EARTH OBSERVATION USING THE ISS IN CLASSROOMS: FROM E-LEARNING TO M-LEARNING

Annette Ortwein
University of Bonn, Department of Geography, Bonn, Germany
columbuseye.uni-bonn.de
www.geographie.uni-bonn.de/forschung/arbeitsgruppe-menz
a.ortwein@geographie.uni-bonn.de

Valerie Graw
University of Bonn, Department of Geography, Bonn, Germany
valerie.graw@uni-bonn.de

Sascha Heinemann
University of Bonn, Department of Geography, Bonn, Germany
sascha1@uni-bonn.de

Tobias Henning
University of Bonn, Department of Geography, Bonn, Germany
s6tohenn@uni-bonn.de

Johannes Schultz
University of Bonn, Department of Geography, Bonn, Germany
schultz@geographie.uni-bonn.de

Fabian Selg
University of Bonn, Department of Geography, Bonn, Germany
selg@uni-bonn.de

Kilian Staar
University of Bonn, Department of Geography, Bonn, Germany
kstaar@uni-bonn.de

Andreas Rienow
University of Bonn, Department of Geography, Bonn, Germany
a.rienow@geographie.uni-bonn.de

Abstract

Since April 2014, four video cameras are observing the Earth from the International Space Station (ISS) as part of the High Definition Earth Viewing (HDEV) experiment. In cooperation with NASA, the project 'Columbus Eye – Live-Imagery from the ISS in Schools' has published a learning portal for ISS earth observation (EO) including a large educational portfolio (http://columbuseye.uni-bonn.de/). As there is an undoubtedly wide-spread use of remote sensing techniques and image processing analyses for scientific and societal purposes such as weather forecasting, ecological monitoring, or disaster management, the need to understand the underlying processes and techniques is clearly recognizable. Nevertheless, the application of EO-products in everyday school lessons is sparse and mostly relying on static satellite images. The project Columbus Eye, therefore, aims at the sustainable integration of earth observation in schools. One of its key success factors is the e-learning environment, as it is combining computer-based and traditional learning methodologies. This paper introduces the interactive learning materials for different educational levels such as the Columbus Eye Observatory providing insights in natural and man-made phenomena. The Observatory provides an interactive tool that allows pupils to develop a land-use map on their own. Moving on to more complex learning modules, e.g. the teaching unit “Calculating the Mean from the ISS” shows how curricular maths topics and earth observation can be combined. Finally, it will be explained how the project’s paradigm takes the next step towards smartphone-supported m-learning. Augmented reality (AR) is used to address hurricane movements and pressure characteristics in a mobile app. In doing so, the astronaut’s perspective becomes a tangible experience in regular school lessons.

Keywords*: ISS, Education, Earth Observation, Augmented Reality, HDEV Experiment.*

1. INTRODUCTION: EDUCATION AND THE ISS

How can we awaken the pupils’ interest in natural sciences? There is no simple answer to this question; we need a mixture of stimulating their spirit of research, evoke fascination for science and provide tools that enable to access new fields of knowledge. With regard to these aspects, space and manned spaceflight can create an inspiring atmosphere in being part of the pupil’s dreams and reality at the same time. Our Blue Planet, seen from above, reveals the interconnection between humans and the environment, action and reaction, leading to a deeper understanding of coupled human-environment systems (Voß et al. 2010, Ortwein et al. 2016): "Man must rise above the Earth – to the top of the atmosphere and beyond – for only thus will he fully understand the world in which he lives" (Socrates). Therefore, the mission of the scientific project ‘Columbus Eye – Live-Imagery from ISS in Schools’ is to integrate Earth observation in schools sustainably in order to provide pupils with decision-making competence and responsibility and, simultaneously, with scientific knowledge of remote sensing techniques. To achieve this, fascinating videos of the Earth are used, providing teachers and pupils with free, accessible, easy-to-use software and learning environments based on ISS imagery generated by the HDEV experiment (Rienow et al. 2015a).

2. HDEV EXPERIMENT OF NASA

The ISS Columbus External Facility holds four commercial off-the-shelf cameras as payload since April 2014. Two cameras placed in the aft, one in forward and one in nadir view are monitoring the Earth from the ISS continuously and in sequence. In nadir view, the spatial resolution is approx. 500 m with a spectral resolution of 390 to 750 nm delivered by the CMOS sensor (Runco 2015). Including loss of signal and nighttime, the temporal resolution varies from 180 minutes to 3 days. The first part of Table 1 shows the camera specifications.

The general (and changing) conditions of the ISS determine the resolution and angle; moving in about 400 km height with flexible altitude and yaw. Reaching similar exposure once every 90 days, the ISS holds unique features for Earth observation cameras (Rienow et al. 2014). Connected through integrated avionics for commanding and data handling, the cameras can be operated externally via a TReK workstation, one switched on at a time. Although the power cycle can be influenced, zoom, lens, and light sensitivity remain pre-set. The videos are streamed down to Earth using a tracking and data relay satellite (TDRS) system, neither processed nor filed on the devices themselves (Runco 2015).

Table 1. Specifications of the HDEV ISS cameras and application in school lessons.

	Hitachi©	**Panasonic©**	**Sony©**	**Toshiba©**
Specifications				
	HD, COTS, static zoom and lens, non-adaptive light sensitivity			
View	forward	aft	aft	nadir
Exemplary Topic	typhoon formation	image correction		scattering light
Learning Unit	The Eye of the Cyclone	Beyond Average – Calculating the Mean		Scattering and Colours in the Atmosphere
Type	augmented reality	learning module		observatory

Source: NASA, Columbus Eye

Originally mounted to determine the longevity, use and usefulness of each of the four different CMOS cameras in space, the High Definition Earth View (HDEV) Experiment on board the ISS produces highly valuable videos of the Earth's surface which can be valorized for didactical purposes. Columbus Eye as the exclusive European partner of NASA is in charge of archiving, filing and preparing the HDEV videos for school lessons and to meet the public interest. In order to do so, Columbus Eye is sponsored by the German Aerospace Center (DLR) Space Administration. Currently, the Bonn HDEV archive holds 24 terabytes of data, including all videos since the 23rd of September 2014.

3. COLUMBUS EYE – INTRODUCING LIVE IMAGERY FROM THE ISS TO SCHOOLS

How can the interested public participate in manned spaceflight? Let them take the astronauts' view of the Earth! Therefore, Columbus Eye provides a free-to-use live stream of the cameras online, embedded in a news section and background information on the ISS and Alexander Gerst's mission "Blue Dot – Shaping the future" (DLR 2014). The users can follow the path of the ISS in real time and compare the videos from above with topographic map information. Additionally, highlight videos are presented on the web portal, featuring the rising sun or spectacular weather events. In order to create maximum usability, the highlight videos are pre-processed, i.e. to minimize the effects caused by Rayleigh and Mie scattering, and to improve contrast and color intensity values (Rienow et al. 2015b). A map-based search tool allows users to find highlights according to the region, geographic phenomena, and actions on-board the ISS. Geotagging allows for location of the videos along the ISS path. The archive provides maximum flexibility for the use in school lessons; teachers can use these highlight videos to accentuate curricular topics like weather phenomena or forest fires.

Additionally, other user groups are targeted by advertising selected highlights on Facebook. Despite displaying the videos and mission background lucidly, the portal links both sections through multiple learning environments for educational purposes. This approach strengthens (1) natural science education and, subsequently, (2) future scientific workforce as well as (3) public support of (future) space missions (Rienow et al. 2014, 2015b, Ortwein et al. 2016). Accounting for media literacy as one of the major goals of modern school education, interactive work with videos at hand is the key component of the Columbus Eye Portal. (DGfG 2014)

4. FROM E-LEARNING TO M-LEARNING

Computer-aided e-learning is consistently established in educational theory. It is well-examined, how interactive learning environments support the understanding of underlying processes, and improve self-organisation. The concept of e-learning includes virtual classrooms, learning modules using computational facilities, as well as online (search) tools (Voß et al. 2011, Gryl 2012). A new approach to virtual learning environments is the so-called augmented reality (AR), a technique predominantly based on smartphones, which enriches real environments with virtual content. The shift from "E-Learning to M-Learning", i.e. from online to mobile learning environments, takes advantage of the anytime-anywhere availability of mobile devices (Clarke 2008, Korocu & Alkan 2011).

Smartphone applications, so-called "Apps", register to markers like charts, maps or environmental settings and add virtual content to the real time camera image (Dunleavy et al. 2009, Vuforia 2016). Thus, the addition of knowledge to objects used every day does not require an isolated learning environment, the smartphone facilitates merging reality and additional knowledge. Ordinary paper maps can become interactive playgrounds, where ISS videos or ISS astronauts' imagery like cities at night can be discovered in a new dimension. This experience leads to a critical reflection of the object on the one hand and on (educational) smartphone use on the other hand (Clarke et al. 2008, Korucu & Alkan 2011, Vuforia 2016, Ortwein et al. 2016). Technologically speaking, these Apps are meeting the latest technological requirements but are still executable with older Android versions. The apps were developed using Android Developer© extended by Vuforia© and distributed via the Google Play Store© and therefore reach a potential audience of over 85 % of smartphone users worldwide (Statista 2016).

This key concept of intermediality includes the combination and application of different media in order to improve media literacy. Intermediality is combined with an interdisciplinary approach to address curricular topics (Figure 1).

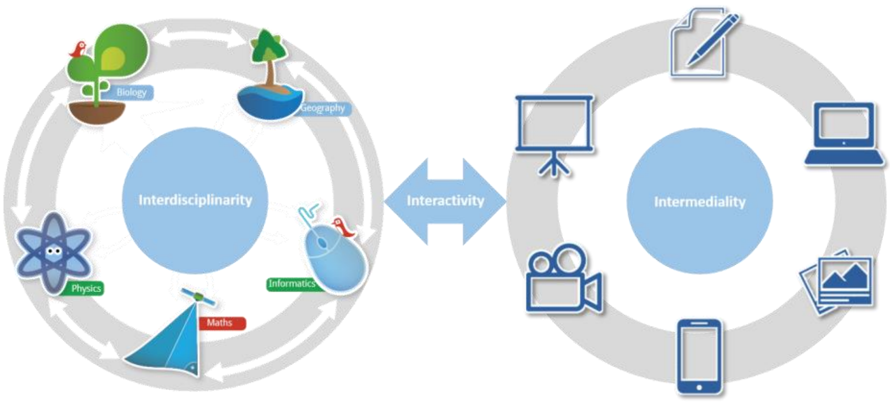

Figure 1. Linking interdisciplinarity and intermediality using interactive learning methods.

Questions addressed are: How are images generated? Why are they generated? And for what purpose? Using ISS data, these questions can be addressed in multiple subjects, combining their individual strengths to explain natural, social or even ethical phenomena. As the Earth can be observed from 3 different angles 24/7, the video material is predestined for the use in research-oriented subjects like Physics, as well as in the Social Sciences and

Geography. There are multiple perspectives to do so – not only regarding camera angles, but also regarding teaching and learning material (see Table 1). On the one hand, interdisciplinarity secures a sustainable integration of remote sensing techniques and applications throughout the school career and challenges the pupils' ability to transfer knowledge. Interactive learning environments, on the other hand, couple the methodological approach of intermediality with the content-based interdisciplinary approach. The following section briefly discusses the aforementioned computer-aided learning materials and online tools and presents the recently adopted 3D and m-learning techniques.

4.1 E-Learning: Using Computer-based Learning Modules

One key element of the content provided by Columbus Eye is comprehensive teaching units, each focusing on one topic regularly addressed in the curricula of German schools. The computer-based learning modules incorporate a ready-to-use software application suitable for pupils. The modules are designed to be carried out by the pupils themselves, ideally without active instruction by the teacher (Rienow et al. 2015a). Following a problem-centered introduction to the topic, the interactive part can be accessed, where remote sensing techniques are applied to the images in order to extract the information needed to solve the accompanying questions. Wrapping up, a small examination of the most important facts and techniques is conducted in a final quiz section. A teacher's guide is available for every learning module in order to minimize preparation and ease integration into the lessons.

One example is the mathematical learning module "Beyond Average – Calculating the Mean" (see Figure 2). Here, pupils apply mathematical operations in order to reduce noise in static ISS imagery. In the course of the module, the pupils familiarize with statistical methods and information science, and simultaneously see the benefit of this theoretical knowledge when they put it into practice (Rienow et al. 2016).

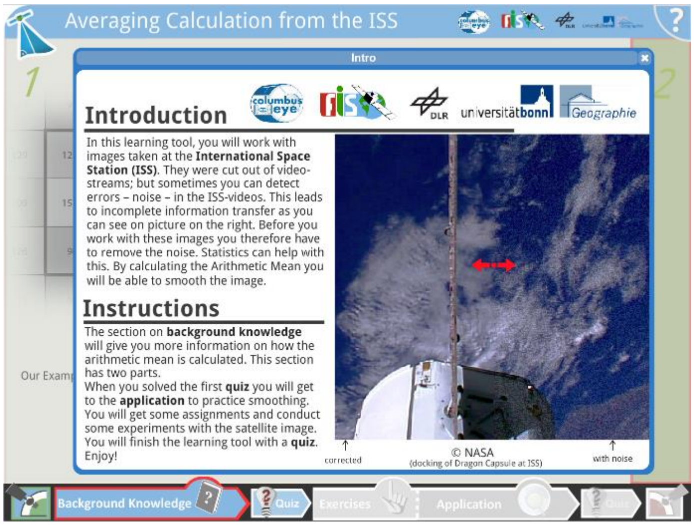

Figure 2. Pupils calculate the mean to correct image noise.

For the pupils, the module starts with a general introduction to the topic dealing with noise in ISS imagery. Once they have followed the instructions and internalized the mathematical concept of moving windows, averages and the calculation of the arithmetic mean, they can solve the quiz to finalize section one of the learning module. In order to guide the learning path, only after solving the quiz correctly the pupils can conduct the filtering on their own. For this, a filtering tool using a moving window can be applied to a selected number of images.

This tool is modelled on actual remote sensing software. Having analyzed their result, the final quiz can be solved and thus part two of the learning module is concluded. During the interactive application, the pupils will learn that methods can have drawbacks and earth observation is also a limited epistemological instrument. This learning material can be linked to the nowadays extensive use of filters when children make selfies and just polish them a bit. Using this tool they will learn that the modification of images often leads to loss of information. Using the arithmetic mean in this tool filter the image results in a smoothed image. But at the same time several details get lost that would still be recognizable in the original image even though some pixels are missing as seen in Figure 3 when comparing filtered and the original image.

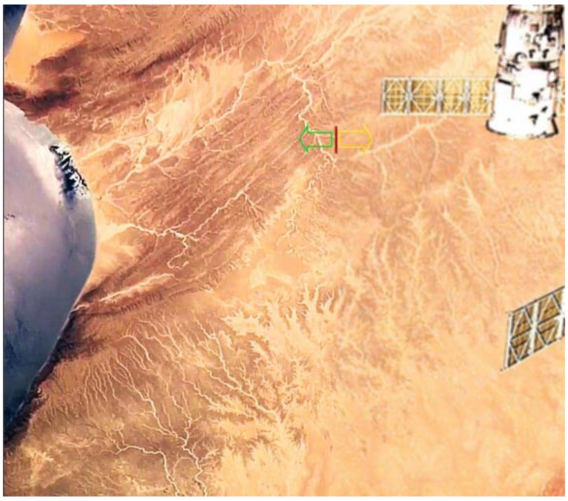

Figure 3. Mathematical thinking and remote sensing methods. The filtered image can be seen on the right, the original image on the left. The two arrows (green and yellow) mark the segments.

4.2 E-Learning: Online Classification Tools

Another way of working with the ISS video material is the examination of exclusive panorama shots derived from the videos. Transforming animated pictures into static pictures allows the application of various "traditional" remote sensing methods (Rienow et al. 2015b). Compiled in the so-called Observatory, the panoramas used here portray three geographical regions so far: West Africa, South America, Canada and the tropical rainforest. The world's largest desert, the Andes as well as ice–covered regions and the Amazonas rainforest and are prepared for analyses. Simple online classification tools enable pupils to filter land cover information from the panorama shots and thus become easily acquainted with remote sensing workflows (Rienow et al. 2015b, Voß et al. 2011). Selecting their own training samples, the pupils carry out instant classification using a minimum-distance-approach (see Figure 4). This supervised classification technique requires training of the classifier by several so-called training samples. With the help of those samples derived from training sites, the color characteristics of a pixel within a certain area as well as their object characteristics, i.e. their distribution, is inquired. The determining variable is the distance of the classified pixel to the midpoint of the color characteristics represented by the training samples. The allocation of one pixel to a certain class is determined by the least Euclidean distance. Thus, the smallest distance to the midpoint of one class defines to which class the pixel belongs in the final classification scheme (Wacker & Langrebe 1972). As seen in Figure 4, the pupils choose the respective training samples by creating a "New Surface". For each panorama, multiple classification schemes can be applied simultaneously; e.g. highlighting the cloud cover in the southern regions in contrast to deserts in the northern, both found in the panorama of West Africa.

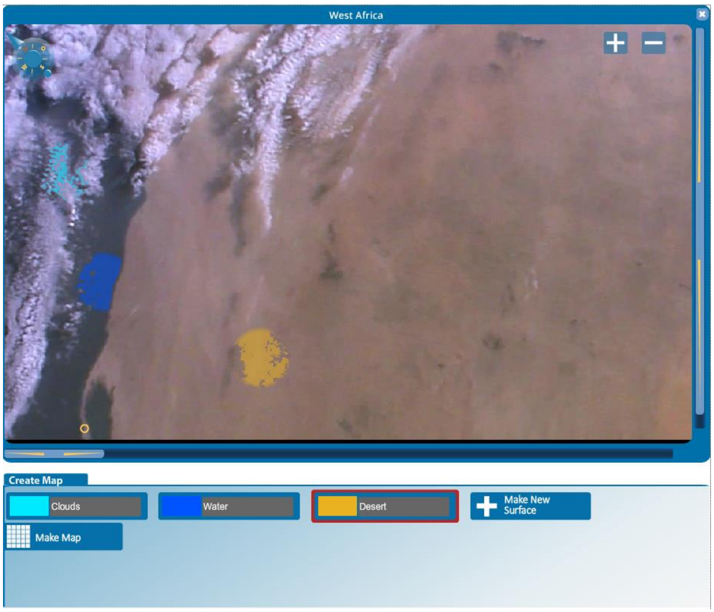

Figure 4. West Africa in focus: Performing a minimum-distance classification.

Additionally, the tool also provides new knowledge about a region. By clicking so-called information points that can be found in certain parts of the panorama, the pupils get further information about certain land cover characteristics or specific phenomena in the region. Figure 5 shows the example of West Africa and the Ship Graveyard of Nouadhibou.

Figure 5. Retrieving more information about the region and its phenomena by clicking on the information points.

Throughout the image, pupils can always spot between 8 to 12 information points classified in “Region” and “Phenomenon”.

Later on, the pupils create their own map based on the classes they chose and the colors they selected (see Figure 6). Moreover, they have the chance to quantify the area that is covered with the respective cover. Based on the first classification, the pupils are asked to create several maps within the same study area.

Comparing their results, they will recognize that (1) the more carefully they conduct the classification and (2) the more detailed classes they choose, the more representative the produced map will be.

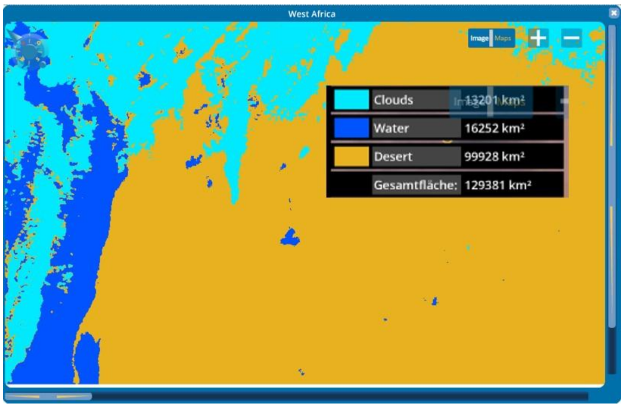

Figure 6. Map based on the chosen land cover classes.

The classification tool can be used either as a stand-alone application or embedded in a larger educational context by either addressing remote sensing techniques or using the thematic maps as an asset for curricular school topics in social sciences. Short texts incorporated in the design of the classification module give interpretation assistance. A sample lesson with corresponding questions and tasks can be downloaded as well.

4.3 Worksheets – the traditional way?

Traditional worksheets benefit from a structured approach to a narrow topic and manual, repetitive intake of knowledge. At the same time, encouraging tasks provide the framework for independent thinking. The Columbus Eye work sheets use these advantages, adding video material for understanding. The worksheets section features e.g. Atmospheric Scattering (Physics), Metropolises and their Natural Environment (Biology/Geography) or also Deserts (Geography). Adding a further twist to simple pen-and-paper applications, a new generation of interactive worksheets are presented, featuring e.g. stereoscopy and 3D. Based on multiple imagery, e.g. satellite images, ISS images, astronauts' images, and 3D videos, pupils discover the physical background of stereoscopy. The topics absorption, complementary colors, and polarizing filters are covered at once. Having acquired this knowledge, the pupils are able to produce their own 3D images and learn to understand the basics of new technologies such as 3D televisions or virtual reality (VR).

The worksheet "Stereoscopy and 3D" explains all relevant techniques and methods to produce and view stereoscopic pictures. It compares anaglyph images which are 3D visualizations consisting of two differently filtered color images, one for each eye to be viewed through "color-coded" (red and cyan) glasses as seen in Figure 7, to methods based on polarization. Our ISS HDEV anaglyph images, e.g. Mojave Desert (Figure 7) illustrated in this worksheet, were calculated using MATLAB© (Michel 2013).

Figure 7. Plunge into Mojave Desert – 3D experience with red cyan glasses. (Processed ISS048-E-68432, 30.08.2016, 20:21:00 GMT).

The worksheet consists of two sections: (i) the material section, where all necessary background information is given, and (ii) examples for 3D images comparing satellite and ISS imagery. The pupils are guided through the sections by several questions; in order to answer them correctly, the information provided by the material of section 1 has to be combined with the understanding of physical principles and the comparison of the imagery at hand.

4.4 M-Learning: Android Apps to get the view from space

In 2016, Columbus Eye launched its first educational Android App. The smartphone-based learning environment thereby introduces m-learning to the classrooms using ISS imagery. The first learning unit is called "The Eye of the Cyclone" and addresses the formation and path of typhoon Maysak using a multi-media approach. Based on a traditional worksheet, the static diagrams bring Philippine typhoon Maysak alive when viewed through the smartphone's camera. A diagram of the typhoon's secret interior mechanics morphs into a video of Maysak as seen from the ISS on 31st of March 2015, holding additional information on its unique characteristics. The second diagram of air masses shows the path of typhoon Maysak over time (see Figure 8).

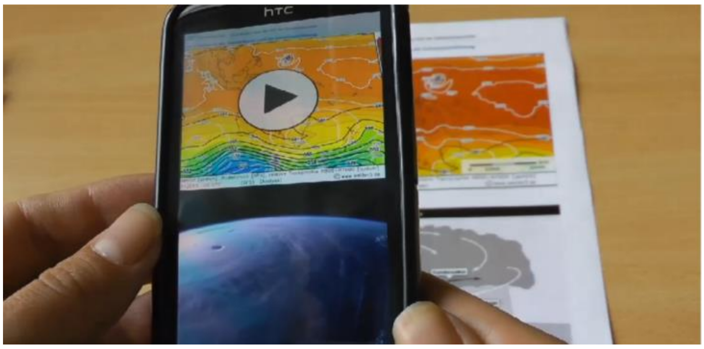

Figure 8. Demonstration of the Android App "The Eye of the Cyclone".

But before those interactive parts can be explored by the pupils, the background information is presented in the worksheet by means of written scientific learning materials. These include information on the occurrence, formation and inner structure of typhoons, thus, fostering the comprehension competence. The pupils' comprehension of the topic is assessed by several tasks on the work sheet's final page. Those tasks can only be solved after the pupils have combined the information provided on the worksheet and extracted the interactive information with the smartphone. Whereas the materials hold general information, specific information on Maysak can only be extracted by working with the App itself, such as measuring the diameter of the typhoon. When it comes to testing the knowledge acquired, the traditional dimension of pen and paper comes into play. The haptic experience of writing their solutions on a sheet of paper makes the knowledge paper-bound and “real”, literally lifting pens and papers into space.

5. ACTIVITIES IN SCHOOLS

In addition to the developing of learning material Columbus Eye is also active in practical school lessons and interacting with schools and teachers. When the project Columbus Eye started in 2013, it was also accompanying the German astronaut Alexander Gerst on his mission “Blue Dot – Shaping the Future”, who was the third German on-board the ISS in 2014 and will be the first German ISS commander in 2018.

Project days in schools and teaching-the-teacher events in cooperation with educational institutions all over Germany brought the fascinating views from the ISS directly into everyday school lessons. So far, more than 1,200 pupils and 200 teachers were approached directly. Lessons based on developed educational material have also been aired on TV and radio reaching a wide audience (RTL Nord 2016). The download numbers of the learning materials reach a number of approximately 150 each month. In order to reach as great an audience as possible, multiple workshops are held in Germany. As a result, an elective subject named “Geography-Physics” using remote sensing methods based on teaching materials of the projects Columbus Eye and FIS was established at the secondary school Alleestraße in Siegburg, Germany.

5.1 Workshops for Teachers

During an ongoing road show the fascinating views from the ISS can be spread to the young audience. Throughout “Teaching the teacher events” it was recognized that there is still hesitation to integrate new learning materials in schools lessons and to move away from pen and paper to computer- or mobile phone-based learning materials. Moreover, lesson preparation is time-consuming and it is still easier to use already known and tested material.

Teacher in general act as a multiplier. After using and approving learning tools they can integrate them into the everyday school lessons. During the Teacher this Teacher events they can test the learning materials in a supervised way, experiencing the easy-to-use software and self-explanatory tools and furthermore come to appreciate the accompanying teaching materials for embedding the learning units into their school routine. The presentation of Columbus Eye at teachers’ workshops and educational fairs is adding to the project´s visibility in the community as seen in the sheer traffic values of our portal. The positive feedback given during and after these events encourages to continue the development of technologically up-to-date learning materials. Easy and fast integration in school lessons benefitting from the integration of new media, i.e. computer or mobile phone applications, are most emphasized.

5.2 Creating a New Subject: “Geography-Physics”

In collaboration with Columbus Eye, teachers of a secondary school in Siegburg, have developed a new subject called “Geography-Physics” for grade 8 and 9 in secondary education. Teachers integrated learning materials of Columbus Eye into the internal school curriculum in order to strengthen the pupils’ understanding of the interdisciplinary character of remote sensing. Earth observation is the link between the two subjects Geography and

Physics whereas Geography stands for the application-oriented sciences, Physics is needed for the understanding of underlying technical and physical principles. Geography-Physics is currently taught for the first time as part of the elective subjects covering the field of natural science. The framework of the subject connects pupils with university researchers so that they can pose questions to "experts of earth observation". Collaborative field trips and GPS rallies build the bases for the pupils' scientific propaedeutic in early ages.

6. NEW TECHNIQUES – NEW CHALLENGES

Nowadays, new technologies and tools are developing very fast. Still, young generations keep track and are motivated by new things especially when also targeting their playful spirits. Nevertheless, competent and responsible use of new media and technology plays a key role for pupils. As discussed, e- and m-learning does not only support modern teaching but also imparts media literacy while arousing the pupils' attention. These advantages can often only integrated in school practice via externally generated learning materials as teachers do not have sufficient time and computational resources to develop complex topics and related methods themselves. This is the ongoing task for Columbus Eye in order to establish remote sensing and earth observation in school lessons.

The portal Columbus Eye portal was established in 2013 and considerably improved and re-invented in October 2016 will represent a platform for teachers and pupils but also other interested users. Here, information about the ISS can be gained, while observing our blue planet from different angles. Collaboration with more educational institutions is furthermore in focus and will be approached in the near future.

This paper shows how remote sensing and earth observation can build the bases for interdisciplinary school lessons bridging the gap between physical and mathematical background information and geographical application analysis. Future actions will focus on teaching units developed in order to communicate the knowledge and the handling of natural and man-made phenomena in times of global change. By raising the level of immersion from augmented to virtual reality the pupil's awareness of technical progress should be raised simultaneously. While the HDEV-mission will end in 2017, NASA is currently working on a successor to pursue the goal of entertaining and educating the public with the astronaut's view from above.

ACKNOWLEDGEMENTS

Columbus Eye is funded by the German Aerospace Center (DLR) with grants of the Federal Ministry for Economic Affairs and Energy (grant number 50JR1307).

We would also like to take this opportunity to thank our former project leader, Prof. Dr. Gunter Menz, who passed away after a severe accident in August 2016. He enjoyed motivating young children and scientists for the view from space.

REFERENCES

Clarke, K., Dede, J.C. and Dieterle, E. 2008. Emerging Technologies for Collaborative, Mediated, Immersive Learning. In *International Handbook of Information Technology in Primary and Secondary Education*, ed. J. Voogt, G. Knezek. Springer.

Deutsche Gesellschaft für Geographie (Eds.). 2014. *Bildungsstandards im Fach Geographie für den Mittleren Schulabschluss mit Aufgabenbeispielen*. Bonn.

Deutsches Zentrum für Luft-und Raumfahrt (Eds.). 2014. Blue Dot – Alexander Gerst shapes our future on the International Space Station. Bonn.

Dunleavy, M., Dede, C. and Mitchell, R. 2009. Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. *Journal of Science Education and Technology*: 18: 7-22.

Gryl, I. 2012. *Reflexivity and Geomedia – Going Beyond Domain-specific Competence Development. In GI-Forum Geovisualization, Society and Learning*. Salzburg.

Korucu, A.T. and Alkan, A. 2011. Differences between m-learning (mobile learning) and e-learning, basic terminology and usage of m-learning in education. *Procedia Social and Behavioral Sciences*: 15: 1925-1930.

Michel, B. 2013. *Digital Stereoscopy: Scene to Screen 3D Production Workflows*. Stereoscopy News.

Rienow, A., Hodam, H., Menz, G., Weppler, J. and Runco, S. 2014. Columbus Eye – High Definition Earth Viewing from the ISS in Secondary Schools. 65th International Astronautical Congress. Toronto.

Rienow, A., Hodam, H., Selg, F. and Menz, G. 2015a. Columbus Eye. Interactive Earth Observation from the ISS in Class Rooms. *GI-Forum, Journal for Geographic Information Science*, 349-353. Berlin: Wichmann.

Rienow, A., Graw, V., Menz, G., Schultz, J., Selg, F. and Weppler, J. 2015b. Experiencing Space by Exploring the Earth – Easy-to-use Image Processing Tools in School Lessons. *66th International Astronautical Congress.* Jerusalem.

Rienow, A., Graw, V. Heinemann, S., Schultz, J., Selg, F. and Menz, G. 2016. Mathematikunterricht aus dem All – Interdisziplinäre Lernwerkzeuge für den Einsatz von Erdbeobachtung im Schulunterricht. *Dreiländertagung der DGPF, der OVG und der SGPF*, 428-435. Bern.

Runco, S. 2015. *International Space Station – High Definition Earth Viewing* (HDEV). http://www.nasa.gov/mission_pages/station/research/experiments/917.html (accessed 07.09.2016).

RTL Nord 2016. Projekttag an der Oberschule In der Sandwehen - RTL Nord. RTL, TV Sendung vom 20.04.2016. http://rtlnord.de/nachrichten/projekttag-columbus-eye-an-der-oberschule-an-der-sandwehen.html (accessed 07.09.2016).

Statista (eds.) 2016. Prognose zu den Marktanteilen der Betriebssysteme am Absatz vom Smartphones weltweit in den Jahren 2016 und 2020.

http://de.statista.com/statistik/daten/studie/182363/umfrage/prognostizierte-marktanteile-bei-smart phone-betriebssystemen/ (accessed 07.09.2016).

Ortwein, A., Graw, V., Heinemann, S., Selg, F. and Rienow, A. 2016. Beyond the Pixel – Interdisciplinary Earth Observation Education in Schools. 67th International Astronautical Congress. Guadalajara.

Voß, K., Hodam, H. and Goetzke, R. 2010. Feuerspuren im Satellitenbild – Mit Fernerkundung die Bewertungskompetenz stärken. In *Lernen mit Geoinformationen*, eds. T. Jekel, A. Koller, K. Donert, R. Vogler: IV: 171-181.

Voß, K., Goetzke, R., Hodam, H. and Rienow, A. 2011. Remote Sensing, New Media and Scientific Literacy - A New Integrated Learning Portal for Schools Using Satellite Images. In *Learning with GI 2011 - Implementing Digital Earth in Education*, 172–180. Berlin.

Vuforia 2016. Developer's Guide. https://library.vuforia.com/ (accessed 07.09.2016).

Wacker, A.G. and Landgrebe, D.A. 1972. Minimum Distance Classification in Remote Sensing. *LARS Technical Reports 25*. Indiana.