LEARNING MODULES – A WAY TO INTEGRATE REMOTE SENSING METHODS IN SCHOOL EDUCATION

K. Voss [a], R. Goetzke [a], H. Hodam [a]

[a] Remote Sensing Research Group, Department of Geography, University of Bonn - (k.voss, r.goetzke, h.hodam)@geographie.uni-bonn.de

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ABSTRACT:

Despite political demands for a more intensive development of the subject of remote sensing in school lessons, it still plays an inferior role. It appears that many of the software solutions created explicitly for school lessons have not been introduced to school curricula due to their complexity. As a result, the subject is either not integrated in lessons at all or, at best, does not go beyond the level of analogue image interpretation. Yet because remote sensing represents more than just the visual interpretation of satellite images, it also requires the facilitation of basic maths and physics, as well as methodological and media competence. For the sustainable integration of remote sensing as a school subject, this paper therefore presents digital, interactive and interdisciplinary learning modules which can promote the methodological and media competence of pupils, as well as their independent study skills.

1. INTRODUCATION

As part of the aerospace industry, remote sensing represents a key technology in our modern-day information society and is attached with an increasing degree of economic relevance. Among other things, this is reflected in the continual development of new sensors such as TerraSAR-X and RapidEye, and in the growing need for qualified employees.

In addition, satellite images are affecting our everyday lives more and more – and not just through the weather forecasts in the news, either. In news coverage, remote sensing data is also being increasingly implemented in reports on natural disasters or the global climate change. Moreover, a poll has revealed that 80 percent of German pupils use Google Earth on a regular basis. The programme was downloaded over 100 million times in 2006 alone.

Against the background of the growing relevance of issues revolving around global environmental changes—also in the media—, as well as a high demand for employees in the area of engineering and natural sciences, remote sensing can help get pupils interested in these topics with its fascinating satellite images and modern technology.

Apart from giving school curricula a stronger scientific focus (Stork, Sakamoto, Cowan, 1999, Bednarz & Whisenant, 2000, Sneider, 2000, Merry & Stockman, 2001), the adoption of remote sensing in school lessons holds a range of additional advantages

- Remote sensing data offers the possibility of handling a range of curriculum-specific topics in the school subjects of geography, biology, maths, physics and computer science – in a **problem-oriented and integrative** manner.
- The high degree of topicality and multitude of spatial, temporal and spectral resolutions of remote sensing data make it possible to work on **up-to-date** and **dynamic problems**.
- The graphic quality of the data allows for a **new view** of certain problems and offers a **high degree of vividness**.
- Through the combination of images and technology, remote sensing data has a **motivating and fascinating effect** on pupils.
- By working independently with remote sensing data, students' **methodological skills** can be facilitated in the area of data processing, general computer work and digital image processing.
- The use of remote sensing in school lessons allows new forms of teaching, learning and instruction methods to be put into effect.

Due to this diverse range of advantages, there has already been an ongoing discussion for years now about using satellite images more heavily as an additional medium in school lessons (Ante & Busche, 1979, Brucker, 1981, Frömel, 1981, Hassenpflug, 1999, Theissen, 1986). Accordingly, a stronger use of modern media and working materials are explicitly called for in the latest formal curricula and education standards of the Deutsche Gesellschaft für Geographie (DGfG – German society for geography) – at least for the subject of geography. In some German states, the use of GIS and remote sensing is even explicitly compulsory. Despite this development, the topic of satellite remote sensing still plays a subordinate role in European schools (Neumann-Meyer, 2005, Siegmund & Menz, 2005, Reuschenbach, 2006, Reuschenbach, 2007a).

In addition, it is noticeable that satellite images are primarily used in geography lessons, if they are even put to use at all in school lessons. Due to strict specifications in the curriculum, however, teachers often only have a relatively small window to integrate new topics in their geography lessons. In such, satellite images are often only integrated to demonstrate topics relevant to the curriculum. Without an intensive examination of the image data though, the pupils' methodological skills cannot be cultivated. This is why Reuschenbach (2007a) developed a volume of transparencies and working materials for the subject of geography, years 5 to 13, which aims at facilitating the intensive study of satellite images. With this approach, remote sensing is integrated in the lessons in the form of an analogue medium: colour transparencies. The satellite images of the 32 colour transparencies in total are embedded in a problem-oriented manner in various geographical fields and serve as working materials for answering different geographical questions. The advantage of this approach is that it promotes both the visual competence and spatial orientation of students (Reuschenbach, 2007b).

However, remote sensing encompasses more than just the purely visual interpretation of aerial and satellite images, meaning that this method only covers one area of remote sensing's topic spectrum. Essentially, the approach neglects the physical and mathematical fundaments of remote sensing, as well as contact with "new media".

To avoid this reduction, there are and have been efforts to integrate the topic of remote sensing in school lessons with software explicitly developed for pupils (e.g. LeoWorks or MultiSpec). Despite the fact that these programmes were created especially for use in school lessons, it seems they have not been widely introduced to school curricula due to their complexity. A survey of involved teachers conducted within the scope of the University of Bonn's project "Fernerkundung in Schulen (FIS)" (remote sensing in schools)[*] showed that getting accustomed with these programmes is too time-consuming and requires too much effort. In addition, many of the interviewed teachers shy away from the complex installation procedure for these programmes.

In order to promote a more intensive use of remote sensing in school lessons, a new didactical concept was developed within the scope of the FIS project at the Geographical Institute of the University of Bonn, which is sponsored by the German Federal Ministry of Economics and Technology. This concept goes beyond the level of analogue image interpretation, examining remote sensing in its entire breadth including physics and maths basics. For the actual digital implementation, however, elaborate and complex software solutions have been avoided. Instead, the use of digital, interactive and interdisciplinary learning modules is seen as a sustainable and practical solution for use in schools, as they can promote the methodological and media competence of pupils, and cultivate their independent study skills.

2. TEACHING PLAN

Alean & Biber (2005) summarise the advantages of remote sensing for school lessons as follows: *"Satellite images clarify, highlight issues and attract attention. Mostly, however, they allow students (…) to recognise correlations themselves."* (Alean & Biber, 2005:35; freely translated from the German).

For this reason, the subject of remote sensing is integrated in school lessons with bifunctional, interactive and digital learning modules in order to sustainably convey the subject matter through animation and interaction. Intensively working on problems and solving assignments pursue the objective of giving pupils a better understanding of the computer medium not only as a purely informational and entertaining device, but also as a tool. Through practical work on computers and subsequent experimentation, investigation and analysis, the latest range of topics in the area of information processing are examined so that pupils' general exposure to electronic data processing is improved. Accordingly, students' methodological and media competence is promoted through practical use and application. In the sense of constructivist didactics, the interactive learning modules also facilitate their independent work skills. The teaching units therefore aim at more than just providing background information, images, animations and assignments; they also zero in on the independent examination and solution of problems.

In addition, the following objectives are pursued:

Facilitation of networked learning – Due to the complexity of the remote sensing subject, the topic itself is split up between numerous school subjects (cf. Voss, Hodam & Goetzke, 2008). The theoretical and physical basics are conveyed in maths, computer science and physics classes. As a result of this, the theoretical fundament for a user-oriented integration of remote sensing in geography and biology lessons is established in these three basic subjects. Through the targeted collaboration between different school subjects, pupils' ability to think in a networked manner, determine interdisciplinary correlations and look at things holistically are all facilitated (White, 2001).

Sustainable integration of remote sensing as a subject – To permanently integrate remote sensing topics in school lessons, the subject has to be linked to the teaching units already anchored in the curriculum. This not only increases students' motivation to work on classic coursework, but also boosts the learning spectrum because contents and methodological aspects of remote sensing are conveyed in addition to the subject matter foreseen by the curriculum (cf. Voß, Hodam & Goetzke, 2008).

Fostering of competence – Through a constructivist approach and intensive occupation and analysis with satellite images, different skills are fostered in pupils. These primarily include visual competence, methodological and media skills, and the ability to work independently.

Compared to teacher-oriented methods of instruction, the entire pedagogic concept is distinguished by students' active participation in class. By actively incorporating pupils in the lessons, the teacher's role transforms into that of a learning coach (see above; cf. Voss et al. 2008).

3. EXAMPLES OF INSTRUCTION

Based on four examples, it will be shown here how digital learning modules can be utilised in the subjects of physics, computer science, maths and geography. Correspondent to sustainable integration, the learning modules are linked with existing topics in the curriculum. All digital learning modules are characterised by a high degree of interactivity so that pupils are given the necessary room for an intensive examination of the subject matter by actively and independently working with the learning module. Their understanding should primarily be supported and facilitated by the diverse range of interactive options.

For example, students can independently combine different spectral channels with one another, and directly examine and gain a grasp of the differences in the image. To promote intensive work with contents, every modular unit has a quiz at the end which tests students' newly acquired knowledge. Only when pupils have correctly answered the questions can they move on to the next unit. This quiz is viewed as an aid for students because it does not directly confront them with the entire subject matter, which would possibly "swamp" them. Once a modular unit has been successfully completed, pupils can switch back and forth between the units to repeat or review contents before answering any of the questions that follow.

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3.1 Physics – On the Trail of the Invisible

In the German state of North Rhine Westphalia, the physics curriculum for secondary schools foresees the subject area of physical optics. This is split up into three subgroups: light on the surface, optical lenses and the sight procedure and optical instruments.

Satellite images could form a sort of bridge between these three topic areas, as the physical basics of satellite remote sensing range from the actual exposure itself to the "finished" satellite image. The **goal** of the teaching unit called "On the trail of the invisible" is to understand connections between the electromagnetic spectrum, reflectance, absorption, exposure and development of satellite images. As a result, the topics from all three sub-groups are set in correlation with one another.

All together, this teaching unit is comprised of numerous components. The first part of the learning module introduces pupils to the subject of reflectance: together with a virtual professor, they conduct a playful experiment on the reflectance of various objects, the goal of which is to determine the characteristics of the objects in terms of their reflectance attributes. In order for students to tie into their own experiences and everyday background knowledge, the first modular unit concentrates on the area of visible light in the electromagnetic spectrum. In the second modular unit (fig.1), students can then transfer their newly acquired knowledge from the virtual laboratory to a satellite. Accordingly, the goal of the second part of the learning module is to understand how a satellite actually works. The focus of attention is thus on the following question: how does a satellite convert the reflectance signals it receives into colour image information? In the last modular unit, an overall look at the electromagnetic spectrum is given, followed by a corresponding examination of whether a satellite can also use other wavelengths apart from the area of visible light.

Figure 1. Learning Module: On the Trail of the Invisible

3.2 Computer Science – Contrast Programme

The "Contrast programme" learning module ties into the themed areas "active principles of informatics systems" and "interaction with informatics systems", thus facilitating an examination of data structures and digital image processing. The complexity of the module is designed in such that it can be used in years nine and ten.

Working with satellite images in this field is particularly suitable because with satellite images, the composition of digital images and fundaments of digital image processing can be very vividly conveyed. The goal of the "Contrast programme" teaching unit is to learn to understand the basics of digital image processing.

In the first part of the learning module (Fig. 2), students are introduced to the general subject of digital image processing. A section of a satellite image showing the Statue of Liberty is provided for this purpose. Once students launch the learning programme, an initial image will be output, which holds two problems: 1. it is relatively low-contrast and 2. it contains two "erroneous" pixels. To first get a grasp of how digital images are composed, pupils interactively determine the position of the two "faulty" pixels. To do so, they can scroll with the cursor integrated in the image over the input section for the numerical values for the image's column and scanning line.

In the second modular unit, students correct the grey scale values of both faulty pixels in the image. To do this, they can refer to the information box to find out all about 1, 2, 3, 4 and 8-bit images. The additional information box also addresses the correlation between the available grey scale values for different bits and the binary notation of the grey scale values. To further their knowledge, students should interactively correct the grey scale values of the faulty pixels by entering the correct combination of binary values. For a simplified introduction to the matter, a 4-bit image is provided at first. In the next step, both pixels are corrected again, but in an 8-bit image this time.

The last part of the learning module (Fig.2) is focussed on improving the image's contrast. The image's distribution of grey scale values is shown in a bar chart. Pupils are then asked to inform themselves of the range of values the image's pixels take up. Finally, they can interactively adjust this range of values to improve the image's overall contrast.

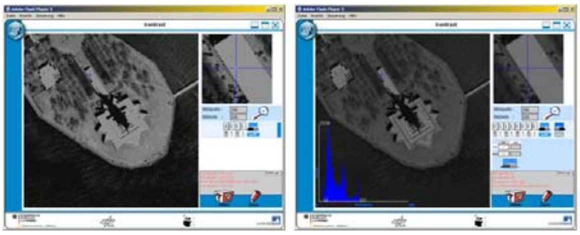

Figure 2. Learning Module: Contrast Programme

3.3 Maths – Pixels Gone Wrong

The learning module "Pixels gone wrong" was conceived for year eight and deals with the combination of linear functions and the geometric correction of remote sensing images. The learning module encompasses four parts in total. The first modular unit comprises an animated introduction in which the problem is briefly outlined (Fig. 3): *"The preliminary construction on an important building project was swamped by floods this past winter. Now an aeroplane is supposed to scan the construction site from the air, in order to show the extent of the damage. Just as the aeroplane is nearly over the target area, it is blown off its course by a gust of wind. The image of the site is now blurry and can't really be used... unless this error is mathematically corrected."*

Based on this introduction, students then have to sum up the core of the problem in part two of the module. They are provided with two images to do this: an undistorted image for comparison and the blurry image. The objective is to compare both pictures and accurately specify and describe the differences between the two. For the detailed image analysis, pupils are provided with a tool with which they can enlarge a cropped section in both images. The difference in the position of the pixels can thus be precisely determined and described. Through their intensive work with the images and detailed description of the differences in the pictures, pupils' visual and lingual skills are also promoted, even in maths.

To acquire additional background knowledge, students can do some research in an information box. This provides them with fundamental information on the subject of pixels and digital image composition. The knowledge acquired here makes it possible for them to verbally formulate what a computer application has to do to get the pixels back into their correct position. In such, the first connection between the distorted aerial image and maths can be established, and mathematical knowledge can be transferred to a specific, real situation.

In the third modular unit, a link is then made between mathematical basics and the practical example by searching for a simple linear function to correct the image. For this task, students are provided with the distorted image, details on the aeroplane's deviation from its optimal flight path, and a coordinate plane. Calculating the real dimensions of the scanned area in pixels allows the distortion to be described as a graph in an interactive graph module. By calculating and adjusting the corresponding function, students come closer to a solution.

In the fourth modular unit, pupils can then test their calculated and adjusted functions by entering their results in an input field in the module. The image is now displayed based on the function they input. This also means that an unsuitable function will output an erroneous image. However, because this incorrect output is also the result of a function, it is easy to grasp and helps pupils understand how a function works.

Figure 3. Learning Module: Pixel gone wrong

3.4 Geography – Tsunami

The teaching unit "Tsunami" is part of a topic area in year seven which covers the endangerment of habitats. The goal of this teaching unit is to familiarise students with the meaning of natural disasters, to gain spatial cognition and do a spatial assessment, grasp the possible formations and causes of tsunamis, and get to know the possibilities remote sensing can offer for damage ascertainment.

To begin with, in the first part of the learning module pupils are introduced to the subject of natural disasters in general and tsunamis in particular by the professor they have already become familiar with in the physics module. Here students can gain background information on the tsunami that raged over Southeast Asia in 2004 through a newspaper the professor is reading.

In the second modular unit, the knowledge gained through the professor's virtual newspaper should be linked with two satellite images (one before the tsunami, one of the aftermath). Students are first asked to compare both satellite images by using an interactive controller, and to familiarise themselves with both images (Fig. 4). Then they have to name the structures that were destroyed by the tsunami. They should also put themselves in the position of the residents who lived in the disaster area, and reflect on the effects the damage had on them.

In addition, pupils are asked to consider the value of satellite images in such cases of natural catastrophes, and how these images can be used during these disasters. For this purpose, they can refer to the information box for more details where the procedure of change detection is also vividly explained in a short film. Once the pupils have grasped the concept of change detection, they can classify specific land surfaces in the last modular unit and, for example, ascertain how much of the land surface shown in the picture was flooded, or how much of the agricultural area was destroyed by the tsunami (Fig.4).

Figure 4. Learning Module: Tsunami

4. EVALUATION AND OUTLOOK

The learning modules finalised in the FIS project were and will be made available in the form of e-learning modules on the project's homepage (www.giub.uni-bonn.de/fis), i.e. e-learning modules v1.0 (Kerres, 2006) are provided to the partner schools, used in school lessons and evaluated throughout the entire process. The results of the evaluation show that the lesson plan developed in the FIS project can be implemented quite well in practice. In particular, teachers frequently emphasise the tightly-knit link with existing curricula, since a high degree of practicality is achieved through the topics' great relevance. Because teachers can also integrate the teaching units very well in their individual lesson plans, a sustainable use of the modules is warranted. As a result of this, the integration of the subject of remote sensing is described as a positive supplement to coursework. For one, satellite data is said to be more illustrative, which means that pupils learn and remember the contents of the lesson better. Second, this also boosts the learning spectrum because contents and methodological aspects of remote sensing are conveyed in addition to the subject matter foreseen by the curriculum. According to these qualitative testimonies, the use of satellite data is attributed with a high to very high degree of relevance for reaching educational objectives.

The results of the evaluation also show that the compiled digital learning modules can be put to good practical use in school lessons. This practicality is assessed so strongly mainly because the modules can either be directly launched from a CD-ROM or integrated in existing in-house learning platforms without having to install any proprietary software in advance. The teachers surveyed attributed significant added value to the digital learning modules, both in terms of their use in comparison with analogue satellite images (as e.g. transparencies) and in comparison to existing software solutions (Fig.5).

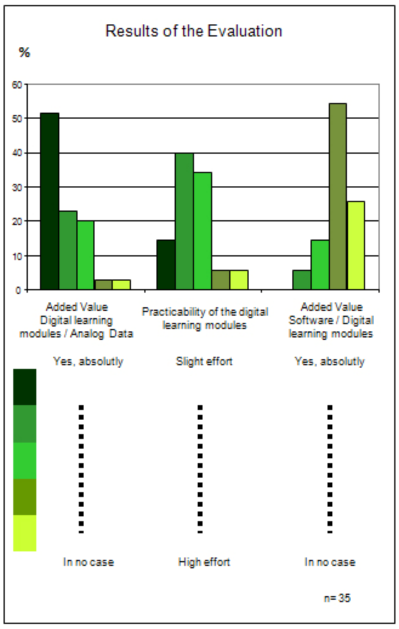

Figure 5. Results of Evaluation

The reason for this is that existing software solutions developed for use in schools are not actually suitable because they usually do not have any scalable approach, and are often not intuitive or user-friendly in their application. In addition to this there are organisational difficulties teachers often experience when they are not authorised to install new software. This in turn makes long-term planning necessary, which is often not easy to coordinate with everyday school life.

Due to the positive feedback on the practical use at schools, we plan on expanding and supplementing the existing learning modules both in terms of their content and in a methodical sense. This will allow us to ultimately provide an extensive collection of interdisciplinary learning modules for school lessons.

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