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From Aerospace to Classroom: Physics in Context of Remote Sensing of the Atmosphere

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Abstract

To students, physics might seem to be far from reality. In particular, atomic and molecular physics is an abstract topic to many students. The project outlined in this paper offers an innovative way to teach aspects of atomic and molecular physics in the context of remote sensing of the atmosphere. Like many other context-based initiatives, this approach intends to increase students' interest and motivation. Since the topic doesn't only incorporate physics, but also climate change and the changes to the ozone layer, it is meant to be meaningful to students. The joint project of the German Aerospace Center (DLR) and European Space Agency (ESA), called "GOME", has been the basis for the innovative teaching concept resulting in our workshop. Its essential topic is the Global Ozone Monitoring Experiment (GOME) which was installed on the European Remote Sensing Satellite ERS-2. GOME investigated the ozone layer by remote sensing. The workshop intends to teach students about atmospheric processes and the measurement principles employed by the satellite sensor by using physical concepts. A modular structure permits its successful handling almost independent of students' prior knowledge. The implementation of the workshop contains numerous experiments, e.g. spectrometry and analysis of gas-mixtures. The pilot-phase of the project has taken place at DLR_School_Lab, the student lab of DLR Oberpfaffenhofen. The workshop was evaluated with 40 students in a pre- and post-test configuration. The evaluation results show an increase in students' knowledge and confirm that the context of remote sensing of the atmosphere is meaningful for high-school students.

Keywords: *remote sensing of the atmosphere, satellites, context-based learning, extra-curricular education*;

1. Remote sensing of the atmosphere as a context for physics education

In developing the workshop, two import aspects needed to be considered: teaching methods and the underlying physics. The scientific part concerns methods of investigating the atmosphere as well as changings in the atmosphere, e.g. the ozone hole. Developing the teaching methods is tied to the question of how to convey complex atmospheric processes to students.

1.1 The Global Ozone Monitoring Experiment

Concerning physics, the workshop deals with satellite remote sensing of the atmosphere. An example of this is the Global Ozone Monitoring Experiment (GOME), which was installed on the European Remote Sensing Satellite ERS-2. GOME investigated the earth's atmosphere by measuring the concentration of different trace gases by hyperspectral analysis (for further information see [1], [2], [3]). For this purpose, a differential optical absorption spectrometer has been used. Its measuring principle is based on the fact that any chemical compound in a gas mixture can be clearly identified by its absorption lines and bands. For example, the ozone-layer (Figure 1) absorbs high-energetic ultraviolet radiation from the sun, hence, protecting the earth's surface and any living organisms from a high-level ultraviolet radiation causing e.g. sun burn or skin cancer. Thus any changes to the ozone layer are of high relevance to life on earth and are carefully observed through remote sensing and in situ measurements.

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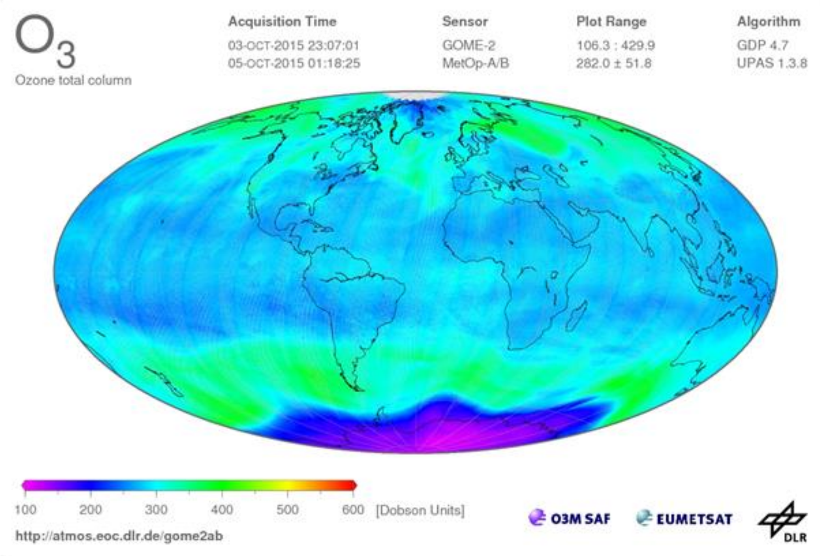

Figure 1: Map showing the Ozone layer on October 3-5 2015 based on GOME-2-data (https://atmos.eoc.dlr.de/app/calendar. 08.01.18)

Other commonly studied trace gases are sulfur dioxide and nitrogen dioxide. The atmospheric concentration of sulfur dioxide is a predictor of volcanic activity and can be used for forecasting volcanic eruptions. Nitrogen dioxide is a major constituent of smog. It is produced in many processes combusting fossil fuels.

1.2 Why to teach physics in a context of remote sensing of the atmosphere?

The developed concept uses a context-based approach to teach physics. Hence, during the whole workshop the main focus is on remote sensing of the atmosphere. Physics is used to explain different phenomena in this context. As usual for context-based learning units, the physical background knowledge required to understand this context is assigned to different sectors of physics. Dealing with remote sensing of the atmosphere, the students acquire knowledge of different aspects of atomic and molecular physics, as well as optics and radiation. Context-based learning environments pursue the aim to find a balance between instruction and construction. Therefore a certain authenticity of the context is needed [4]. Consequently the teacher needs to support the students in complex domains of the context-based workshop.

Furthermore, structuring or enriching science education by meaningful, authentic contexts pursues the objective to not only expand the student’s skills and knowledge but also to enhance their interest and motivation (e.g. [5]). Since today’s youth as well as future generations will be concerned with climate change, investigating atmospheric processes and changes can be considered as such a meaningful context.

2. Conceptual design of the workshop

Student laboratories, such as the DLR_School_Lab, offer context-based extracurricular education. The workshop was developed at DLR_School_Lab Oberpfaffenhofen, one of the student laboratories operated by DLR. The visiting classes are separated into small groups and join workshops about current research-topics of DLR’s institutes like remote sensing, robotics and many more. The developed teaching concept has been part of a joint project of DLR and ESA, intending to increase awareness of satellite technologies. Therefore, technical equipment as well as the possibility to run extracurricular education in small groups was needed. Hence, the DLR_School_Lab fulfilled the requirements needed to achieve the aim of the project.

The workshop leads to a conceptual understanding of remote sensing of the atmosphere. Hence, different sectors and aspects of physics are involved in establishing students’ understanding of satellite remote sensing of the atmosphere by hyperspectral analysis.

Pursuing this objective, the workshop GOME is based on two main principles. On the one hand, a high-tech-spectrometer is used to measure gas spectra in an analogous way to the satellite sensor. On the other hand, the workshop contains some simple hands-on-experiments introducing basic physical concepts used to explain and prepare the high-tech measurements. Those simple experiments concern, for example, the spectra of different lamps or the principles of reflection, absorption and transmission (Figure 2) leading to characteristic absorption bands of different constituents of the atmosphere. Since the hands-on experiments are done by the students on their own, they actively and autonomously deal with the basic knowledge needed to understand the context. Furthermore, they improve their experimentation skills. Each simple experiment concerns one basic aspect of the context. Thereby, the complexity of the context is reduced by dividing the topic into smaller units leading to a better understanding of the whole concept of remote sensing.

a) b) c)

Figure 2: The experiment illustrates reflection and absorption: a) illumination by daylight b) red illumination c) green illumination. The red light is absorbed by green objects and vice versa. In an analogous way, different gases in the atmosphere absorb different, characteristic regions of wavelengths, leading to characteristic absorption bands.

Finally, the complexity of the context is represented by a high-tech experiment. This main experiment of the workshop is to measure absorption spectra of different gases using the hyperspectral optic spectrometer, ASD FieldSpecPro. Figure 3 shows the experimental setup. This experiment impressively reveals that every chemical compound in a gas mixture can be identified by its absorption lines and bands. The experimental setup and the measurements are prepared and executed by the students themselves.

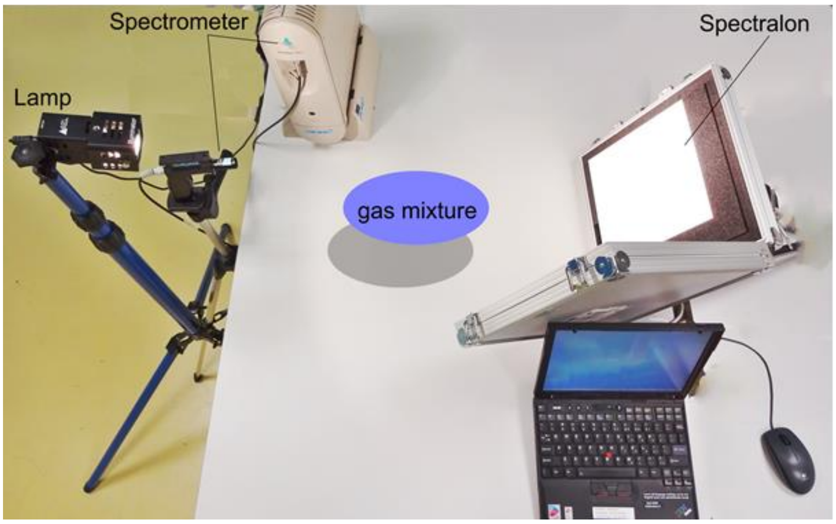

Figure 3: Experimental setup to record absorption spectra of gas mixtures

The field spectrometer has a wavelength range from 350 nm to 2500 nm and can be used to record the spectra of different gas mixtures, e.g. H2O, NO2, CO2 and different sprays. For each analyzed medium, the students identify its characteristic absorption lines and bands in the recorded spectrum. Comparing the spectra of different gas mixtures, they perceive that different compounds absorb radiation in different wavelength-ranges of the electromagnetic spectrum. Depending on students' prior knowledge, basic atomic and molecular physics is used to explain the characteristic position of the absorption bands for a chemical compound. Specifically, ground and excited states of atoms and molecules as well as linked electromagnetic interactions are integrated into explanations.

To give an example of a spectrum recorded and analyzed by students, figure 4 shows the white-reference (100% reflection at full range) and the spectrum of a boiling alcoholic solution showing characteristic absorption bands of water vapor (main absorption at about 1350 nm) and vaporized alcohol (at about 1400 nm). Subsequently, the students identify identic and different components such as water vapor and alcohol in different gas mixtures (hairspray, deodorant-spray, etc.). The position of the absorption bands tells the students if a gas is greenhouse active or not. As an example of greenhouse gases, the spectrum and the atmospheric effect of CO2 are discussed. Furthermore, the students learn about ozone, its UV-absorption bands and the impact of the ozone layer to human life and health.

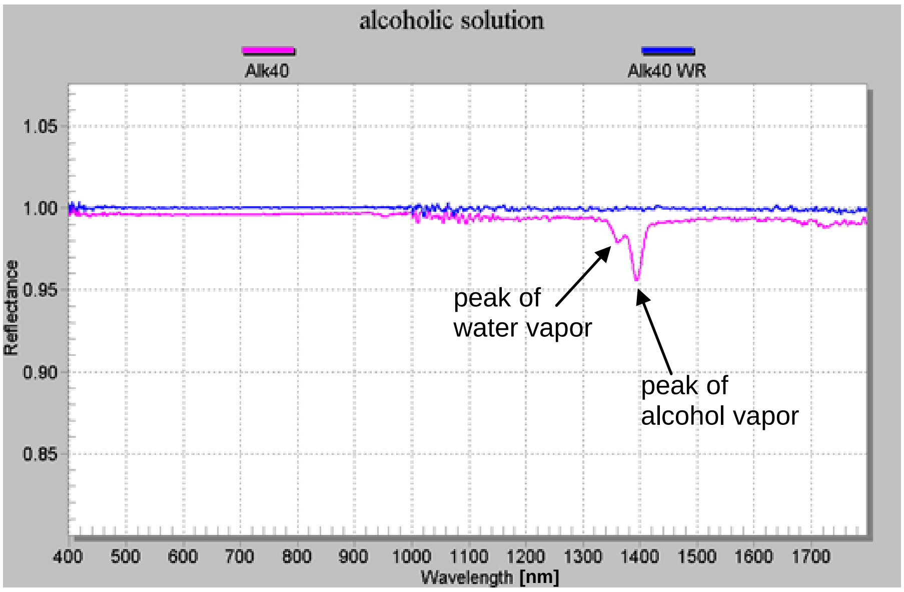

Figure 4: spectrum of the white reference (blue line) and an alcoholic solution (pink line)

The experiment illustrates the basic measuring principle of hyperspectral remote sensing of the atmosphere: the spectrometer on the satellite measures the spectrum reflected by the earth's surface and the atmosphere. Comparing it to the direct sun-spectrum, the concentration of a gas in the atmosphere is determined. Finally, the students learn how measuring results can be used, e.g. for observing and forecasting volcanic activity and to detect air pollution. In this way the workshop is embedded in a larger context to demonstrate the relevance of satellite remote sensing for everyday life.

3. Evaluation of the Concept

3.1. Selected results

The developed workshop has been tested with 40 high-school students at the DLR_School_Lab Oberpfaffenhofen. Different items of this explorative study questioned the students' term knowledge, interest, affection and self-concept. Two of those questions and the corresponding results shall be outlined in this paper. The first one concerns the students' conceptual understanding and knowledge: is it possible for students to learn a physical concept in the context of remote sensing of the atmosphere? The second question concerns the students' attitude: does the topic of the workshop appear meaningful to the students - and thus - can remote sensing of the atmosphere be considered as a meaningful context for high-school students?

After the workshop, 58% of the participating students did interpret a given spectrum of a gas mixture absolutely correctly. Further 38% identified at least single absorption bands in a shown spectrum. Another task required the students to describe why grass looks green using physical terminology. Doing the pretest, only 33% solved this task correctly. After the workshop the rate of correct answers increased to 63%. Concerning the students' assessment of the chosen context, the following results arise: 77.5% expressed that the workshop did reasonably complement school's science education. 70% of participating students rate the topic of investigating and observing the earth's atmosphere as interesting or very interesting.

3.2 Discussion

Overall, the evaluation shows a positive effect of the workshop. Despite the complexity of the context, the students' knowledge increases. The result of 77.5% confirming that the workshop did reasonably complement science education can be classified as quite positive. It points out the significance and the potential of extracurricular education. Since appropriate spectrometers usually aren't available at schools, student laboratories currently are the only institutions having the ability to execute the whole workshop. The students' interest indicates that the chosen context of remote sensing of the atmosphere is meaningful for high-school students. More generally, these results indicate that integrating context-based sequences to science education, e.g. by visiting student laboratories, could increase its success.

There are different ways to integrate remote sensing of the atmosphere into science education. The introduced workshop offers one possibility to enrich science education with high-tech laboratory equipment in a context of satellite technologies. Focusing on physics and environmental science the developed teaching concept intends an increase of students' interest, fascination and motivation. Furthermore, it illustrates the complexity and sensitivity of systems like the earth's atmosphere and demonstrates to the students how many aspects of physics can be hidden in only one single technical application.

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