1000+ tonnes, so the question is: *How do you move a detector slice of 1000+ tons that is 100m underground in a tight space* (Figure 1a)? The answer: CERN is using air pads that can lift up to 350 tonnes each by using pressurised air at 25-35 bar (Figure 1b). This enables the detector to be opened and closed within minutes at a top speed of 0.5m/min.

In parallel with this exists a very successful DIY hovercraft activity [16] that is popular and gets students excited about science. The Jet Propulsion Laboratory at NASA has taken this activity on board [17] and created some materials to show how NASA uses hovercraft in a different context, when testing and evaluating how objects move when there is hardly any friction. Beyond this, air pads are used in a wide array of applications and have the potential to serve as a hook to get students interested in engineering.

The new educational activity at CERN Science Gateway builds on these successful outreach activities and involves 3D printed air pads (= hovercraft) that are powered using toy balloons (Figure 1c). Activities involving 3D printed compounds are popular and have been widely employed in making CERN technologies accessible to anyone with access to a 3D printer [18]. Referring to the design principles in Section 2, this is an authentic activity rooted in existing CERN engineering and technology, where participants have to use their Hands (design, build and test their hovercraft), their Head (solve a series of increasingly difficult engineering challenges) and Heart (be put on a large hovercraft that enables the students to experience this effect themselves). This activity even links up with a new science show on particle detection as well as a short video explaining how you can build your own hovercraft at home [19].

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The engineering concepts tackled in this workshop are design, build, test and involve an element of tinkering that the participants need to solve creatively and collaboratively. For example, the students need to optimise various parameters such as the air flow rate and analyse how much mass each air pad can carry. This is complemented by a series of operational constraints corresponding to the actual challenges CMS engineers face on the ground daily. For instance, the alignment of the CMS detector is of crucial importance and requires careful control over the movement of the air pads, which is replicated in the task (Figure 1d).

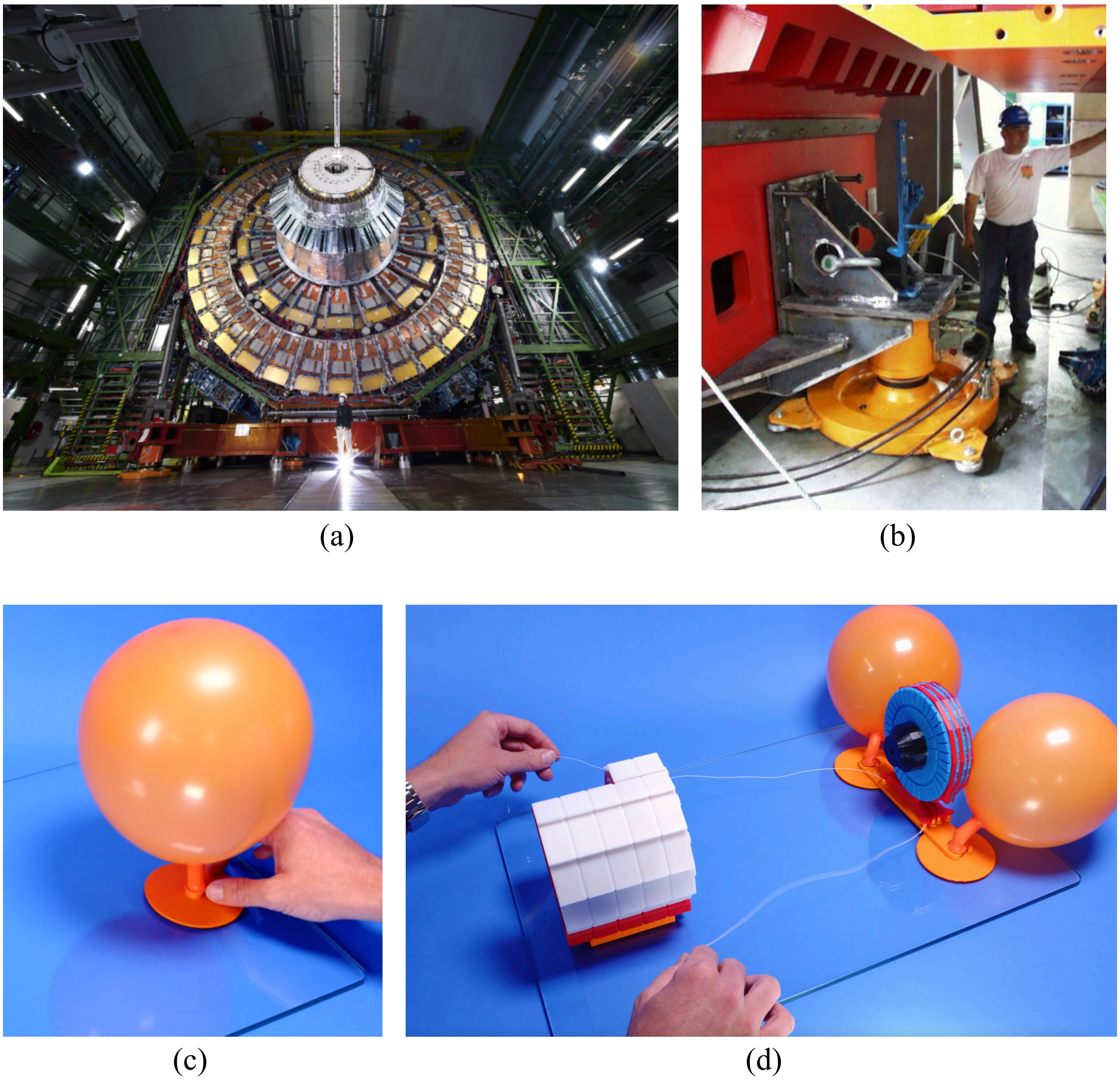

Figure 1: (a) Slice of CMS detector (b) Air pads (in orange) (c) 3D printed air pad for new educational activity at CERN Science Gateway (d) Alignment and closing challenge in new educational activity replicating real engineering challenge at CERN. *Image credit: CERN.*

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