Chapter 11
Reading Satellite Images, Aerial Photos and Maps: Development of Cartographic and Visual Literacy

Hana Svatoňová

11.1 Introduction

The accessibility of servers, websites and the Internet has allowed the public to discover the world of aerial and satellite imagery. The most noticeable source of such information is Google Earth, which, together with Virtual Globe, NASA World Wind and ESRI's ArcGIS Explorer, has become extremely popular for educational and noneducational applications (Schultz et al. 2008). Adults and children are now confronted with new topographical materials, such as aerial and satellite images. While people have been using maps for more than 1000 years, high-resolution digital imagery represents a progressive option and a new experience for viewers. Although both maps and aerial images present a bird's-eye view of the earth, aerial images are not maps. Maps and images differ in many aspects, and therefore the reading of an image differs from the reading of a map. A map is a representation of the earth's surface supplemented with annotations and provides geometrically accurate shapes and distances. Aerial and satellite images contain no explanatory text and have certain distortions which need correction. Although people have just started to discover the advantages of surface imagery of the earth and gain experience in utilising such imagery, this method already has taken its place in daily life. Results of research among children and teenagers indicate an extremely rapid increase in popularity of aerospace imagery supported by development of new technologies, such as smart phones, tablets, laptops and social media. This situation raises questions as to how young people (in this study 11-, 15- and 19-year-old students) can handle various types of images and tasks, if there is some variation in the efficiency of map and image interpretation, and how children judge the images.

H. Svatoňová (✉)
Faculty of Education, Department of Geography, Masaryk University in Brno,
Poříčí 7, 639 00 Brno, Czech Republic
e-mail: svatonova@ped.muni.cz

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Therefore, this research presents the results of a study focused on visual and cartographic skills, as well as the development of imagination at various stages of pupils' growing maturity.

11.2 Image Is Not a Map

Prior to the testing of the students' ability to read and interpret maps and images, it was necessary to clarify the basic differences between these documents. Aerial or satellite images differ from maps of the same area in many aspects, and this fact could affect the interpretation of the content. This issue was described in detail by Kovařík (2012).

An image depicts the real situation of the landscape up to the limit of the camera or sensor's resolution. However, as the images show all the features in detail, it can be difficult to distinguish important objects from those less important, and some features can be completely invisible. An image cannot contain any names, spot heights or grid lines. One single image cannot provide real information about landscape profile. Interpretation aids must be used to identify the features in an image. The fundamental tools for visual image interpretation are as follows: tone, texture, shadow, pattern, association, shape, size and site.

Images show real features, whereas maps depict features using cartographic symbols. The interpretation of images is therefore straightforward, without the necessity to work with a legend as is the case of maps. Images can be classified according to various criteria. Considering the research described in this paper, images can be classified according to viewing angle and colour and by how up to date they are. Based on the viewing angle, images can be classified as oblique or vertical. Based on the colours used, we distinguish between true-colour images, not-true-colour images and black and white images. In terms of date, the images can be recent or historical.

Different types of images place different demands on their readers. Reading orthogonal images is unusual for non-expert readers. The orthogonal view, without information about the object and sidewall height or a landscape profile, is more difficult to interpret compared to the oblique view. The oblique image is more familiar to non-expert readers. It provides a more familiar view of the depicted area. However, a big disadvantage of oblique images is shape deformation and variable scale. The viewing angle of orthogonal images directly affects the use of interpretation aids such as shape, size, site and shadow.

Colour (or a tone) represents another important image interpretation aid. Black and white images generally appear to be more difficult to interpret. In the case of colour images (both true colour and not true colour), the method of interpretation depends on the aim of the particular task and the need to identify the features as having various physical or chemical properties.

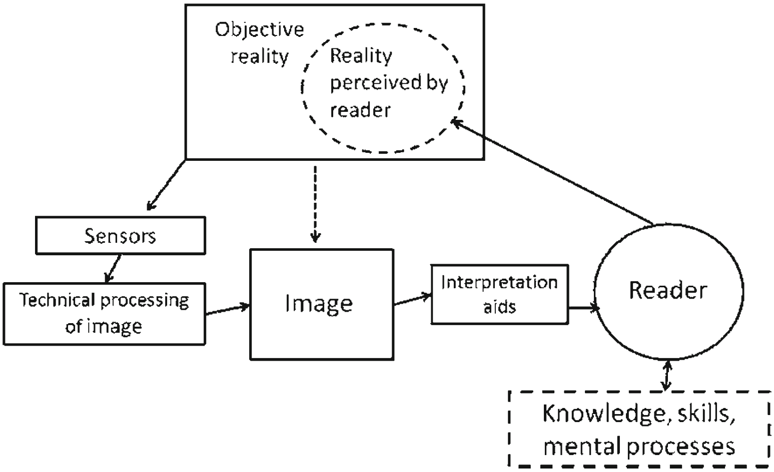

Fig. 11.1 Model of image reading (Source: Author)

11.3 Images as Models of Communication

According to a theory of information technologies, a map and an image can be viewed as a means of communication. The fundamental components of that communication system were presented by Robinson and Petchenik (1977). MacEachren (2004) states that the first models of cartographic communication were introduced by Board in 1967 and by Kolacny in 1969. Particularly, the model of Kolacny inspired us to create the "image-reader" communication model which is shown in Fig. 11.1. Similarly as in the model of Kolacny, the reader creates a mental representation of a reality on the basis of both the received information depicted in the image and his or her previous experience. Such representation is identical with reality to some extent. Unlike map reading, where the communication medium of the process is represented by a map, the image does not offer the subjective view of a cartographer and the use of a coded language. The coding of information in the image can be associated with a colour of the images or with the image classification. It is possible to generate a hybrid product, known as an image map, where the image also contains coded information in the form of cartographic symbols, lettering, etc.

11.4 The Reading of Images vs. the Reading of Maps

The reading of images and maps belongs to cartographic and visual literacy. The International Visual Literacy Association defines the term "visual literacy" as the skill of receiving and evaluating information using a visual medium. According to Pravda (2001), "cartographic literacy" comprises reading, using and creating maps. It can be divided into natural and acquired cartographic literacy. When working with aerial and satellite images, both visual and cartographic literacy are needed. When preparing the experiment, we built on theoretical works and research concerning cartographic skills that included reading maps and, in a broader context, reading images.

11.4.1 Cartographic Skills

The term "cartographic skills" is a specific expression of cartographic and visual literacy. Van der Schee (2000, 218) states that the degree of mastery regarding cartographic skills corresponds to the amount of information that we are able to obtain from a map. Differences in the mastery of cartographic skills in pupils are associated with their age as well as with their own practice, i.e. cartographic skills are developed when the children are working in the classroom with maps and the teacher pays particular attention to these activities (Gerber 1981, 128). According to Catling (1978), children are able to use either an existing map or their own cognitive map at an early age, but their map-reading skills are at a low level. Wiegand (2002, 19) cites three options of using maps, each requiring different skills and leading to the acquisition of different information: (1) searching for particular features and determining their locations in relation to other elements, (2) using the map to find a route and (3) using the map to solve problems with an emphasis on the spatial distribution of phenomena and spatial relationships. Catling (1978) and MacEachren (2004) interpret the concept of cartographic skills from two perspectives: (1) as children's ability to understand the spatial arrangement of their own surroundings and the related solving of problems, such as finding an appropriate route and (2) as children's skill to read and interpret information using thematic maps. Wiegand (2002) divided cartographic skills into three groups: (1) decoding maps (reading, understanding and interpreting), (2) assessing maps and (3) creating their own simple maps. Van der Schee (1987) offers a simple definition of cartographic skills as being map reading, map analysis and map interpretation.

11.4.2 Skills of Working with Aerial or Satellite Images

Analogously, the skills of working with aerial or satellite images comprise reading, analysing and interpreting images. The elements of visual image interpretation – tone, texture, shadow, pattern, association, shape and size – are routinely used when interpreting aerial photographs or satellite imagery (Lillesand et al. 2008).

Children, from 3 years old, begin to understand aerial photographs as a representation of real spaces (Blaut 1997), and their understanding continues to develop into adolescence (Downs and Liben 1997; Liben and Downs 1992). Liben and Downs (1989) and Liben and Yekel (1996) described preschoolers' and older children's understanding of maps and map symbols. Liben (1999) proposed a developmental trajectory for understanding spatial representations. Muir and Blaut (1969) tested 5- and 6-year-old American children with vertical black and white aerial photographs and found that children taught about aerial photographs demonstrated map interpretation abilities above those of untaught peers. Stea and Blaut (1973) asked Puerto Rican 5-year-olds to interpret vertical aerial photographs centred on the children's school. They concluded that the children had no trouble reading the content of the photographs. Blaut et al. (1970) tested 5- to 7-year-old children using black and white vertical aerial photographs at scales of 1:2000 and 1:3000, respectively. The children identified the features and then were asked to trace a map on acetate identifying features from the photograph. They also had to plot a route on their maps. Most children successfully completed the task. These studies concerned children before they had attended school or in the first years of primary school. Kim et al. (2012) investigated whether young children possess the potential to understand map-like representations using aerial photographs, how scale affects children's performance and whether children show interest in and enjoy working with spatial representations. Three remote sensing images of different scales were employed to examine children's ability to interpret spatial representation. The results indicate that young children have the ability to use spatial representation. Most participants (Korean pupils) were able to understand aerial photographs. Adults' visual interpretation was also analysed by Lloyd et al. (2002) and Van Coillie et al. (2014). Lloyd et al. (2002) investigated how people process information from aerial photographs to categorise locations. Three cognitive experiments were conducted with human subjects viewing a series of aerial photographs and categorising the land use for target locations. Van Coillie et al. (2014) analysed the accuracy of image digitisation performed by adults with various degrees of experience regarding processing images and various degrees of motivation. Digitising accuracy varied strongly across monitored participants. Moreover, it was stated that, generally, accuracy was very poor. Svatoňová and Rybanský (2014) evaluated various types of landscape visualisation with respect to reality perception. Testing of research participants proved that the most effective visualisations are simulated flights over the country and 3D visualisations using orthogonal images.

Cartographic skills and the skills of working with aerial or satellite images change over time. They can be developed and are related to the development of geospatial thinking. Schuit (2011) studied the use of exercise cards in a new way of teaching the reading of topographical maps. Lee and Bednarz (2012) demonstrated the efficacy of a set of methods which accurately identify the cognitive mapping strategies of individuals. The relation of geospatial thinking and vocabulary was investigated and experimentally verified by Golledge et al. (2008). Lee and Bednarz (2012) performed an analysis of tests focused on spatial thinking using factor analysis that employs principal components.

The purpose of the study described in this paper is to investigate, analyse and compare the efficiency of reading images and maps, the ability of adolescent children to read images in relation to colours used and the subjective opinions of research participants on the difficulty of reading various types of images and their preference for images or maps as a source for acquiring information.

11.5 Research

The research focused on three main areas:

1. A comparison of visual interpretation efficiency regarding aerial images and topographic maps of the same area
2. A comparison of visual interpretation efficiency for true-colour satellite images and not-true-colour satellite images
3. An evaluation of the subjective perception of reading difficulty for various types of aerial and satellite images, preference for maps or images and respondents' experience with use of images in an education process

Differences in visual efficiency regarding reading aerial and satellite images and the subjective evaluation of maps and images related to students' gender and age were briefly analysed as well.

Research respondents solved selected spatial (and identical) tasks in pairs of documents (imaging and map, true-colour image and not-true-colour image). Part of the task was identical for all respondents: to evaluate landscape development based on a pair of satellite images acquired at different points in time, to identify objects in historical aerial images, to evaluate the materials subjectively and to specify a personal preference for images or maps.

According to Catling's research (1978), images of areas known to the respondents were used for several of the test questions. Specifically, some tasks involved identifying objects in large-scale topographic maps and aerial images which captured the vicinity of the school. Other tasks focused on the identification of types of objects and land use defined in satellite images with a scale 1:100,000 taken of environments neutral (i.e. unknown) to participants.

11.5.1 Research Questions

The main research questions, with sub-questions, were formulated with respect to the following research objectives:

1. Is the **interpretation** efficiency identical **for aerial images and maps** with the same scale and showing the same area?
   (a) Is the identification of objects in topographic maps more successful than the identification of objects in images?
   (b) Is the number of objects identified in maps higher than the number of objects identified in images?
   (c) Is there some variability of the identification score (maps, images) related to the participant's age and gender?
   (d) How successful were participants in solving spatial tasks using historical black and white images showing the same landscape in the 1950s?

2. What is the difference in the **visual interpretation of true-colour satellite images and not-true-colour satellite images**? Is the identification score for types of land use and the purpose of selected objects identical for true-colour satellite image and not-true-colour satellite images?
   (a) Are the respondents more successful in the identification of elements in true-colour images or not-true-colour images?
   (b) What types of land use are distinguished better in true-colour images, and what types are easier to identify in not-true-colour images?
   (c) How well can the students interpret satellite images taken at different times?
3. What is the **subjective evaluation of participants concerning the difficulty of visual interpretation** of documents? How frequently do they work with images? Do they like this activity? Do they use such documents at school?
   (a) How do participants evaluate the difficulty of reading aerial images and maps? Which type of documents do they prefer?
   (b) Is there any difference between girls' and boys' scores? How does their preference change with age (regarding maps, images)?
   (c) What are the participants' subjective evaluations of reading true-colour satellite images and not-true-colour satellite images?
   (d) Do they work with satellite images at school and during leisure time?
   (e) Is this activity interesting and amusing for them?

11.5.2 Test Preparation

Considering the research questions, the test consisted of three parts. The first part of the test contained **tasks focused on the evaluation of efficiency regarding the interpretation of aerial images and maps**. The second part focused on **evaluation regarding the efficiency of interpretation of satellite images**, and the third part of the test contained questions concerning the participants' **subjective evaluations**. The documents used were sorted into two groups, and two equivalent test sets were created: version A and version B.

Seven questions were aimed at **objective differences in the interpretation of images and maps**:

1. Find identified objects in the aerial image (orthogonal, true colour) and in the topographic map of the same area, with the same scale.
2. Find and plot described objects; draw the shortest path from the station to school in the aerial image and in the map.
3. List the objects contained in the map and the aerial image.
4. Plot the school building in the historical aerial image. Write down what was at this school's location 60 years ago.
5. Specify which types of land and objects (water area, river, forest, field, built-up area) can be found in the not-true-colour image and the true-colour image.

6. Match the map cut-out into the appropriate segment in the not-true-colour image and the true-colour image.
7. Analyse two satellite images taken of the same locale 20 years apart and describe how the mining area and its vicinity changed.

The next five questions were aimed toward the **subjective evaluation of participants**:

8. Do you find working with images interesting and amusing?
9. Do you look at images on the internet in your leisure time?
10. Do you work with images at school?
11. Evaluate the difficulty of reading various types of images and maps.
12. Which do you prefer: maps or images?

11.5.3 Test Documents: Maps and Images

Images and maps available in the map server "Národní geoportal INSPIRE" (Geoportal 2015) were used as a main source to ensure the availability of images for participants and researchers. Cut-outs from images taken by the LANDSAT satellite were used to test work with satellite images. The colour combination labelled "742" was selected for not-true colours, which allowed for good recognition of water areas, rivers and forests. The colours of the LANDSAT images combined with the red, green and blue (RGB) "742" option show water areas in blue or black, water streams in blue and forests in green. Fields are displayed by a pink-green mosaic and built-up areas appear in violet-pink. Moreover, a cut-out from the historical (1950s) black and white mosaic of aerial images showing the required area was used.

Test documents:

- Basic topographic maps, scale 1:10 000
- Orthogonal, colour, aerial images, resolution 0.5 m
- True-colour satellite images (LANDSAT 7, RGB "321"), scale 1:100,000, resolution 30 m.
- Not-true-colour satellite images (LANDSAT 7, RGB "742"), scale 1:100,000, resolution 30 m.
- A pair of satellite images from the LANDSAT satellite (RGB "432") dated 1984 and 2005.
- Historical aerial black and white images from the 1950s, cut out from a mosaic.

11.5.4 Participants

Research was performed with students ages 11, 15 and 19. In total, **378 students** participated in the research: 198 boys and 180 girls (Table 11.1). Students ages 11 and 15 were educated at primary school. They were members of eight different

Table 11.1 Research participants

	Age		
	11	15	19
Total number	108	134	136
Girls	59	61	60
Boys	49	73	76
School and class	Elementary school, sixth year	Elementary school, ninth year	Bachelor studies, first year
Number of classes	4	4	2

classes and two different schools. One teacher conducted all the lessons in each school. The 19-year-old participants were first-year university students (teaching of geography, Masaryk University, Brno, Czechia). Ninety percent of the students studied at grammar school in the past. Two subsequent classes whose lessons were conducted by one teacher were tested.

11.5.5 Testing Process

Testing was performed at the schools in the spring and autumn of 2013. Research questionnaires were distributed as individual tests for students. The purpose of the test and organisational instructions was presented to students at the beginning. No time limit was specified; however, students completed the test in an average time of 20 min. Any ambiguities were answered during the test. With respect to the test form and task specification, the score was assigned manually. The answers were evaluated by one person.

11.5.6 Test Evaluation and Scoring

The following subchapters contain results and scores achieved in the test.

11.5.6.1 Evaluation of Results: Comparison of Objective Efficiency Regarding Object Identification in Aerial Images and Topographic Maps

The following conclusions can be made based on the evaluation of tasks focused on the **identification of particular objects in aerial images or in maps**:

– 64–80 % of objects were successfully identified in the aerial images; 53–70 % of objects were successfully identified in the maps (Fig. 11.2).

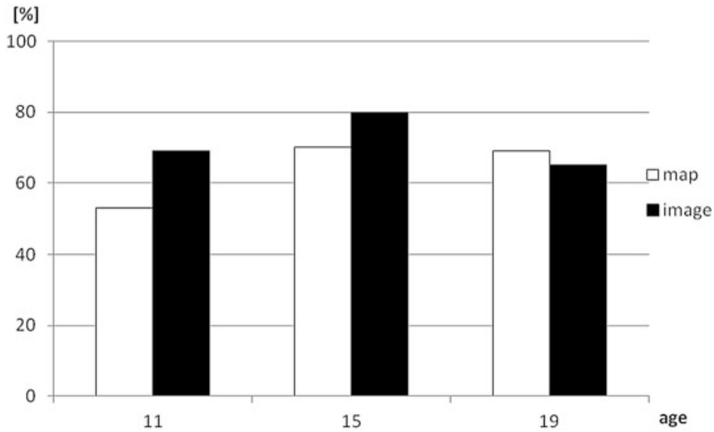

Fig. 11.2 Aerial image and map – reading efficiency in relation to participants' age

- The older the age of the students, the lower the difference between image and map processing efficiency. The highest difference was detected in the group of 11-year-old students. Among the 19-year-olds, the efficiency of map reading was slightly higher (+4 %); see Fig. 11.2 for more details.
- The results revealed interesting information when compared according to gender. Both genders solved tasks with similar efficiency (difference within 5 %). However, a detailed analysis of map-reading efficiency showed significant differences between genders. In the 11-year-old students' group, the girls achieved better results (difference 10 %), but boys were more successful in the 15- and 19-year-old students' groups (+12 %; +16 %). Differences in map reading between genders were also confirmed by Chang and Antes (1987). That article evaluated males as better at map reading.
- Participants were asked to write down objects which they were able to identify in areas displayed in the map or image. The document contained ten objects to identify. Participants identified more objects in the image than in the map (4.9–6.7 objects in map vs. 3.8–5.6 objects in map). This observation corresponds with a better score for object identification achieved in aerial images. The amount of identified objects slightly increased with participants' age. This was in line with our assumption that abstract thinking develops with age.
- The results of plotting specified objects and the shortest path on maps or aerial images correspond with the evaluation of object identification. Younger students can better read aerial images (+15 % and +16 % for images); 19-year-old students are better at reading maps (+21 % for maps). Map-reading efficiency again shows a slightly increasing trend if put in relation to the participants' ages (results for age groups ascendantly 48 %, 70 % and 81 %, respectively).

Besides actual colour aerial images, the **solving of spatial tasks in historical, black and white aerial images showing the area 60 years ago** was included in the test as well. Students were asked to plot the school building and several old and newly established streets in the historical aerial image. The students were asked to find out what was originally located on the school site. Actual aerial images with identical scale and street names were provided as a support document to help solve these tasks.

- Generally, the participants achieved scores of 66–76 % on average. It should be noted that the scores varied with the participants' age. Participants with high scores (min. 85 %) identified the location of their school in the historical image. They also discovered that there were fields in this location in the past. They could plot the neighbouring streets in the vicinity with lower accuracy (ca. 50 %). Participants identified the school building and objects in the vicinity very well (up to 90 %), but more distant objects were more difficult for them (ca. 40 %).
- The achieved scores were very similar across ages and genders (between 66 % and 76 %). Better results were expected from the group of 19-year-old students. Their performance could have been affected by the fact that they solved the task in an area unknown to them, while the 11- and 15-year-olds solved the task in the vicinity of their school. Thus, we believe that knowledge of the area increases the chance to identify the object/element in images showing the same area under significantly different conditions.

Participants were also asked to provide **their personal subjective feelings concerning the difficulty of reading aerial images and maps**. A 1–5 scale was defined for this purpose (1, very easy; 5, very difficult). The results and chart in Fig. 11.3 show that:

- The students consider maps and colour aerial images well readable.
- The perception of difficulty changes with age. The older the participant, the better feedback concerning map readability and the better the assigned score. Eleven-year-old students achieved an average score of 2.28; 19-year-old students achieved an average score of 1.48. The opposite trend was observed for aerial images: 11-year-old students achieved an average score of 1.75 and 19-year-old students achieved an average score of 2.52. Fifteen-year-old students achieved similar scores in maps and aerial images, which means that they consider the difficulty of reading them to be equivalent.
- All the age groups stated that the black and white image was significantly more difficult to read. Scores here varied from 3.48 (min) and 4.05 (max). The highest scores (worst) were achieved by the 19-year-old students. This indicates that the colours in the aerial image are of significant interpretive help and increase the chance of identifying the objects in the image.

Subjective preference (Fig. 11.4) – selection of maps or images for obtaining needed information showed that:

- 19-year-old students prefer maps (67 %), 11-year-old students showed a similar preference for both options (46 % and 49 %) and over 20 % of 15-year-old participants preferred both materials similarly, i.e. one fifth of 15-year-old participants did not indicate a preference for either of these options.

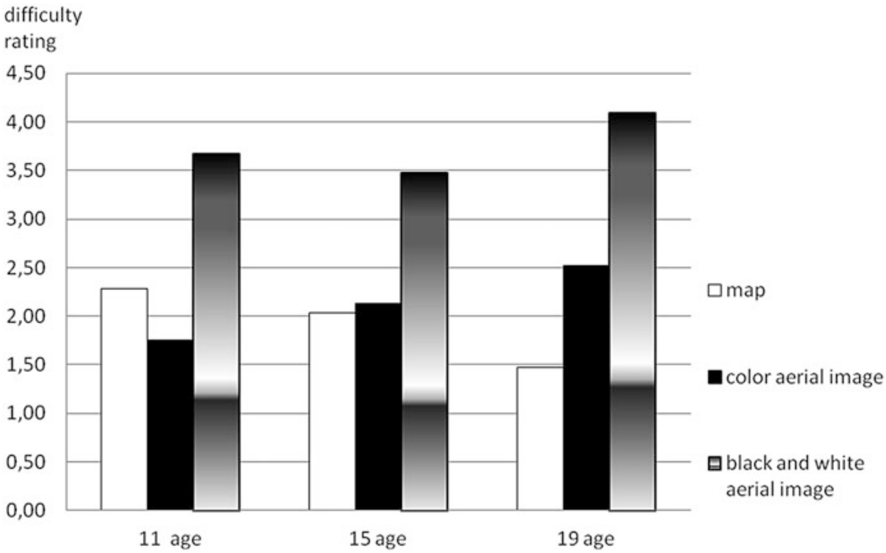

Fig. 11.3 Subjective statements concerning the difficulty of reading aerial images and maps

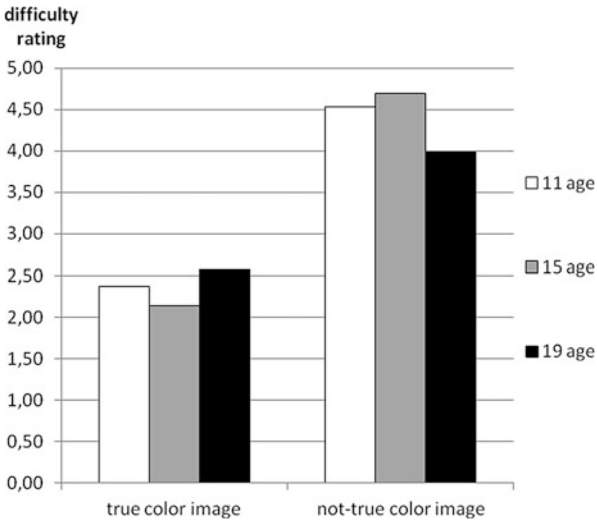

Fig. 11.4 Subjective preference for maps and images

– From the results it is possible to conclude that 19-year-old students realise the information value of maps. Moreover, they achieve objectively better results on maps compared to images.
– Interesting results might be obtained by also comparing the results with orthophotomap preferences, but this question was not included in the test.

11.5.6.2 Evaluation and Results of Comparison of Visual Interpretation Efficiency Regarding True-Colour Satellite Images and not-True-Colour Satellite Images

The second part of the research focused on a comparison of visual interpretation of true-colour images and not-true-colour images by non-experts, specifically adolescents. True-colour images contain clear, needed colour combinations of channels in RGB, evoking an impression of the true colours. Images taken by the LANDSAT 7 satellite were selected for testing. In this image the true colours can be obtained from channels 1, 2 and 3 in green, red and blue. The colour combination "123" is favourable for non-expert interpretation, because the colours of the object match with reality. However, not-true colours are frequently used for practical applications. In this case, combinations of different channels and colours are used and provide better interpretability of objects or their features. The colour combination "742" for LANDSAT satellite images were used for testing. The image colours enabled a very good distinguishing of water areas and flows. These are displayed in blue or black, which is very close to the real colours. Similarly, the forests are displayed in green. Fields are more difficult to find a parallel with reality for non-expert interpreters; depending on the crop or surface, they appear as a pink-green mosaic. Built-up areas are displayed with violet shades.

The participants solved identical tasks using true-colour images or not-true-colour images. With respect to the purpose of not-true colours, we were interested whether untrained interpreters could achieve better results identifying particular objects, even if these colours were not true.

The following conclusions can be made based on an evaluation of tasks focused on the **identification of particular objects in not-true-colour images and colour images**:

- The participants achieved an average score of 66–94 %.
- The average score achieved in images with different colours is not the same. Differences in score were small; differences corresponding to the age groups of participants were at most 5 % (Fig. 11.5). Slightly better scores were achieved with not-true-colour images.
- Image interpretation skills changed with the participants' age. Eleven- and 15-year-old students achieved better results with not-true-colour images. That result is in contrast with their subjective evaluation of image-reading difficulty as related to colours, as the participants considered the not-true-colour images very difficult to read, see Fig. 11.5.
- The evaluation of interpretation efficiency in relation to gender shows very similar values. The only exception was 11-year-old girls, who had significantly better scores for true-colour images (difference 15 %). This supplements and confirms the analysis of the reading of aerial images and maps. In this case, both genders showed similar results with images (there was a difference for maps).
- The efficiency of identification of selected objects and areas varies in relation to colours used in the image provided as a source for identification (Fig. 11.6).

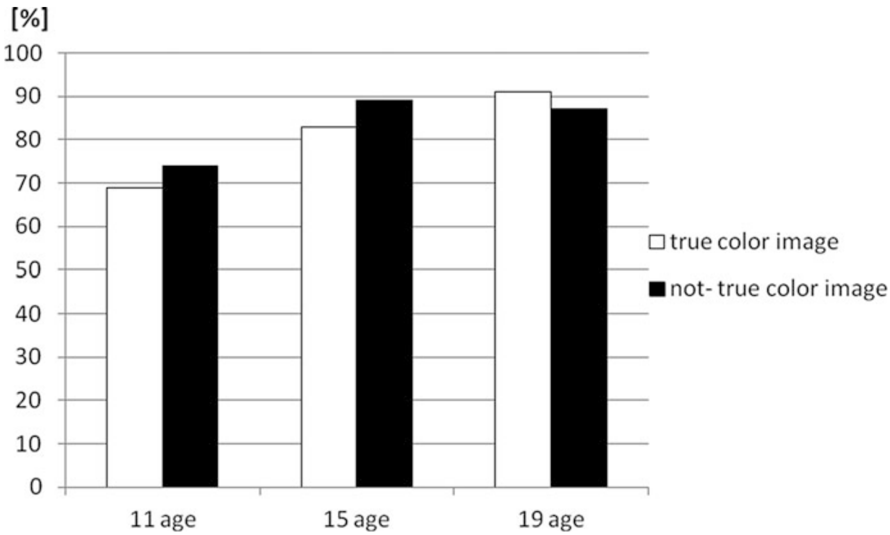

Fig. 11.5 Efficiency of object identification regarding true-colour images and not-true-colour images

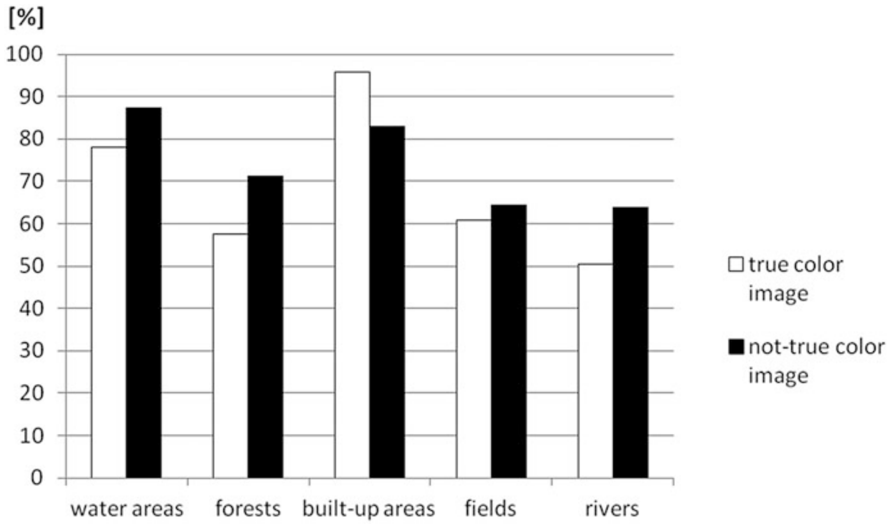

Fig. 11.6 Efficiency of interpretation of types of land in satellite images in relation to image colour type

– Participants achieved very good scores in the identification of water areas and rivers shown in not-true colours (water areas: on average 95 %, 15- and 19-year-old students achieved full 100 %; 83 % for rivers in not-true-colour images vs. 61 % for true-colour images). This confirms the assumption that the selected colour combination, i.e. LANDSAT 7 image with combination "742", enables a very good distinction of water areas and water flows to non-experts. The reason is that these elements appear in expected and predictable colours.
– Participants were slightly more successful in identifying built-up areas, fields and forests in true-colour images. However, the differences were within 5 %. The unusual colours used to display built-up areas in not-true-colour images only confused 11-year-old participants, who achieved a score of 83 % (a very high score all the same) compared to 96 % achieved with true-colour images. Consistent scores exceeding 70 % were achieved for forest identification in true-colour images, and the score increased with age, specifically from 58 to 93 %.
– Generally we can observe that non-experts and children without previous training are able to interpret not-true-colour images very well.

Detailed analysis in relation to participants' age was performed for the task of **identifying the type of land use.** (Note: There were very small differences between genders, so a detailed analysis of results related to gender was not performed.)

– The older participants showed a more efficient identification of land-use type.
– Significant difference was detected between 11-year-old children and the other two age groups. The youngest group did achieve a significantly lower score. The other two age groups were quite equipollent. In other words, there is a big jump in score between 11-year-old students and the older participants.
– Only the score for identification of built-up area types in true-colour image was very similar across all age groups. Eleven-year-old children achieved almost the same score as older students.
– The success ratio remained unchanged for various areas. Eleven-year-old participants showed the same differences in score according to the type of area, but the total results were approximately 20 % lower than the score achieved by 19-year-old participants.

The participants were also asked to **assign a map cut-out to the appropriate location in satellite image** (**in both true-colour images and not-true-colour images**). The two cut-outs contained objects with noticeable colours or shapes (e.g. lake and airport runway); the other two cut-outs contained less noticeable objects (suburban settlement ad highway crossing). The evaluation brought a number of results:

– Cut-outs with noticeable objects (e.g. lake, shape and colour; airport, shape) were assigned correctly with a score up to 100 % in several groups of participants, including the youngest participants.
– Colours did not play an important role for map cut-out assignment in aerial images. Figure 11.7 shows that the score is slightly higher for not-true-colour images, but the differences are within 9 %.

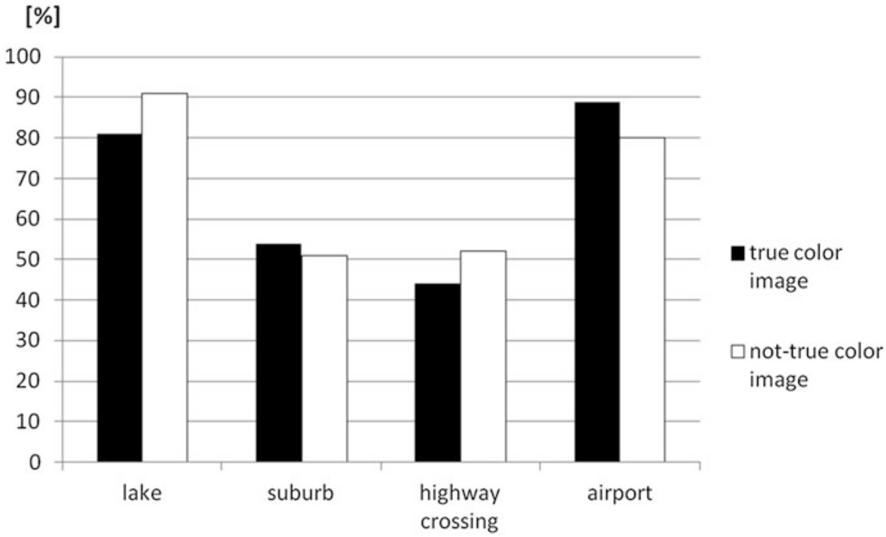

Fig. 11.7 Score for identification of particular objects in true-colour and not-true-colour satellite images

– For the cut-outs containing less noticeable objects, the score was significantly lower – working with suburban settlements: approximately 50 % of participants correctly assigned a round settlement with a forested area, and approximately 44 % of participants correctly assigned a highway crossing (both were presented in true-colour images, see Fig. 11.7).

The identification of landscape changes over time was quite difficult for students. The real situation in LANDSAT 5 and LANDSAT 7 satellite images displayed a landscape dramatically damaged by surface coal extraction, surrounded by damaged forest in 1984. After 20 years, this area is significantly reclaimed, but the extraction still continues in to a limited extent (image dated 2005). However, all the answers containing a formulation mentioning a positive change, such as "forest ratio is increased", "forests are greener", "there are more meadows, fields and ponds", "the damaged areas are smaller", "the landscape looks more healthy, greener", etc., were considered to be correct.

The results show that:

– Participant's age played a significant role in the ability to specify the changes in the area. Nineteen-year-old students achieved significantly higher scores, probably also thanks to a deeper knowledge of environmental issues, as they are confronted with these issues throughout their education.
– Further analysis of results according to gender shows that girls achieved higher average scores than boys. In the 15-year-old students' group, this could be due to girls' faster development to maturity and better formulation and synthetic thinking. Figure 11.8 shows that in the 19-year-old students' group, both genders are much more capable.

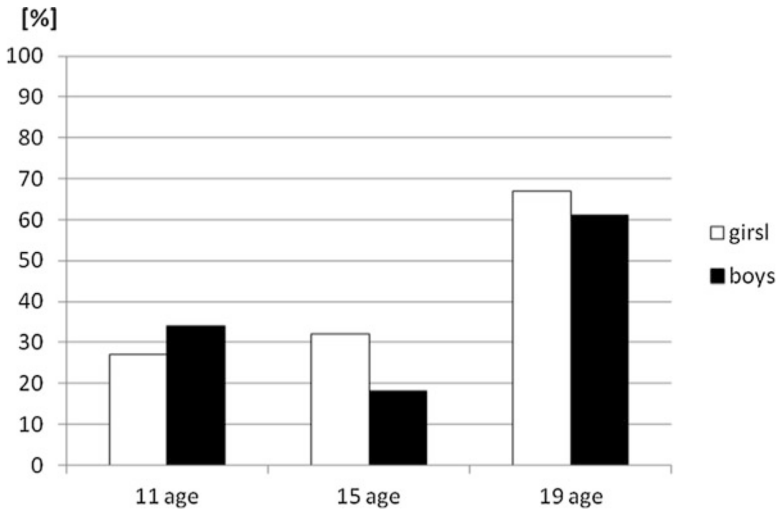

Fig. 11.8 Identification of changes in landscape based on pair of satellite images from different time points, sorted according to gender

Moreover, **subjective classification of the difficulty of object identification in true-colour images and not-true-colour images** was evaluated as well. We wanted to know if the subjective evaluation corresponds with the objective results and how the subjective evaluations change with participants' age.

The following conclusions can be derived from an analysis of the subjective evaluations:

– Although objectively the students achieved better scores with not-true-colour images, eventually the results were very similar (see Figs. 11.5, 11.6 and 11.7). Subjectively they considered reading of not-true-colour images to be very difficult.
– Participants assigned ratings ranging from 4.0 to 4.8 to the not-true-colour (scale 1–5; 5 for maximum difficulty). The true-colour images obtained ratings from 2.1 to 2.6.
– Subjective evaluation of the difficulty of satellite image interpretation in relation to colours used (Fig. 11.9) does not correspond with the objective scores achieved by participants for the particular type of image. Not-true-colour images are considered very difficult to read. Objectively, the efficiency of reading true-colour images and not-true-colour images is very similar. In some cases, the participants achieved higher scores with not-true-colour images.
– From our investigation it is obvious that colours used in the image have a significant impact on the subjective perception of interpretation difficulty.

Just as a curiosity, we mention that during the testing, the students frequently called the not-true-colour image "that map". We asked why they used this expression,

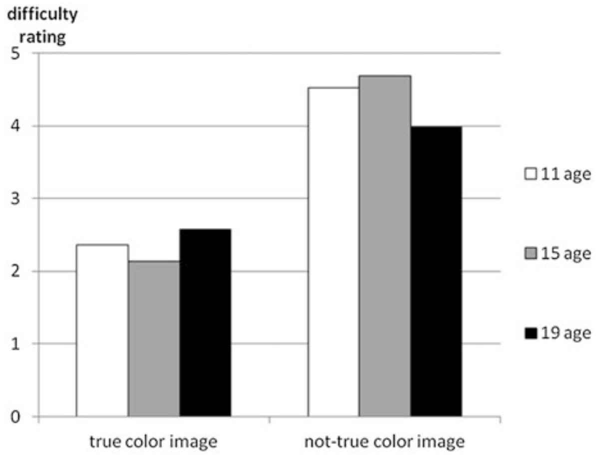

Fig. 11.9 Subjective rating of the difficulty of reading satellite images in relation to colours used

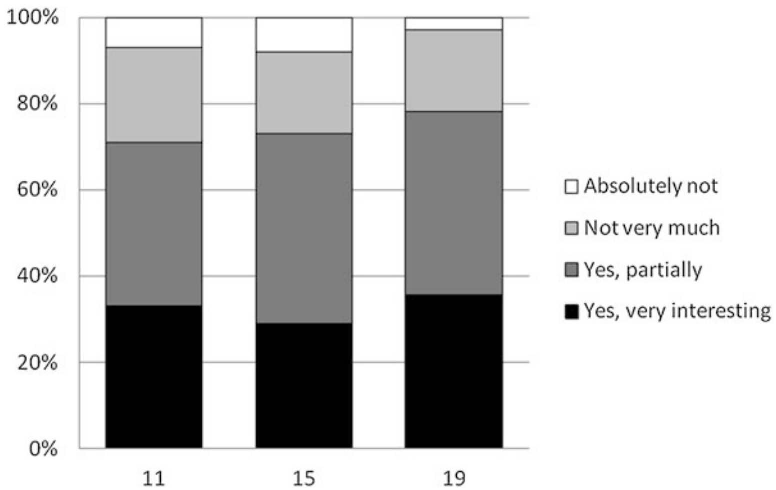

Fig. 11.10 Subjective evaluation of reading images – is it interesting and amusing?

and they specified the colours as the reason. They saw a parallel with the map which also used colours deviating from reality.

– Students find the work with images interesting. More than 70 % of participants selected the answer "yes, very interesting" or "yes, partially" (see Fig. 11.10).
– The answers were very similar across age groups. More than 70 % of students regularly (i.e. at least twice monthly) or irregularly look over images.

One question in the test was focused on **the use of images in lessons from the students' view**, i.e. if they use images and, if so, if the use is detailed or just marginal. **A high degree of evaluation subjectivity** was detected in the answers. Specifically, students from the same class provided different answers, even if they attended the same lessons. Our research shows that the use of images in lessons occurs later and less intensively compared to students' desire to work with images. The use of images at school depends on the teacher's interest. According to students' feedback, the degree of image integration in lessons varies across individual schools. However, it is necessary to mention that the 11- and 15-year-old participants were from two schools only, and thus this result cannot be generalised. More complex information concerning use of images in high schools can be deduced from the answers of 19-year-old participants, who graduated from various grammar schools. Students worked with aerial or satellite images during their studies in high school rather sporadically; 68 % of participants selected the answer "never", 31 % of participants selected the answer "rarely" and only 2 % of participants selected the answer "regularly".

A special questionnaire for geography teachers (45 participants in 2013) showed that older teachers who were not specifically trained on the use of remote exploration in geography integrated a significantly lower number of images into their lessons and were also more sceptical of the students' abilities to interpret images.

11.6 General Conclusion of the Research

Young people explore the world using aerial and satellite images accessible mainly via the Internet. These images might be gradually integrated into lessons as new material for tasks in geography and other subjects.

The purpose of the research performed in 2013 with 378 participants, specifically 11-, 15- and 19-year-olds, was to compare differences in the efficiency of visual interpretation of maps, aerial images and satellite images in various colour presentations. It was found that 11-year-old students achieve better scores with images than with maps and that the scores are very similar for girls and boys. Nevertheless, boys achieved better scores with maps than girls. Differences in map skills related to gender were also confirmed by Chang and Antes (1987). Personal preference for maps or images varied with age. Younger students preferred images, while 19-year-old students preferred maps. These results could be connected with the gradual development of abstract and spatial thinking in adolescence. A comparison of scores for true-colour images and not-true-colour images provided interesting results. Although objectively the students achieved better scores with not-true-colour images, subjectively they considered the reading of not-true-colour images to be very difficult. Participants' age was identified as a significant factor of success for tasks focused on the investigation of landscape changes in satellite images. This specific task was too complicated for 11-year-old students, and they needed the teacher's support. More than 70 % of students view images in their leisure time and find this activity interesting and amusing. Despite that interest, more than half of the participants report that they do not work with images at school. Images produced by high-end technology are still better accessible via the Internet, and young people find them attractive. Their integration in geography lessons could bring new incentives for both students and teachers.

The primary contribution of this research to teaching activities is the finding that students possess high-level skills for work with images, especially younger students, who are better at interpreting images than maps. Children's ability to interpret aerial images was also confirmed in a study performed by Liben and Yekel (1996) and Muir and Blaut (1969). It would be suitable therefore to integrate both document types (aerial images and maps) in education. Students can better realise abstract representation of reality in the map. Working with images helps students develop their skills related to unusual orthogonal views, including the gradual transition from the interpretation of oblique images to the interpretation of orthogonal images and subsequent interpretation of the map, which is in fact also an orthogonal view of the area using symbols.

Work with true-colour and not-true-colour satellite images also helps develop cartographic skills. Using not-true colours also proved to be favourable for primary school students; no increased difficulty of image interpretation related to not-true colours was confirmed. Working with not-true-colour images develops new skills applicable for map interpretation. Students are confronted with documents showing reality in unnatural colours, i.e. the reader must deal with the fact that the picture deviates from reality. This skill can also be used later for map interpretation. Another advantage of not-true-colour expression is the potential for highlighting some objects and features normally hidden from standard sight.

The development of visual and cartographic skills by tracking landscape changes in satellite images taken from different points in time seems very promising. This activity and skill must be trained. It is difficult for younger students, but they achieve very good results with a teacher's support (see also studies performed by Blaut et al. (1970)). Landscape changes and their environmental evaluation represent an important part of an education in landscape and environment protection. The monitoring of landscape changes is also necessary in case of an emergency situation when such changes could indicate a natural or human-induced catastrophe. Working with satellite images, aerial images and maps is an educative activity requiring student involvement. Blaut (1997) confirms that an active approach to working with maps and images supports improved development of new knowledge and cartographic skills. When testing the big group (in total 378 participants), we observed that most students were absorbed by the activity and worked continuously from start to end. This is significant, as students work and learn best when the activity is interesting for them and gives them a feeling of satisfaction and practical usefulness. According to the trend, satellite and aerial images are very useful tools which can be integrated into geography lessons. Our research supports the use of satellite and aerial images in education. The research will continue with other test groups composed of older students as well as senior participants, non-experts and professionals working with images and maps.

References

Blaut, J. M. (1997). The mapping abilities of young children: Children can. *Annals of American Geographers, 87*(1), 152–158.

Blaut, J. M., McCleary, G. S., & Blaut, A. S. (1970). Environmental mapping in young children. *Environment and Behavior, 2*(3), 335–349.

Catling, J. S. (1978). The child's spatial conception and geographic education. *Journal of Geography, 77*(1), 24–28.

Chang, K., & Antes, J. J. R. (1987). Sex and cultural differences in map reading. *The American Cartographer, 14*(1), 29–42.

Downs, R. M., & Liben, L. S. (1997). The final summation: The defense rests. *Annals of American Geographers, 87*(1), 178–180.

Geoportal (2015). *Národní geoportál INSPIRE*. https://geoportal.gov.cz/web/guest/home. Accessed 30 July 2015.

Gerber, R. V. (1981). Young children's understanding of elements on maps. *Teaching Geography, 1*, 128–133.

Golledge, R. G., Marsh, M. J., & Battersby, S. J. (2008). A conceptual framework for facilitating geospatial thinking. *Annals of the Association of American Geographers, 98*(2), 285–308.

Kim, M., Bednarz, R., & Kim, J. (2012). The ability of young Korean children to use spatial representations. *International Research in Geographical and Environmental Education, 21*(3), 261–277.

Kovařík, V. (2012). *Effects and limitations of spatial resolution of imagery for imagery intelligence.* Proceedings of the International Conference on Military Technologies and Special Technologies – ICMT'-2012 (pp. 363–368). Trenčín: Alexander Dubček University of Trenčín.

Lee, J., & Bednarz, R. (2012). Components of spatial thinking: evidence from a spatial thinking ability test. *Journal of Geography, 111*(1), 15–26.

Liben, L. S. (1999). Developing an understanding of external spatial representation. In I. E. Sigel (Ed.), *Development of mental representation*. Mahwah: Lawrence Erlbaum Associates.

Liben, L. S., & Downs, R. (1989). Understanding maps as symbols: Development of map concepts in children. In Reese H. (Eds.), *Advances in child development*, New York: Academic Press.

Liben, L. S., & Downs, R. (1992). Developing an understanding of graphic representations in Children and Adults: The Case of GEO-Graphic. *Cognitive Development, 7*, 331–349.

Liben, L. S., & Yekel, C. A. (1996). Preschoolers' understanding of plan and oblique maps: The role of geometric and representational correspondence. *Child Development, 67*(6), 2780–2796.

Lillesand, T., Kiefer, R. W., & Chipman, J. W. (2008). *Remote sensing and image interpretation*. New York: Wiley.

Lloyd, R., Hodgson, M. E., & Stokes, A. (2002). Visual categorization with aerial photographs. *Annals of the Association of American Geographers, 92*(2), 241–266.

MacEachren, A. M. (2004). *How maps work: Representation, visualization, and design*. New York: The Guilford Press.

Muir, M., & Blaut, J. (1969). *The use of aerial photographs in teaching mapping to children in first grade: An experimental study*. The Minnesota Geographer 22 (pp. 4–19). New York: Wiley.

Pravda, J. (2001). *Výskum niektorých stránok kartografickej gramotnosti*. [Research of certain aspects of cartographic literacy]. Bratislava: Geografický ústav SaV.

Robinson, A. H., & Petchenik, B. B. (1977). The map as a communication system. *Cartographica: The International Journal for Geographic Information and Geovisualization, 1*(14), 92–110.

Schuit, W. (2011). A method for teaching topographic map interpretation. *Journal of Geography, 110*(5), 209–216.

Schultz, R. J., Kerski, J. J., & Patterson, T. C. (2008). The use of virtual globes as a spatial teaching tool with suggestions for metadata standards. *Journal of Geography, 107*(1), 27–34.

Stea, D., & Blaut, J. (1973). Some preliminary observations on spatial learning in school children. In R. M. Downs & D. Stea (Eds.), *Image and environment*. Chicago: Aldine.

Svatoňová, H., & Rybanský, M. (2014). Visualization of landscape changes and threatening environmental processes using digital landscape model. *IOP Conference Series: Earth Environmental Science, 18*, 012018. doi:10.1088/1755-1315/18/1/012018.

Van Coillie, F., Gardin, S., Anseel, F., Duyck, W., Verbeke, L., & De Wulf, R. (2014). Variability of operator performance in remote-sensing image interpretation: The importance of human and external factors. *International Journal of Remote Sensing, 35*(2), 754–778.

Van der Schee, J. A. (1987). *Kijk op Kaarten* [Look at maps] (Dissertation). Amsterdam: Vrije Universiteit.

Van der Schee, J. A. (2000). Helping children to analyse a changing world: Looking for patterns and relationships in space. In M. E. Robertson & R. Gerber (Eds.), *The child's world: Triggers for learning* (pp. 214–231). Camberwell: ACR Press.

Wiegand, P. (2002). *Learning and teaching with maps*. Abingdon: Routledge.