PRACTICAL SCIENCE EDUCATION IN REMOTE SENSING AT THE DLR_SCHOOL_LAB OBERPFAFFENHOFEN

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ABSTRACT

The DLR_School_Lab Oberpfaffenhofen, operated by Germany's national research center for aeronautics and space (DLR) is a typical extracurricular science lab, its main objective being to attract secondary school students to Mathematics, Informatics, Natural Sciences, and Technology (MINT). It has been developed and operated since 2003 and offers thirteen hands-on experiments for secondary school classes, as well as advanced teacher trainings in physics and geography. Based on the expertise gained in the past eight years with approx. 18,000 students and 2,000 teachers, the concept behind the DLR_School_Lab is described, with special focus on its remote sensing experiments radar, laser, and infrared technology, optical environmental remote sensing, satellite navigation, and earth observation with satellite data. Furthermore, the issue of effectiveness of extracurricular science labs is addressed, as well as their suitability for talent support.

1. INTRODUCTION

According to the Association for Electrical, Electronic & Information Technologies (VDE) in Germany [1], [2] there is currently a shortage of more than 100,000 MINT or STEM[1] specialists (status: February 2011 [3]). This deficit will increase dramatically until the year 2020. It is estimated that by then more than 400,000 jobs in these disciplines will be vacant.

To counteract this development the German Aerospace Center DLR currently operates nine extracurricular science labs, addressing secondary school students in particular. The experiments offered are designed especially for students, and enable them to experience the fascinating professional fields of aeronautics and space as well as high tech research within an authentic research environment.

Since it opened in 2003, the DLR_School_Lab Oberpfaffenhofen has been visited by more than 18,000 students, conducting thirteen different experiments that comprise the core research and technology fields of the DLR Institutes in Oberpfaffenhofen.

2. CONCEPT OF THE DLR_SCHOOL_LAB

The concept of the DLR_School_Lab, as described by Schüttler and Hausamann [4], is based on the combination of fascinating high-tech experiments in the fields of the DLR’s current research in aeronautics, space, energy and transportation, supervised by competent scientists or natural science and engineering students, within the authentic research atmosphere of DLR’s research center in Oberpfaffenhofen, using state-of-the-art high-tech equipment. During each visit, students can choose to conduct up to two experiments and are encouraged to discover on their own the backgrounds and cross-connections of physical, technical and geo-scientific issues. In addition, they are allowed to operate high-tech devices themselves – an experience they never get during everyday school life. A visit to the DLR_School_Lab is always rounded off with a tour of the Galileo Control Center (GCC) and the visitor platform of the German Space Operating Center (GSOC), where the students gain insight into the future European satellite navigation system, the handling of, and communication with, research satellites as well as into the operation of the European research laboratory Columbus on the International Space Station (ISS).

Apart from school classes and interns, the DLR_School_Lab also hosts groups of teachers as a part of an initiative to demonstrate new possibilities within scientific education and since 2010 has been involved in the “experience technology” initiative of the Bavarian State Ministry for Education and Cultural Affairs.

In order to make sure that a visit to the DLR_School_Lab has an enduring impact on the students, teachers are led through the same experiments that their students will later learn to perform, and are supported in the design of applied teaching methods. Furthermore, they are offered teaching materials on topics addressed by the DLR_School_Lab that can be easily integrated into the school curriculum. Approx. 2,000 teachers have taken advantage of this program to date.

[1] STEM = Science, Technology, Engineering, Mathematics

3. REMOTE SENSING EXPERIMENTS

Students in the DLR_School_Lab have the choice to conduct thirteen high-tech experiments each with a remote sensing background to a greater or lesser extent. To give an example, the following six experiments are closest to the subject matter: Radar Measuring Technology, Laser Technology, Infrared Measuring Technology, Optical Environmental Remote Sensing, Satellite Navigation and Earth Observation with Satellite Data. Table 1 gives an overview of the experiments, their subject-specific keywords and the instruments available.

All of these experiments have in common that they start with a short introduction to the subject. The physical basis of almost all those experiments is the theory of electromagnetic radiation. The students are taught the general definitions of radiation and its characteristics as well as the specific theoretical background of the current experiment.

Table 1: Summary of remote sensing experiments with subject-specific keywords and available instruments

Experiment	Keywords	Instruments
Radar Measuring Technology	microwaves, echo, Doppler effect, frequency, SAR, Tandem-X	Imaging Radar (SAR), One Dimensional Radar, Radar Speed Sensor
Laser Technology	polarisation, emission, monochromatic light, quantum optics, signal transmission, LIDAR, HALO	Infrared Class IV Laser, Class II Laser for signal transmission, simulating 3D-Laserscanner
Infrared Measuring Technology	thermometry, emissivity, black body, prism, BIRD, Herschel, Boltzmann	2 FLIR-Cameras, Pyrometer, special coated examination objects
Optical Environmental Remote Sensing	sun spectrum, ozone, reflectance, spectroscopy, VNIR, NDVI	portable Spectro-radiometer, Sun Photometer, Pyrometer
Satellite Navigation	relativity, Einstein, geo caching, travel time measurement, atomic timing device, GALILEO, GPS	GPS Handhelds, simulation tools
Earth Observation with Satellite Data	resolution, multispectral sensor, image processing, change detection, Landsat	Leoworks image processing software, Landsat Data

Subsequently the focus lies on actively exploring and discovering, so the students are given the possibility to use several technical devices, depending on the experiment, in order to learn about remote sensing in more depth. These instruments can range from comparatively simple ones like a pyrometer or a class II Laser right up to complex instruments such as a portable field spectroradiometer or an imaging SAR. The students are supervised by a capable tutor whose main task is to support the students exploring on their own rather than to teach them.

In summary, the three major components of the experiments are technology, methodology and application, with a varying main focus depending on the experiment. The Infrared, Laser, and Radar experiments in particular focus on technological aspects, whereas for Optical Environmental Remote Sensing and Satellite Navigation, the emphasis lies more on methods and theoretical background. Earth Observation with Satellite Data is, by contrast, distinctive for its high degree of practical application.

In the following the procedure and the goals of each experiment will be described.

3.1. Radar Measuring Technology

The focus of the radar measurement technology experiment is on conveying the principle behind radar range and velocity measurements. The experiment is for those students for whom practical aspects of wave propagation may not have been dealt with in physics classes.

At the end of the experiment the students will know how to detect and locate objects using microwaves, how to determine their velocity and direction of movement, and even how the total air traffic situation can be monitored.

For this purpose a complete system for measuring distance and velocity is available. The students can gain experience in radar measurement technology at two experiment set-ups equipped with various radar sensors. The possibilities and limitations are revealed, and by making connections to daily life their understanding of technical measurement procedures is deepened.

Furthermore, in collaboration with the Microwave and Radar Institute, an extension of the experiment for demonstrating the principle of Imaging Radar was developed in 2011. By measuring the reflected signals from two tangentially moving corner reflectors, the principles of high resolution radar imaging and signal reconstruction are demonstrated.

3.2. Laser Technology

The Laser Technology Experiment conveys an idea of how this highly effective radiation can be used, and is primarily concerned with measuring distances and velocities using LIDAR. There is also an opportunity for the students to carry out their own measurements using modern measurement equipment.

In order to carry out such measurements in the first place, a basic understanding is needed of how a laser works. In the beginning of the 20th century Albert Einstein established the theoretical basis in his description of the phenomenon of "stimulated emission of radiation," in which electrons are excited, collected, and then allowed to return to their previous state in a regulated way. The first true laser, a ruby laser, was, however, only developed in 1960 by Theodore Maiman. The students learn about the functioning and generation of laser light using such a helium-neon laser as a typical example.

Today, laser applications range from medical treatment to data transmission. But also in everyday life there are uses for lasers, for example in a laser printer, a CD burner or a laser pointer. Some of these application areas are explained and studied at DLR_School_Lab, including in particular the possibility to measure the distance to the moon.

3.3. Infrared Measuring Technology

The experiment begins with Herschel's historical investigation which led him to the discovery of infrared radiation over 200 years ago. Herschel thereby laid the foundation for all the modern radiation measurement instruments which followed.

Many scientists after Herschel investigated the concept of "radiation" and made important contributions toward understanding it as a physical phenomenon. The procedures followed in experimental investigations are introduced in several thermometry experiments.

In the DLR_School_Lab students also have the opportunity to work with highly sensitive measuring instruments. They can find out how these instruments work and get acquainted with a number of applications. With a thermal infrared camera the students can even convert heat radiation into visible images.

3.4. Optical Environmental Remote Sensing

In this experiment students acquaint themselves with various types of equipment and technologies used to measure changes in the environment. It is possible for them to determine the total ozone column, water vapor content, temperature, and humidity of the atmosphere, as well as the reflection characteristics of various surfaces.

The environmental spectroscopy experiment has two parts: the Atmosphere Experiment is specifically concerned with measuring ozone and water vapor concentrations. A five-channel solar photometer is used to make these measurements on the spot. The required input data and especially the results of the measurement are discussed and compared with satellite recordings.

In the Ground Experiment the focus is on measuring with the help of a portable spectroradiometer. After a brief introduction on how it functions and how to operate it, various measurements are taken and interpreted, as in the previous experiment.

The measurements in the environmental spectroscopy experiment are based on the characteristics of the total solar spectrum. Both atmospheric and ground-specific parameters are derived with the help of shortwave, longwave, and visible radiation.

3.5. Satellite Navigation

Navigation systems like the U.S. GPS system have become commonplace. The necessary equipment can easily be purchased and is not prohibitively expensive. Three of these receivers are also available to students for the DLR_School_Lab experiment "Satellite Navigation." Using the example of the GPS system, students learn how precisely a private user can navigate with GPS. They can also learn about what errors have to be taken into account, for example those caused by the atmosphere and the surroundings. This is because as modern and fascinating as this technology is, it is not infallible, by far.

The experiment also deals with tracking down possible sources of error leading to imprecise measurement data. For example, changes in the atmosphere can really disturb the measurements, but something as simple as a tunnel can also be an apparently insurmountable barrier.

However, since the technology is constantly improving, new applications are gradually becoming available which are hardly imaginable. The available systems can provide positioning information accurate to a few meters. But once Galileo is fully functional, positioning should be even more precise.

3.6. Earth Observation with Satellite Data

This experiment shows why earth observation with satellites is important, and teaches how to handle current satellite images in a practical way. The experiment has two parts; a theoretical part in the beginning to support students' learning of terms including satellite orbit or the different types of resolution of a satellite sensor (temporal, spatial, radiometric and spectral).

In the practical part students use ESA's educational software LEOWorks for image processing. Based on Landsat data they get a better understanding of basic operations such as building RGB true color images and contrast stretching by manipulating the histogram of each channel. The use of pseudocolor images explains the importance of the near infrared for identification of vegetation in the satellite image. In a next step, students calculate and analyze the NDVI of the image.

By the use of several short wave and thermal infrared channels, the land surface area is masked so different temperatures in lakes and the ocean become visible.

Once students are confident with the software and understand the use of multichannel satellite data, they are encouraged to do a change detection on their own. With two Landsat scenes of the years 1987 and 2003, students are able to build a map that illustrates the ablation of the glaciers in the Oetztaler Alps (Austria) caused by climate change, using methods such as index calculation, look up table manipulation, masking and overlaying.

4. DISCUSSION

Over the past years a great deal of effort has been invested in natural science and technology, so the question arises as to how effective all these endeavors really are. For the DLR_School_Lab, different studies, e.g. by Pawek [5], have shown a positive long-term impact on the interest of secondary school students in natural sciences in general and in the subjects they encountered during their visit to the science lab in particular. Reasons for this effect could be the relevance to current research of the subject presented, the fascination of an authentic research institution, and the opportunity for hands-on involvement with the subject under examination. The stimulating atmosphere of extracurricular science labs is especially useful for MINT talent support [6], [7], [8].

5. CONCLUSION

The multidisciplinary field of remote sensing offers a wide range of technology and applications and thus it represents an important component of state-of the-art science and research. This pertains especially to the MINT disciplines, where a skilled worker shortage predominates and will increase further. This situation makes it necessary to encourage scientific education in remote sensing not only for students but also for teachers, as they are the primary figures guiding and influencing their students. With this diversified range of experiments on offer, the DLR_School_Lab strives to cover and to convey the broad spectrum of remote sensing and thereby encourage adolescents to choose to study or undertake an apprenticeship in a technical or scientific field.

6. REFERENCES

[1] O. Koppel, "Ingenieurlücke in Deutschland – Ausmaß, Wertschöpfungsverluste und Strategien." VDI Verein Deutscher Ingenieure und Institut der deutschen Wirtschaft, Köln, 2008. http://www.vdi.de/uploads/media/Studie_Ingenieurluecke_VDI-IW_02.pdf

[2] H.-P. Klös, "Ingenieurmangel in Deutschland – Ausmaß und gesamtwirtschaftliche Konsequenzen." VDI Verein Deutscher Ingenieure und Institut der deutschen Wirtschaft, Köln, 2007. http://www.vdi.de/41065.0.html, http://www.vdi.de/fileadmin/vdi_de/redakteur/dps_bilder/SK/2008/2007-04-16-VDI-Studie_Ingenieurmangel_Layout_VDI_und_IW.pdf

[3] VDE, "Deutschland gehen die Techniker aus", Berlin, 2011. http://www.vde.com/de/Regionalorganisation/Bezirksvereine/Dresden/News/Seiten/DeutscheTechniker.aspx

[4] T. Schüttler, D. Hausamann, „Das DLR_School_Lab Oberpfaffenhofen – ein besonderer außerschulischer Lernort“. SchulVerwaltung Bayern 12/2011, pp. 324 – 327 2011.

[5] C. Pawek, "Schülerlabore als interessefördernde außerschulische Lernumgebungen für Schülerinnen und Schüler aus der Mittel- und Oberstufe.", Dissertation, Kiel, 2009. http://eldiss.uni-kiel.de/macau/receive/dissertation_diss_00003669. urn:nbn:de:gbv:8-diss-36693

[6] D. Hausamann, "Extracurricular Science Labs for STEM Talent Support.", Roeper Review, in print, 2012.

[7] D. Hausamann, W. Schmitz, “Enrichment at the Doorstep of University - The Einstein GPS Project”. In Tirri, Kirsi; Ubani, Martin (Eds.), Policies and programs in gifted education, Studia Paedagogica, 34 (pp. 37 – 46). Helsinki: Yliopistopaino, 2007

[8] D. Hausamann K.A.Heller, (Eds.), „MINT-Talentförderung“. Journal für Begabtenförderung, Vol. 1-2011. Innsbruck, Wien, Bozen: StudienVerlag, 2011.