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Education in Cartography: What is the Status of Young People's Map Reading Skills?

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Abstract: Due to recent technological progress, maps have become more popular than ever before. This is especially true for young people, who interact with these technologies on a daily basis. Therefore, it is essential that these potential map users possess sufficient knowledge and skills to process the content of cartographic products. A user study was conducted during which pupils (aged 11-18 years) and geography students (>18 years) had to solve a number of cartography questions using topographic maps. The data were analysed statistically, taking into account a number of potentially influencing factors (user characteristics) on the participants' results: age, gender, youth club membership, knowledge about the area, among others. The results show a rising trend in the pupils' scores with increasing age, which can be explained by education in cartography at school. Geography students perform much better, but no influence of any other user characteristics was detected. For pupils, knowledge about the area and gender might be considered as influencing factors. However, the detected influence of gender depends on the scoring system.

Keywords: Map reading, user study, young people

Introduction

Nowadays, maps can be found nearly anywhere and they are used more than ever before. Therefore, it is important to know how well the educational systems succeed in teaching vital map reading skills. Kimerling et al. (2009) provide a number of reasons why maps (in general) are popular: their convenience in use, simplification of surroundings, credibility and strong visual impact. Despite the popularity of the Internet and mobile applications, paper maps are still widely used. Paper documents (including maps) still have a lot of advantages in comparison to digital products: easy to use, transportation,

archiving, tangibility,... They function as visual cues because they are easier to read, give an overview of the complete document, etc. (Johnson et al. 1993; Hurst & Clough 2013).
Nevertheless, already in 2003 it was estimated that the number of maps distributed daily on the Internet (about 200 million), surpassed the number of maps printed each day (Peterson 2003). The mapping site MapQuest had, for example, 47.5 million unique visitors in May 2008 (Mapquest, 2008). GlobalWebIndex.net published (on August 2, 2013) a top 10 of global smartphone apps. They stated: “It’s no surprise to see that Google Maps is No. 1 used by 54% of the global smartphone population in the last month…”. The popularity of the mobile mapping sites is closely linked with the world wide use of the Global Positioning System (GPS), which has been integrated in smartphones (Pedersen et al. 2005; Hurst & Clough 2013). All these applications have made maps more accessible to the general public.
What is more, with the introduction of Web 2.0 and neocartography, the ‘general public’ can also contribute to the contents of these maps or create so-called mashup-maps based on available API’s (Turner 2006; Haklay et al. 2008; Crampton 2009; Kraak 2011; Roth & Ross 2012; Dodge & Kitchin 2013; Peterson 2014). The best known example of user generated contents (or Volunteered Geographic Information, VGI) can be found in Open Street maps. Figure 1 shows the rising trend in the number of registered users and contributors of OSM since 2007.

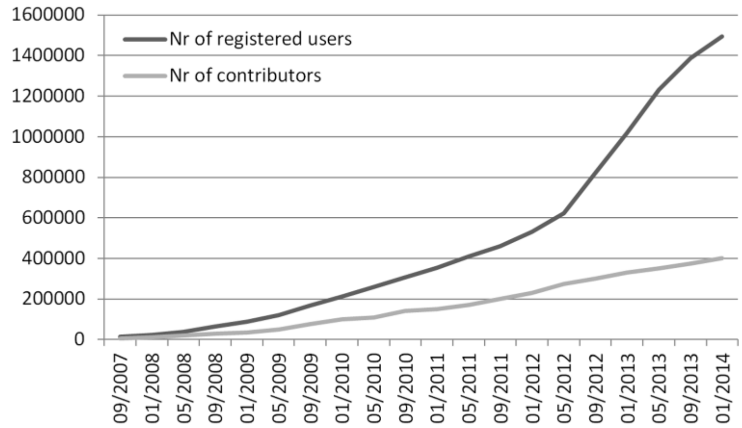


Figure 1: Rising trend in the use and users of Open Street Map
(source: based on http://wiki.openstreetmap.org/wiki/Stats)

The website ‘ProgrammableWeb.com’ gives an overview of API’s, mashups and the Web as platform. On this website, 379 API’s are listed in the category ‘Mapping’ and 2740 mashups are tagged in this category. This means that the creation of maps has also become much more accessible to the general public. Because maps are more commonly used (and created) by the general public, it is of major importance that these products still fulfil their main goal: effective communication of spatial and geographical information (e.g. MacEachren 1995; Robinson et al. 1995). In the past, an influential communication model has been proposed by Koláčný (1969) (see Figure 2), which clearly illustrates the need for education in cartography for both the map makers and the map users.

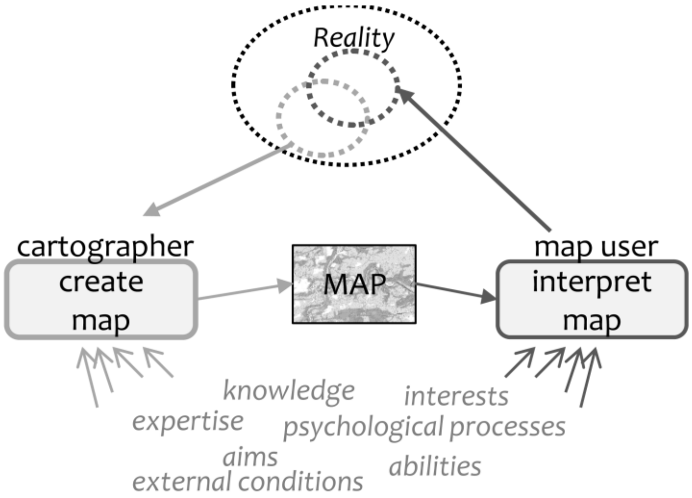


Figure 2: Cartographic communication model as proposed by Koláčný (1969)

Liben and Downs (1992) linked cartography with 'graphic representations that represent the world' or GEO-Graphics. They defined a graphic representation as follows "A graphic representation is composed of marks (points, lines, shading, colors) on a two-dimensional surface such that the marks carry meaning through the properties of their spatial arrangement on the surface (size, shape, density and distribution). The spatial arrangement is designed to stand for some referent, be it: real, constructed or imagined". They also added that these graphic representations can use symbol systems that may not be spatial themselves, to communicate information. A person's ability to understand cartographic signs can be used, according to Gerber (1984), to measure his competence in cartographic language. The theories on 'how maps work' and thus how they can be processed by us are described in detail by MacEachren (1995).

Nevertheless, understanding the meaning of these symbols and signs requires some kind of education. Ikonovic (2001) and Phillips (1989) stressed the need for education regarding how to learn to read maps (and other graphic displays). In this context, individuals who cannot understand these symbols (and thus maps), can be considered as functional map illiterate (Clarke 2003, 2014). This is also closely linked to the concept of spatial literacy as described by van der Merwe (2009). Clarke (2003, 2014) stated that map literacy is not well understood yet but that it is narrowly connected with literacy – the ability to read and write – and numeracy – the ability to calculate. He defined three levels of competence concerning map literacy, which are associated with the main (subsequent) map use activities as presented by Muehrcke and Muehrcke (1978) and Kimerling et al. (2009): map reading, map analysis and map interpretation. Nonetheless, other authors used a different subdivision in the subsequent map use activities. Keates (1996), for example, described the map reading process as the detection of symbols; discrimination of symbols; understanding of the symbols' meaning; recognition of symbols; interpretation (adding meaning to it); retaining relationships. Board (1978) identified three main groups of map reading tasks, which should all be addressed in order to effectively evaluate map reading skills: navigation, measurement and visualization.

Research on Education in Cartography

Nakos et al. (1999) described a theoretical approach regarding cartography didactics. They considered the why, what and how of school cartography. The rising popularity of maps is a main driving force for the why-component. Nakos et al. (1999) break down the what-component into three parts: (1)'conceptual and geometrical structure of the map, including generalization and symbolization, scale and projections'; (2) 'locations, attributes at locations and relations between these'; (3) 'the different map reading processes as described by Keates (1996)'. The how-component refers to the teaching methods that should be used, such as lectures and activities. They stress that this component should focus on the development of the cartographic concepts and map-use skills, not on the education of efficient map makers (Nakos et al. 1999).

Most research on education in cartography focused on children (<12 years old). This can be explained by their ability to understand certain aspects of cartography at a certain stage in their development. A number of authors (e.g. Newcombe & Liben 1982; Liben 2009) reviewed (research in) the children's understanding of fundamental symbolic and spatial meaning of maps in their development: use of symbols, projections, spatial concepts, scale, unfamiliar viewing angles, etc. Other studies highlighted the children's skills to understand specific cartographic topics such as generalization (Filippakopoulou et al. 2000); landform representations (Filippakopoulou et al. 1998); symbolization in crises situations (Bandrova & Vasilev 2008) or in general (Liben & Downs 1992).

Bac-Bronowicz (1999) focused on the use of satellite and aerial photographs in cartographic education of children aged 11-12 years. Wiegand and Tait (1999) investigated the use of a software mapping tool in the cartographic education of children in the age span 11-14 years. Nevertheless, few studies focused on the cartographic education of pupils between the age of 12-18 years. It is important however to know how well these pupils are able to read maps, especially in the light of the increasing popularity of cartographic products.

Another group of researchers focused on the education and training of cartographers at universities (age >18). Meissner (2003), for example, presented an overview of the various national education programs in cartography in Europe. Other authors discussed the changes that have taken place in the cartographic discipline in higher education during the past decades (Beard et al. 1993; Zentai 2009; Fraser et al. 2011). However, there exists almost no research considering the map reading skills of these future professional cartographers.

The aim of this article is to fill these gaps. A user study was conducted in which the map reading skills of pupils, aged between 11-18, will be assessed. Certain characteristics of these pupils will be considered as well, as these can influence their skills (Phillips 1989). In Belgium, the skills are listed in 'learning outcomes', or 'eindtermen' (ET) in Dutch. A summary of the end terms (related to cartographic skills) is presented in the next section. These map reading skills of these pupils will be compared to these of university students at the Department of Geography. The structure of the user study is described in detail in section 'Study design'.

Table 1: Cartography-related learning outcomes (ET) in basic and secondary education in Belgium

Basic education
World orientation, Space – Orientation and map skills
The pupils …
… are able to describe to each other a route between two places in their own community or city. They can also indicate this route on a plan. (ET 6.1)
… are able to, based on a map, calculate and describe the distance between two places in Flanders (ET 6.1bis)
-… are able to indicate in a practical situation the equator, poles, oceans, countries of the EU and continents on an appropriate map or globe (ET 6.2)
… are able to determine, during an orientation in the field, the compass directions (main and sub directions) based on the position of the sun or a compass (ET 6.3)
… are able to use terms like district, hamlet, village, city, province, community, country and continent in a correct context (ET 6.3bis)
…have a representation of the map of Flanders and Belgium as such that they can indicate the communities, provinces and province capitals in a practical situation (ET 6.4)
Secondary Education
1st grade (12-14 years)
The pupils…
…are able to describe a real landscape and image hereof with elementary geographical terms and indicate this on a corresponding map (ET 1)
…are able to read maps and plans by using the legend, scale and orientation (ET 2)
…are able to find and locate a map and a geographical element based on the table of contents and the index with names (ET 3)
…are able to name landscape components on a map of Flanders or Belgium and other linked regions, including relief areas, rivers, agricultural areas, industrial areas, agglomerations and cities, sea ports, axes of transportation, touristic regions and touristic centers. (ET 4)
... are able to read the elevation and elevation zones on a map using elevation points, elevation lines and colors (ET 14)
…learn spontaneously to consult the appropriate map (ET 5)
…know that information will be lost in a 2D representation of a 3D situation (Math, ET 29)
…use the concept of scale to calculate distances in geometric shapes (Math, ET 33)
…determine points on a surface using coordinates (Math, ET 38)
2nd grade (14-16 years)
The pupils…
…are able to indicate and name on a map: continents and oceans; the most important topographic units and rivers; the most important states; natural and human geographical entities (ET 1)
…are able to situate studied regions and themes on a simple thematic map of the world (ET 2)
…are able to cartographically represent geographical data in a simplified way (ET 17)
…are able to calculate distances between two given points in a surface, using their coordinates in a Cartesian system (Math, ET 40)
.. can resolve simple spatial problems using the attributes of plane figures (Math, ET 41)
…can illustrate, using examples, that information can be lost when depicting 3D situations in 2D (Math, ET 42)
…are able to calculate the effects of a change in scale on a volume and surface (Math, ET 44)
3rd grade (16-18 years)
The pupils…
…are able to indicate, with an example, that an image or map corresponds to a coded representation of the reality (ET 2)
…are able to select a map representation in function of its use (ET 17)
…are able to read a West-European weather map (ET 20)
…are able to estimate a weather situation taking into account weather maps and messages (ET 21)
…are able to read simplified geological and soil maps (ET 24)
... are able to illustrate using an example the importance of GIS for society (ET 3)
... are able to search for, organize and process geographical information in a simple way, using available contemporary information sources and techniques (ET 16)

Study Design

The main aim of this study is to assess the map reading skills of pupils in secondary education in Flanders. In order to be able to reach a potential high number of pupils, we decided to construct a questionnaire on paper with very simple tasks and a strict limited completion time. In this way, it would be easiest to convince teachers to do the test before their lesson as they would not lose too much time. Furthermore, the printed questionnaires - including the task description - could be handed over to the teachers who just needed to hand them out to their pupils and collect them again afterwards. The teachers only had to observe the pupils, check if they were working individually and maintain the time limitation. This simple structure did not leave much room for errors.

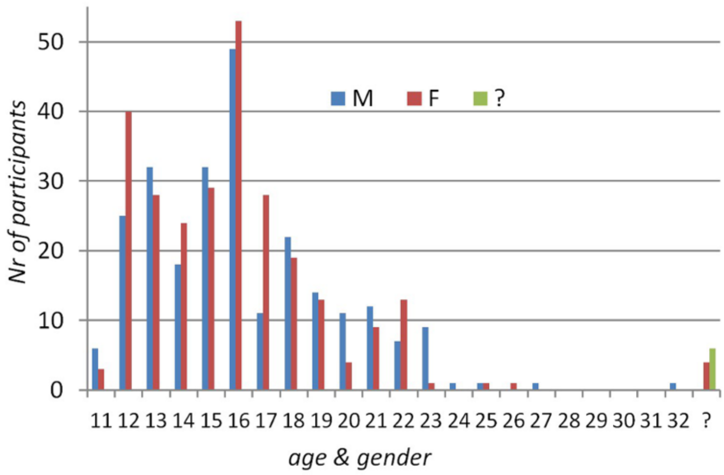
With a digital questionnaire, it would have been much easier to collect and analyze the data, as the answers would be stored directly in a digital format. However, with an online questionnaire we would not be able to control on which type of screen the maps would be visualized. The resolution and color range of the screen could have a severe impact on how the maps are displayed, which would make the answers incomparable. When all maps are printed with the same device, all map characteristics are fixed. The details of the study's structure are described in the next sections.

Participants

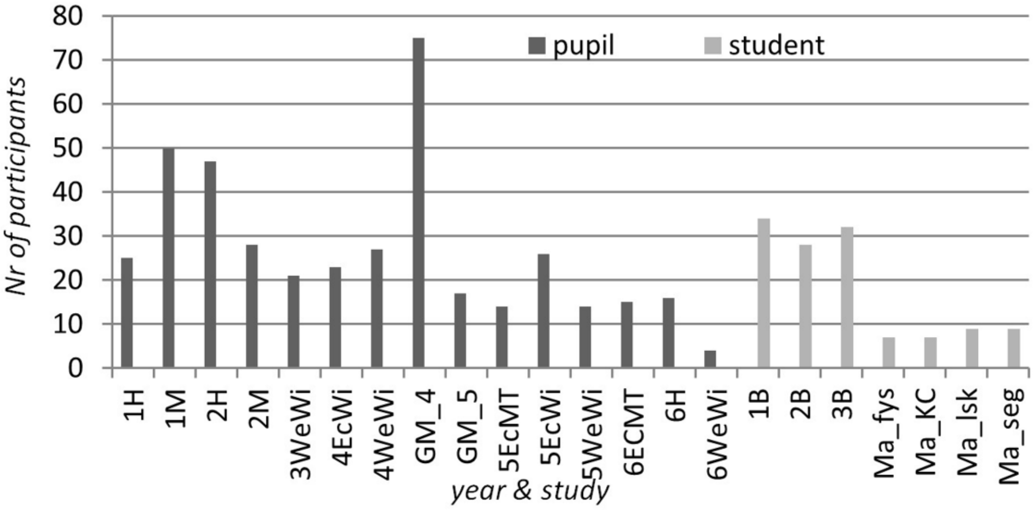
In total, 528 participants took part in the user study. Figure 3b shows the age distribution of all participants including the gender: 252 males, 270 females and 6 persons who did not indicate their gender. From this pool of participants, 402 of them were pupils in secondary education and 126 studied at the Department of Geography, Ghent University (Belgium). Most of the pupils took classes at the secondary school the 'Immaculata Maria-instituut' in Roosdaal (Flanders, Belgium). However, some pupils were tested in the context of the 'Geomobiel'-project. In this project, the pupils visited the university in group and follow a number of modules (e.g. GIS, GPS, topography). Before starting the program, they were asked to take part in the test. All participants were tested in group, corresponding to the class in which they were following a course. These groups are visualized in Figure 3a and 3c.

pupils	
H	Trade
M	Modern Sciences
WeWi	Science-Maths
EcWi	Economy - Maths
EcMT	Economy – Modern Languages
GM	'Geomobiel'-project
students	
B	Bachelor (student)
Ma	Master (student)
fys	Physical Geography
KC	Ma in Surveying and Geomatics
lsk	Landscape
seg	Social and Economic

(a)



(b)



(c)

Figure 3: Distribution of the participants, including study, age and gender

The Experiment's Documents

Every participant received the same set of documents, consisting out of an introduction, a bundle of maps, a bundle of questions related to the maps and a questionnaire (see Figure 4). These documents will be explained in detail in the next paragraphs. All these documents were handed out to the participants at the beginning of the test. They were told to start reading the instructions on the introduction-document before looking at the other documents.

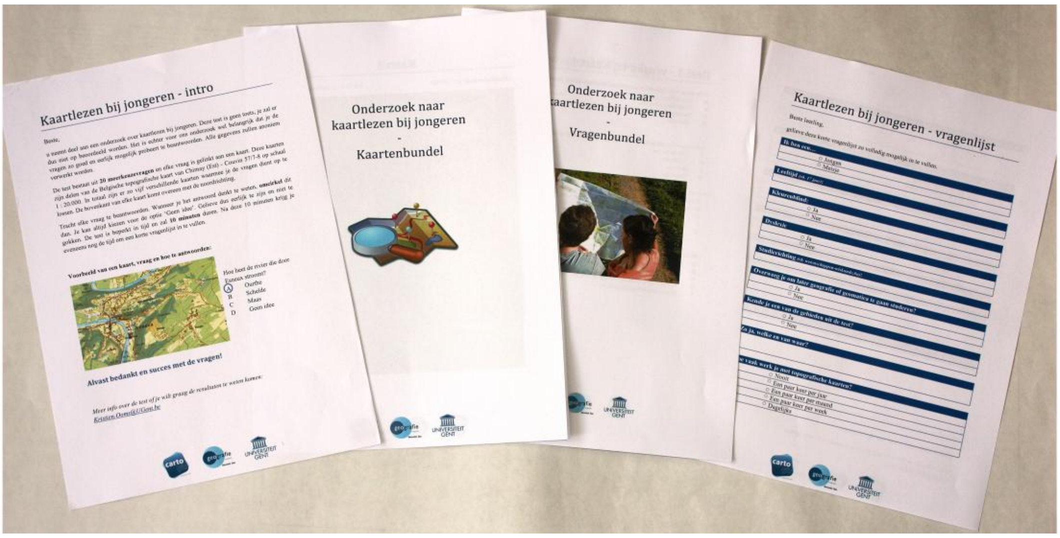
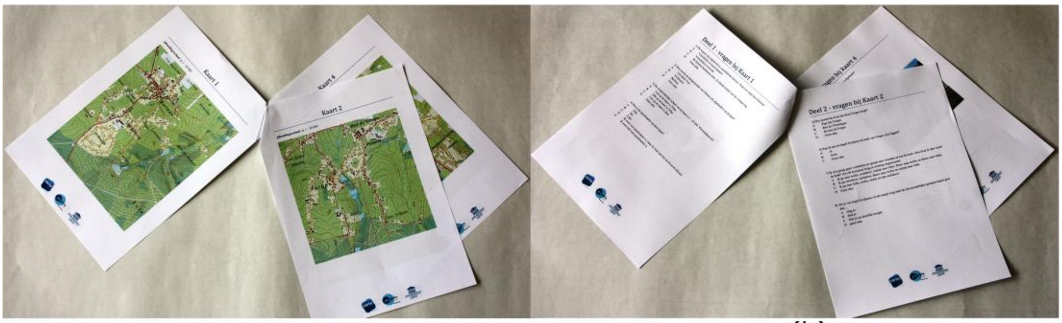


Figure 4: Overview of the documents handed out to the participants

In the introduction, it was explained that the participants would not receive a score on the test, but that it was important to try to fill it in as good and honest as possible. It was also stressed that all data would be analyzed anonymously. Next, the introductory text explained the structure of the questionnaire, the map sheet that was used (including the scale) and the total number of map samples that were included. Finally, the participants were instructed on how to answer a question correctly (draw a circle around the right answer, illustrated at the bottom) and informed that the study was limited in time: they only had 10 minutes to complete 20 questions. After the strict time limit, some additional time was foreseen to be able to fill out the post-study questionnaire. After the pupils or students had read the instructions, they had the possibility to ask questions if the task was not entirely clear.

The bundle with maps (Figure 5a) shows the five map samples that were selected, each on a separate page, printed recto-verso. The number of each map was indicated at the top of the page. We decided to create one separate bundle with maps and one with the related questions, because as such the participants could easily place the questions and associated map next to each other. The sample maps that were selected for this study are discussed in the next section.



(a) (b)

Figure 5: Bundle with sample maps (a) and related questionnaire (b)

The bundle with the questions related to the maps was also printed recto-verso (see Figure 5b). In total, four questions were asked with each map, which were placed together on a separate page. On the top of each page, we indicated which sample map to use with this subset of questions. The content of this questionnaire is discussed further on in this paper.

The last page of the set of documents was a questionnaire, consisting of one page, printed recto-verso. This could be completed after the 10 minute time limit of the main questionnaire. This questionnaire is discussed in detail in the section 'Post-study questionnaire'.

Selected Maps

In order to verify the pupils' and students' map reading skills, we selected a collection of representative map samples. It was decided against thematic maps, since they come in wide variety in forms, functions and complexity. Not all pupils (or students) may be familiar with a certain type of thematic map and the obtained results are only representative for that type of map. What is more, the Belgian topographic maps are produced on a national level, which means that all map sheets have the same layout and design (symbology), independent of which community they cover. The large-scale maps (1 : 20 000 and 1 : 10 000) are sometimes used for assignments in the classroom, but also for leisure activities such as walking, cycling, locating points of interest and possibly in the context of youth club activities. The symbology (and content) that is visualized on both map scales is almost the same.

Moreover, topographic maps (and especially on a large scale) contain a wide variety of cartographic elements with which the students should be familiar: scale, contour lines, visualization of roads, rivers, different categories of buildings, land cover and/or land use, etc. These elements were incorporated in the questionnaire to verify their level of expertise in map reading.

In order to exclude a bias due to previous knowledge of the areas shown on the map, areas located in the French community of Belgium were chosen. We decided to select only one map sheet at a scale of 1 : 20 000 – Chimay (Est)–Couvin 57/7-8 –, from which five smaller sample maps were selected. Each of these sample maps (see Figure 6) contains specifically interesting features which were included in the questionnaire: surrounding of a village or a city, large difference in altitude, etc. When placing the selected map sheets in the actual questionnaire, they had to be minimized and thus rescaled. The resulting five sample maps are all visualized at a scale of 1 : 30 000.

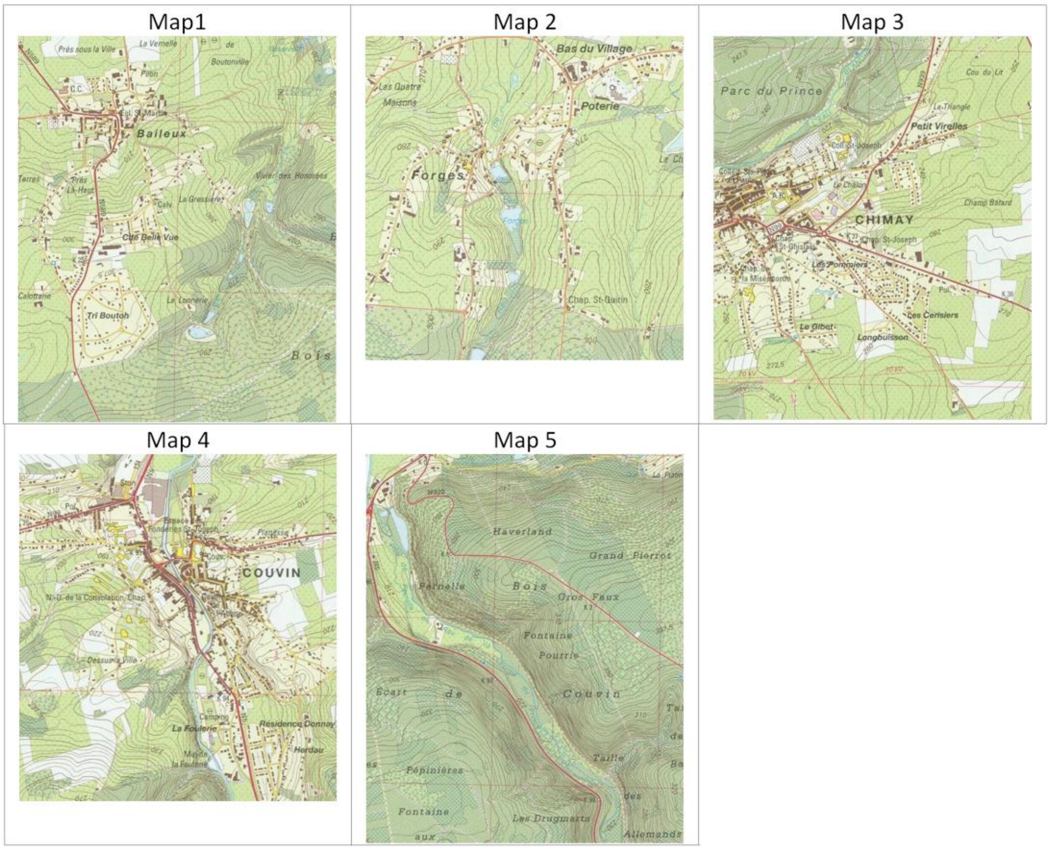


Figure 6: The five sample maps from the topographic map sheet Chimay (Est) – Couvin 57/7-8 on 1 : 20 000

Questionnaire Related to Map Reading Skills

The questionnaire related to the map reading skills consisted out of a cover page and five pages with 20 different questions. Each of the pages with questions corresponded to one of the five sample maps. On each page – and thus related to each map – four multiple choice questions were listed. Except for two (out of 20), all questions listed four potential answers indicated with A to D. The last option (D) was always 'I don't know'. In the introduction, it was stressed that the participants should answer the questions honestly: if they did not know the answer on a question they should not guess but indicate option D. All questions were asked in Dutch, the native language of the pupils and students who took part in the study.

The questions were selected in a way that different map reading skills were tested, taking into account the specific characteristics of topographic maps, such as contour lines. All 20 questions were translated and listed in Table 2. The related map reading task, according to Board (1978), is indicated below each question. Often, a combination sub-tasks was required to solve the question. For example, when the highest camp site needed to be determined, the camp sites itself needed to be found first. To do this, the correct symbol had to be selected and located on the map. Next, the participant had to determine its height and measure which of the solutions was the highest. These sub-tasks are listed in the table in the attachments. Often, participants have to be able to recognize a symbol for a certain object. Nevertheless, recognizing a symbol for a church or campsite without

a legend might be more straightforward, than for a public pool or supermarket. These latter type of (more difficult) symbols are indicated with an asterisk in sub-task lists.
In education, teachers often use Bloom's Taxonomy (Bloom 1956) as a guide to assess on which level their assignments test the pupils thinking skills. This taxonomy distinguishes between six subsequent levels of thinking skills, each with an increased level of difficulty. This is illustrated in Figure 7, along with an explanation of the levels. Some revisions have been proposed (e.g. Krathwohl 2002), but the structure still remained nearly the same over the years.
What is more, the different levels in this (revised) Taxonomy correspond very well to the levels of competence presented by Muehrcke and Muehrcke (1978) and Kimerling et al. (2009): map reading corresponds to the combination of 'remembering' and 'understanding'; map analysis with 'analyzing' and map interpretation with 'evaluation'. The same holds true for how Keates (1996) described the map reading process: detection and discrimination of symbols corresponds to 'remembering'; understanding of the symbols' meaning to 'understanding'; recognition of symbols to a combination of 'understanding' and 'applying'; interpretation to a combination of 'applying' and 'analyzing'; retaining relationships to a combination of 'analyzing' and 'evaluation'.
Therefore, we opted to apply the revised version taxonomy on the questionnaire to obtain insights in the (highest) level of thinking skills that participants should have addressed in order to be able to solve a certain question. To derive the appropriate level of thinking skills, we used the sub-tasks associated with each questions as a starting point. Mainly the type of sub-tasks gives an indication of the subsequent levels of thinking skills required to solve to question. The highest required level is noted down for each question. Furthermore, the obtained levels, verified by (geography) teachers in secondary and higher education, are also added to Table 2. Nevertheless, we must note here that the structure of our questionnaire introduces a limitation on the level that can be obtained: the two highest levels (synthesis and evaluation) require open questions.

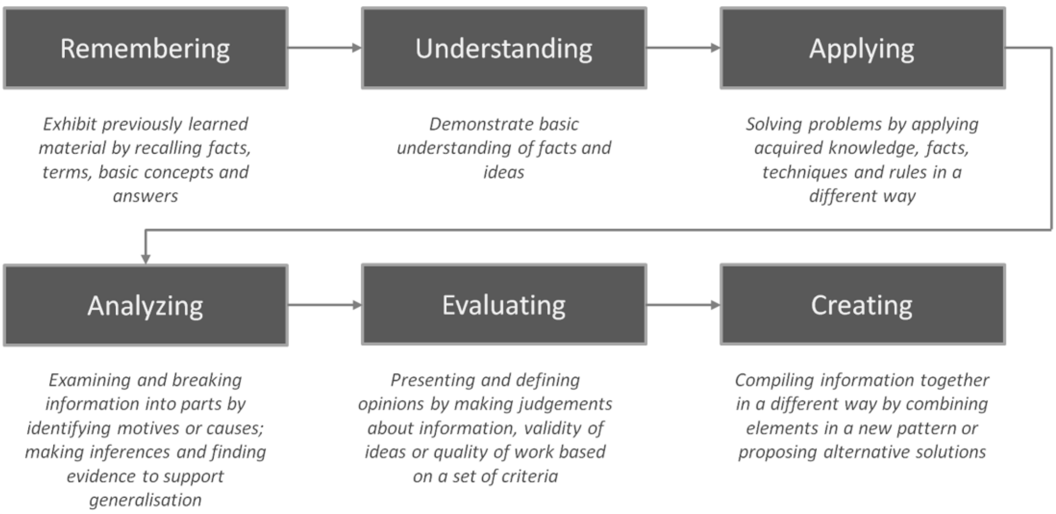


Figure 7: The revised Taxonomy of Bloom *(after Krathwohl 2002)*

The learning outcomes (ETs, as listed in Table 1) which can be associated with each of the questions are listed after the map reading tasks in Table 2. Based on the required skills that should be obtained with the associated learning outcomes, pupils of a certain age should be able to solve the question. It has to be mentioned, however, that it is impossible to verify whether a participant really reached a certain learning outcome based on the obtained score. Although it was discouraged, the participants could, for example, still guess on a question if he did not know the answer. Furthermore, it cannot be ensured that pupils in a certain year of study already obtained the listed learning outcomes, as this is dependent on the teacher's schedule of the different topics. Related to a number of questions, ET2-SE-1stgr (meaning: ET2 in secondary education, 1st grade) is mentioned. Based on this learning outcome, pupils should be able to read a map using a legend, scale and orientation. However, during the test the pupils did not receive a legend of the sample maps. Their knowledge of the symbolization should be based on cartographic insights and possible previous encounters (familiarity) with the selected topographic map series. This way, the participants would not lose any time looking up the meaning of a certain symbol. Furthermore, the deviation in the participants' scores becomes more pronounced: knowledge of the symbols or not.

Finally, the average score that was obtained on each of the questions is listed in the last column of Table 2. These score are categorized in five classes, indicated by a color code: green, white, yellow, orange and red. These classes and the scores will be discussed in detail in relation to the sub-tasks and map reading tasks in a next section.

Table 2: Questions related to the five maps, with related sub-tasks and map reading task(s) and average score

	Question			
	Blooms 's (revised) Taxonomy	**Map reading tasks**	**Learning outcomes**	**Score (%)**
Map 1	**1. The roads are depicted in different colors. What do they stand for?**			
	Level 4: Analyzing	Visualization	ET17-SE-2^{e}gr; ET2-SE-3^{e}gr	78.37
	2. What is the name of the district of Chimay, depicted on the map?			
	Level 3: Applying	Visualization	ET6.3bis-BE	74.81
	3. The original scale of the map is 1 : 20 000. What does this mean?			
	Level 3: Applying	Measurement	ET2-SE-1^{e}gr; ET33-SE-1^{e}gr-Math	59.58
	4. What is the equidistance on this map?			
	Level 3: Applying	Measurement	ET14-SE-1^{e}gr	17.35
Map 2	**5. What is the name of the river that runs through Forges?**			
	Level 2: Understanding	Visualization	ET1-SE_1^{e}gr; ET17-SE-2^{e}gr	41.95
	6. From the chapel St-Quirin, can I see the church of Forges?			
	Level 4: Analyzing	Visualization; Measurement	ET1-SE_1^{e}gr; ET29-SE-1^{e}gr-Math	65.59
	7. I would like to play soccer and meet my friends at the church. How do I have to walk starting from the church? (a direction is indicated at every crossroads)			
	Level 4: Analyzing	Visualization; Navigation	ET6.1-BE; ET2-SE-1^{e}gr; ET17-SE-2^{e}gr ET2-SE-3^{e}gr	33.46
	8. If you go from the chapel St-Quirin via the orange road to the chapel situate somewhat more to the north then… (up/down/same height)			
	Level 4: Analyzing	Visualization;	ET6.3-BE; ET14-SE-	68.69

		Navigation	1^{e}gr; ET2-SE-1^{e}gr; ET17-SE-2^{e}gr; ET2-SE-3^{e}gr	
Map 3	**9. Which school is situated closest to the roofed public pool?**			
	Level 4: Analyzing	Visualization; Measurement	ET6.1bis-BE; ET2-SE-1^{e}gr	24.65
	10. Which N-way does not run through Chimay?			
	Level 3: Applying	Visualization	ET6.3bis-BE; ET2-SE-1^{e}gr	71.54
	11. What is the highest point on the map?			
	Level 3: Applying	Measurement	ET14-SE-1^{e}gr	86.89
	12. What does the dark green color on the map mean (eg. Upper left corner)?			
	Level 2: Understanding	Visualization	ET2-SE-1^{e}gr	84.93
Map 4	**13. Is there a police office on the map?** *(indicate associated road number in answer)*			
	Level 3: Applying	Visualization	ET2-SE-1^{e}gr	38.96
	14. This picture is taken from which position on the map?			
	Level 4: Analyzing	Navigation	ET2-SE-1^{e}gr;	52.88
	15. How many supermarkets are there in the city?			
	Level 2: Understanding	Visualization	ET2-SE-1^{e}gr;	15.37
	16. At which height is the camp site situated?			
	Level 3: Applying	Visualization; Measurement	ET2-SE-1^{e}gr; ET14-SE-1^{e}gr	26.74
Map 5	**17. In which direction is the river flowing?**			
	Level 4: Analyzing	Visualization; Navigation	ET6.3-BE; ET1-SE_1^{e}gr	49.64
	18. What does the section of the river's valley look like?			
	Level 4: Analyzing	Visualization; Measurement	ET1-SE_1^{e}gr; ET14-SE-1^{e}gr	55.47
	19. I organize a hike. To avoid traffic and walk in a calm environment, it would be best to walk on the … (color and shape of the lines).			
	Level 4: Analyzing	Visualization	ET2-SE-1^{e}gr;	58.27
	20. Which slope is most steep?			
	Level 3: Applying	Visualization; Measurement	ET1-SE_1^{e}gr;ET14-SE-1^{e}gr	77.78

For question 4, there were five potential solutions as there were two options for the 'I don't know'-answer: 'I know what equidistance is but I do not know how to read it' and 'I do not know what equidistance is'. Concerning question 6, there were only three possible answers: 'yes', 'no' and 'I don't know'. The suitability of these questions (and related maps) was verified in a pilot study, which was executed in the context of a Master Thesis project at the Department of Geography (UGent) (Van der Veken 2013). The questions and answers are formulated as such that they should be easily understood by pupils who start their education in Geography at the university. Consequently, this might also have an influence on the pupils results, as they might not have fully understood a question or answer (e.g. functionality of a road).
A strict time limit of 10 minutes was placed on the completion of this questionnaire. This time limit was also determined in the Master Thesis (Van der Veken 2013). Van der Veken found that students in the Master of Geomatics and Surveying – which can be considered experienced in the field – needed on average 7.5 minutes to complete the test. In order to allow non-experts to fill out most of the questions (to obtain sufficient data to

process) the time limit was somewhat increased. The goal of introducing the time limit was twofold. First, if the pupils had plenty of time to solve the questions, they would be able to answer more questions correctly. However, with a limited time they would only be able to answer the questions they could solve easily. This way, the obtained results would be more pronounced regarding their acquired (map reading) skills. Second, the time limit makes the study more manageable and structured. This ensures that the study can be executed under the same conditions at different locations: different classes in schools, with the Geomobiel-project and with the students at the university. A limited timeframe was needed to complete the whole test (about 15 minutes), which makes it easier to convince teachers and professors to include the test in their lessons and as such, to reach more test persons.
The pilot study contained an additional test during which 6 pupils (in 3rd year) completed the questionnaire, without the time limit. During this test, the participants were asked to verbalize their thoughts while solving the questions. The resulting recordings (audio and video) give vital information regarding the suitability of the questions, on the one hand, and the strategy to solve the questions on the other hand.

Post-study Questionnaire

The post-study questionnaire consisted of a single page, printed recto-verso. On this page, participants were asked to fill out certain personal characteristics: age, gender, study, color blindness, dyslexia, etc. (Nielsen 1993; Feeney 2003; Harrower & Brewer 2003; Jenny & Kelso 2007). Some of the questions were related to the maps that were shown (e.g. familiarity), which is why participants had to fill out the questionnaire after the main test. This information can be used to group participants according to their characteristics, or to explain potential outliers in the data. In order to avoid any biases due to previous knowledge, the participants were asked if they knew any of the regions that were depicted. They had to indicate which of the regions they knew and how they knew them (to determine their level of knowledge regarding the area). They were also probed for their level of experience with topographic and digital maps. Finally, the participants had to indicate whether they were a member of a youth club (and if so: which club). In youth clubs, maps are typically used for hiking or to plan a dropping or other activities. The participants who were a member of a youth club were also asked for which activities they used maps.

Results

Scoring Systems

An overview of the answers of all participants on the 20 multiple-choice questions can be found in Table 3a-3b. The greyscale indicates how often a certain answer has been chosen (out of the options). At the bottom, the sum of all answers which have been collected per question. As a main trend it can be noticed that this number decreases near the end of the questionnaire, which can be explained by the time limit: not all participants were able to reach the end of the questionnaire. The last number of this row indicates the percentage of all participants answering the last question: 73.30%.

The following row lists the correct answer out of the multiple-choice list. At the bottom, two scoring systems are listed. The first one compares the number of correct answers to the number of answers that were given (e.g. 301 correct answers out of 387 answers: 77.78% correct answers). The second one compares the number of correct answers to the number of participants (e.g. 301 correct answers from 528 participants: 57.01% correct answers). The last two numbers on these rows (see Table 3b) give the average score of all participants across the 20 questions according to the two scoring systems.

Table 3a: Overview of results obtained Q1 – Q12 in the two scoring systems

	map 1				**map 2**				**map 3**			
	Q1	***Q2***	***Q3***	***Q4***	***Q5***	***Q6***	***Q7***	***Q8***	***Q9***	***Q10***	***Q11***	***Q12***
A	413	35	311	33	257	345	97	95	29	50	14	37
B	90	23	32	8	219	116	170	362	125	50	444	434
C	7	389	169	89	18	65	50	40	210	367	21	19
D	17	73	10	41	28		191	30	143	46	32	21
E				342								
Total	**527**	**520**	**522**	**513**	**522**	**526**	**508**	**527**	**507**	**513**	**511**	**511**
CorrectAns.	**A**	**C**	**A**	**C**	**B**	**A**	**B**	**B**	**B**	**C**	**B**	**B**
AvgSc1 (%)	78.37	74.81	59.58	17.35	41.95	65.59	33.46	68.69	24.65	71.54	86.89	84.93
AvgSc2 (%)	78.22	73.67	58.90	16.86	41.48	65.34	32.20	68.56	23.67	69.51	84.09	82.20

Table 3b: Overview of results obtained Q13 – Q20 in the two scoring systems

	map 4				**map 5**				
	Q13	***Q14***	***Q15***	***Q16***	***Q17***	***Q18***	***Q19***	***Q20***	
A	122	56	43	184	205	223	44	301	
B	21	149	58	123	169	56	72	25	
C	187	257	71	83	10	44	229	40	
D	150	24	290	70	29	79	48	21	
E									**Total (%)**
Total	**480**	**486**	**462**	**460**	**413**	**402**	**393**	**387**	**73.30**
CorrectAns.	**C**	**C**	**C**	**B**	**A**	**A**	**C**	**A**	
AvgSc1 (%)	38.96	52.88	15.37	26.74	49.64	55.47	58.27	77.78	**56.52**
AvgSc2 (%)	35.42	48.67	13.45	23.30	38.83	42.23	43.37	57.01	**49.85**

The overall score is 56.52% or 49.85% depending on the scoring system. The lowest score was obtained for question 15. In this case, the participants had to count the number of supermarkets in the city. This low result could be explained by the time limit, as most participants were not sure that they counted all supermarkets they answered option D. The second lowest score was obtained for question 4, in which the participants had been asked what the equidistance was on the map. From the answers on the different options, option E was chosen most frequently (66.67% of the answers): 'I do not know what equidistance is'. The third lowest score was obtained for question 9. In this case, the participants had to indicate which school was closest to the swimming pool. In order to be able to solve this question, participants had to be able to distinguish the symbols of a school and a swimming pool and measure the distances. Most participants (41.4%) gave the answer C, which is not correct: Le Châlon is closest but this is not a school. A high number of participants indicated however that they did not know the answer (28.2%). The highest number of correct answers had been registered for questions 11 and 12 in which the highest point had to be located and the symbolization of a forest had to be known respectively. These general results might have been influenced, on the one hand, by the participants' characteristics: age, gender, previous experience, etc. The type or complexity of the question, on the other hand, could also influence these outcomes. This will be discussed in detail in the next sections.

Influence of Participants' Characteristics

The participants had been asked to fill out a number of their characteristics in the post-study questionnaire. As only 12 participants indicated to be color blind and 31 to have dyslexia, these groups are not displayed in the graphs as they are too small in comparison to the main group. However, they will be included in the statistical tests later on (see next section). The graph in Figure 8a, shows the scores of the different groups of participants for questions 1-10 separately. In Figure 8b, the score related to questions 11-20 are visualized. In these graphs, the first scoring system is used: a comparison of the number of correct answers to the total number of answers on that question (in %). Otherwise, a steadily decrease in the scores would be visible, caused by the time limit: not all participants were able to answer all questions. The pupil-student (P-S) comparison is presented in grey; male-female (M-F) in blue; membership of a youth club (YC-NYC) in green; and knowledge about the area (KA-NKA) in red.

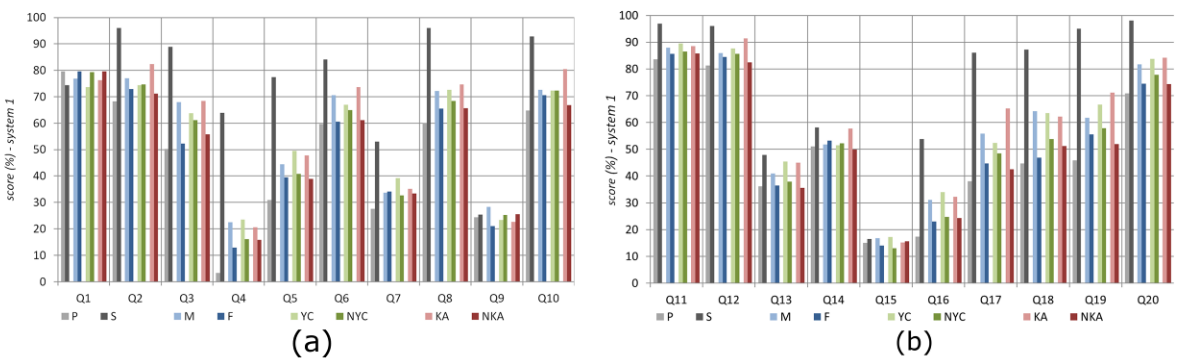


Figure 8: Scores on the 20 questions based on participants' characteristics

The dark grey bars show the geography students' results, which are clearly visible in the graph due to the high scores compared to pupils. Especially the last five questions (Q16-Q20) show a distinctively high score for students, which might be explained by pressure due to the time limit, which students seem to be more able to deal with than pupils. Table 4 gives an overview of how many participants were included in each group and how many of them completed the last question (in %). More students (79.20%) were able to fill out all questions in comparison to the pupils, where still 71.64% completed all questions within the 10 minutes time limit. The students' response rate is also highest in comparison to all other groups. The two last rows list the average score for each group in the two scoring systems explained before. Here it can also be noticed that the average score for the students is the highest (in both scoring systems) in comparison to all other groups, and that the pupils have the lowest score.

Table 4: Overview of the number of participants, response rate on the last question and average scores for each group of participants.

	P	S	M	F	YC	NYC	KA	NKA
N	402	126	252	270	106	357	177	342
completed? (%)	71.64	79.20	71.71	75.56	75.47	74.23	75.14	73.10
avg_score1 (%)	47.65	74.36	57.19	51.38	57.54	53.66	59.72	51.38
avg_score2 (%)	43.74	69.88	52.33	47.78	53.58	49.69	55.14	47.41

In the previous section, it was noticed that the lowest score was related to Q15. Figure 8a shows that all groups obtained a similar low score regarding this question, which can – as mentioned before – be explained by the time limit. For Q4 – the second lowest result – most students (score1 = 63.87% and score2 = 60.8%) knew the correct answer on this question, whereas almost none of the pupils knew the answer (score1 = 3.30% and score2 = 3.23%). For Q11, all participants obtained a high score, although the students still scored higher, with an average of 97.60% (score1) or 96.83% (score2). A cross table was made with the right and wrong answers of all participants on each question. Performing a Chi²-test on these data for comparing the results of pupils and students showed that only for Q1, Q9 and Q15, the result was not significantly different ($P > .05$).
However, the comparison between geography students and pupils is also related to their age and consequently their stage in cartographic education (see the learning outcomes discussed in a previous section). Therefore, it would be more useful to visualize the obtained results (score in %) of the pupils and students in a scatterplot related to their age (see Figure 9). A linear trendline is added which indicates the positive relation between the age and the obtained results. This will be discussed in more detail in the next section.

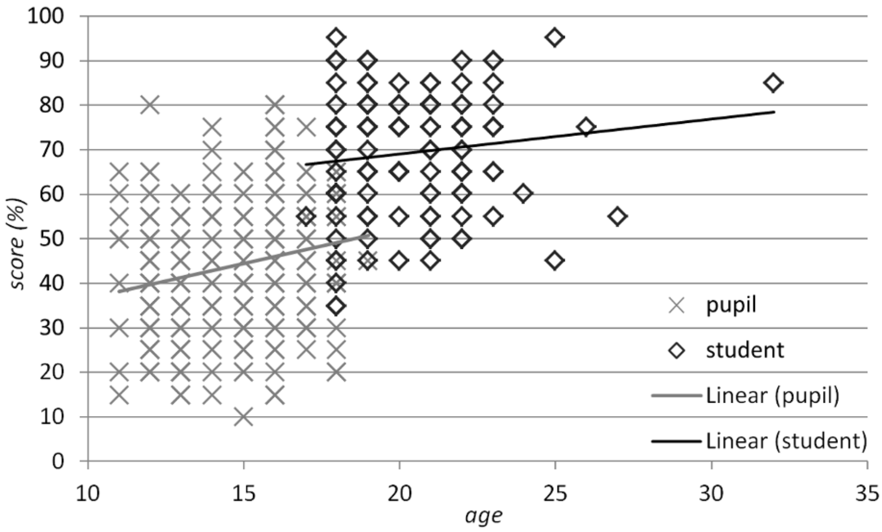


Figure 9: Scatterplot with the scores (%) of pupils and students with associated trendlines

When comparing the results of male and female participants, it can be noticed that male participants had a somewhat higher score on most questions, but not on all. Table 4 shows that more females managed to complete the whole questionnaire, but that their overall score is lower. Nevertheless, the results do not differ as much as between pupils and students. Therefore, further statistical analyzes are needed to verify whether this difference is based on coincidence or not (see next section).
Similar to the gender comparison, it can be noticed that members of a youth club (YC) obtained a slightly higher score on most questions, but not on all. The average score is higher for youth club members but this needs to be analyzed in more detail to verify if this difference is significant.
When analyzing the post-study questionnaire, it was found that not all participants interpreted the question regarding the familiarity of a region correctly. Many participants indicated, for example, that they knew the region and mentioned that they knew the city 'Chimay' from the cheese that was made there. This means that they knew the name, but not the 'layout' of the area by heart. Therefore it is difficult to judge, based on these answers whether they really knew the region or just the name. From Figure 8 and Table 4 it can be derived that participants who indicated they knew the region obtained a somewhat higher score. However, due to the reasons mentioned before, it was not advisable to remove all participants who indicated they knew the region from the analyzes because there is no certainty on how they interpreted the question. This will be verified in more detail in the next section, in which all variables are combined to account for possible interactions between them.

Integrated Approach

In order to statistically analyze all variables, they have to be combined using a univariate ANOVA test. In this analysis, the obtained score of the participants (expressed in %) is the dependent variable. Two parallel univariate analyzes were conducted based on the two scoring systems. The independent variables (or factors) considered are: gender, age, youth club membership, known areas, color blindness and dyslexia. Furthermore, the interaction between the previous variables will be taken into account as well. For each of the two models, we determined which of the independent factors showed a P-value > .05 (not significant) and removed them subsequently. The remaining factors were used in a linear regression analysis to construct an expression that can predict a participant's score.

For model 1 (first scoring system), the interaction term (P= .959) and the factors youth club (P = .398), color blindness (P = .553) and dyslexia (P = .554) could be removed, resulting in the final model presented in Table 5. Based on the remaining variable, score1 can thus be predicted with the following expression: $Y = -.001 + 5.657X_{KA.} + 2.957X_{gender} + 3.2206X_{age}$. The parameters X_{KA} and X_{gender} can only have values 1 or 0: known or not known and male or female respectively.

Table 5: Final parameters of the ANOVA tests and associated parameters for the model based on the first scoring system

	ANOVA				Parameter Estimates			
	df	**Mean Square**	**F**	**P**	**X**	**SD**	**t**	**P**
Corrected model	3	20930.383	119.141	.000				
Intercept	1	348.266	1.982	.160	-.001	3.032	.000	1.000
Age	1	52567.410	299.227	.000	3.220	.186	17.298	.000
KnownArea	1	3643.743	20.741	.000	5.657	1.242	4.554	.000
Gender	1	1110.017	6.318	.012	2.957	1.176	2.514	.012

Similarly as for the first scoring system, the interaction term (P = .970), and the factors youth club (P = .379), color blindness (P = .436) and dyslexia (P = .714) could be removed from the model for the second scoring system. Furthermore, in this second model the factor gender also imposed no significant influence (P = .080) and was thus removed as well. The final model is listed in Table 6 and the resulting linear expression takes the form: $Y = -2.045 + 5.275X_{KA} + 3.146X_{age}$. The X-value for the KnownArea can only have values 1 or 0 (known or not known).

Table 6: Final parameters of the ANOVA tests and associated parameters for the model based on the second scoring system

	ANOVA				Parameter Estimates			
	df	**Mean Square**	**F**	**P**	**X**	**SD**	**t**	**P**
Corrected model	2	28506.117	145.679	.000				
Intercept	1	6.621	.034	.854	-2.045	3.179	-.643	.520
Age	1	50450.522	257.875	.000	3.148	.196	16.058	.000
KnownArea	1	3199.122	16.349	.000	5.275	1.305	4.043	.000

In order to be able to analyze the results of the pupils and students in more detail, both user groups are split up and analyzed separately for the two scoring systems. In both scoring systems, the interaction term, color blindness, dyslexia, youth club membership did not have any significant influence on the scores of pupils nor on those of the students (P > .05) and could thus be removed from the model.

In the first scoring system, age, gender and KnownAreas were found to be an influencing factor for the pupils. Table 7 shows the results for the final model for the pupils based on the first scoring system, which can be linked to this predictive linear expression: $Y_p = 16.462 + 2.002X_{age} + 2.929X_{gender} + 5.282X_{KA}$. The parameters X_{KA} and X_{gender} can only have values 1 or 0: known or not known and male or female respectively. On the contrary, factors age, gender and knownArea did not show a significant influence on the students ($P_{s\_age} = .327$; $P_{s\_gender} = .103$ and $P_{s\_KA} = .437$) and they could thus be removed from their model. This resulting in the following (linear) expression: $Y_s = 74.36$; which corresponds to the average obtained score for students (in %).

Table 7: Final parameters of the ANOVA tests and associated parameters for the pupils' model based on the first scoring system

	ANOVA				Parameter Estimates			
	df	Mean Square	F	P	X	SD	t	P
Corrected model	3	3070.448	17.654	.000				
Intercept	1	2558.646	14.712	.000	16.462	5.357	3.073	.002
Age	1	5289.673	30.414	.000	2.002	.363	5.515	.000
KnownArea	1	2264.144	13.018	.000	5.282	1.464	3.608	.000
Gender	1	826.402	4.752	.030	2.929	1.344	2.180	.030

In the second scoring system, age and KnownAreas were found to be an influencing factor for the pupils, but in contrast with the first scoring system, gender was not found to be significant (P_{s_gender} = .276) and was thus removed from the model as well. The final model can be found in Table 8 and the associated predictive linear expression takes this form: $Y_p = 20.857 + 1.483X_{age} + 4.682X_{KA}$. The parameter X_{KA} can only have values 1 or 0. For the students, age, gender and KnownArea did not show a significant influence (P_{s_age} = .152; P_{s_gender} = .172; P_{s_KA} = .313). This results in the following expressions for the linear regression model for the students: Y_s = 69.88 (the average obtained score for students in %). Figure 9 visualizes the scores of the pupils and students with these associated trendlines when only considering the influence of age on the scores.

Table 8: Final parameters of het ANOVA tests and associated parameters for the pupils' model based on the second scoring system

	ANOVA				Parameter Estimates			
	df	Mean Square	F	P	X	SD	t	P
Corrected model	2	2558.204	14.651	.000				
Intercept	1	3255.660	18.646	.000	20.857	5.322	3.919	.000
Age	1	2904.910	16.637	.000	1.483	.364	4.079	.000
KnownArea	1	1791.432	10.260	.001	4.682	1.462	3.203	.001

Influence of Map Reading Task

In Table 2, the average score that was obtained on each of the questions (related to the given answers) is added. The color code corresponds to a classification of these results, taking into account the performance of students and pupils. This can give insights in the level of difficulty of the question, or in other words, the level of experience which is needed to solve the question (based on the results obtained in previous points). These results are combined with the information that could be derived from the audio and video recordings obtained during the pilot study of 6 participants who were asked to verbalize their thoughts while solving the questions. This gives insights in map reading problems or errors on level of the different sub-tasks (who are listed in the Table in the attachments).

Both students and pupils obtained a good result (average score > 50%) on Q1, Q2, Q11 and Q12 (indicated by a green color). These questions typically need a limited number of sub-tasks and one (simple) map reading task: recognizing a symbolization or reading altitude information. In the next class (indicated in white), both groups obtained a good results but the students still outperformed the pupils. In this group, we find questions with have to be solved by subsequent simple sub-tasks (e.g. locating multiple objects) and a combination of different map reading tasks. The central class (indicated in yellow) contains the questions on which the students obtained an average score >50% and pupils <50%. Some of these questions are related to the more complex map reading tasks: measurement and navigation. However, Q3, Q4 and Q19 probed directly for knowledge regarding the scale, equidistance and symbolization (visualization) of a (pedestrian) path respectively. These questions show a difference in knowledge regarding cartographic terminology and more advanced symbolization in the advantage of the students. From the recorded audio and video data, it could be derived that most pupils make wrong assumptions regarding the calculation of the scale: e.g. 1m corresponds to 1km. The term 'equidistance' is simply not known to them, which could also be derived from the large proportion of 'I do not know' answers on this question. For Q14, pupils try to find churches and bridges on the map (in which they succeed), but wrong conclusions are made on their relative position. Two types of pupils can be distinguished when the shape of the valley needs to be determined: one part uses the altitude lines to solve the question and the other part thinks it is not possible to solve the questions. To solve Q19, the majority of pupils tries to name the function of all line types to find out which of them could be the pedestrian pad.

Questions in the orange category are experienced as difficult by both students and pupils (score <50%) but students still obtained a better result. Two questions in this category are linked to reading altitude information in combination with other sub-tasks. The recorded verbalizations showed that this was the main source of error. Pupils could locate the river and campsite, but could not read information of the altitude lines (which is related to the fact that they are not familiar with the term equidistance). In Q5, most pupils seem to make the same error: they chose the label depicted in blue which is closest to the village, but this does not correspond to a river.

Finally, the red category is linked to questions which show a nearly equal bad result by both students and pupils. This questions can thus be considered as most complex or difficult to answer correctly related to the time constraint, such as navigation in combination with other sub-tasks, counting how many objects of a certain category are present. Most pupils who verbalized their thoughts could locate the required objects of Q7 (church and soccer field). They used their fingers to try to trace the route between both locations, but failed to construct it. In Q9 there was some confusion on the exact meaning of the objects on the map: the object of answer B is closest but it is not a school. Two problems arise to solve Q13, some students could not locate the police office and who did could not always determine the correct name of the road on which it was located. For Q15, the pupils simply did not know the symbol of a supermarket. They tried to solve the question by searching for 'large' buildings. In these questions, we probed for more complex symbol knowledge, which was indicated with an asterisk in the sub-tasks.

Discussion

The statistical tests show that no statistical significant influence was detected due to dyslexia and color blindness. Nevertheless, these results might be explained by the very small portion of participants (31 and 12 respectively) who indicated that they had dyslexia or were color blind. In the case of the characteristic ‘membership in a youth club’ an acceptable number of participants was obtained in each group (106 members and 357 non-members), and the graphs in Figure 8 indicate a trend. However, the ANOVA-tests show that the influence of this factor on their score was not found to be of any influence. This means that the map-related activities in these clubs do not attribute to the members’ map reading skills or that too few map related activities are integrated in their program.

In the post-study questionnaire, participants were asked to indicate whether they knew any of the depicted regions and how they knew them. From the how-question, it could be derived that not all participants interpreted this question as was intended: they indicated to known the area when they knew the name, but not necessarily the region. The graphs in Figure 8 show that this factor had a positive influence on the results for most questions, but not for all. The statistical tests (Table 5-6) confirm that the influence ‘knowing the area’ was significant on participants’ results. This finding holds true for the two scoring systems that were considered in the analyzes. When splitting up the analyzes between pupils and students, however, it was found not to be of any significant influence on the scores of the students. This might be explained by their higher level of interest and expertise in map reading, which could compensate for a lack of knowledge regarding the area.

Regarding the independent factor ‘gender’, a different result was found in the two scoring systems. These two scoring systems are a consequence of the strict time limit that was introduced in the study: the participants had 10 minutes to complete all 20 questions. The difference that are found could be attributed to this time limit and associated time pressure that was experienced. In the first scoring system (see Table 5 and Table 7), gender was found to be an influencing factor on the scores of all participants and the pupils, which is not the case in the second scoring system. Only for the students, no influence was found in the two scoring systems. The graphs in Figure 8 – which are related to scoring system 1 – show a higher score of male participants on most questions. From Table 4, it can be derived that more female participants completed all questions in comparison to the males (75.56% versus 71.71% respectively). Nevertheless, the overall average score of females was lower (in both scoring systems). This means that female participants (especially with the pupils), although they answered more questions than the male participants, the amount of correct answers was nearly the same between both groups. The females could thus work faster or more efficient, but this did not result in a higher score (or effectiveness). This finding is in correspondence with existing research on gender and time pressure: females perform worse than man when a competition is introduced, such as a time constraint (e.g. Chen 2004; Shurchkov 2012). Females have the tendency to pay more attention to details and can stay focused on a certain task for a longer time span. Men focus on the quantity of work, resulting in a larger relative number of mistakes. Without the time limit, female participants might, on the one hand, have been able to solve the questions more thought through and thus effectively, which would result in a higher score. The male participants, on the other hand, would have been able to solve more questions without this time limit, also resulting in a higher score. Further analyzes are needed to verify the effect of this time limit on the male and female participants' performance.

When considering all participants, their age was found to be a significant influencing factor in both scoring systems. This positive relation (significant rise in the pupils' map reading skills) can be linked to the different learning outcomes in the subsequent grades in secondary education. In the scatterplot of Figure 9, a break line in the score between students and pupils can be observed. Furthermore, the graphs in Figures 8 and Chi^2-test indicate that this large difference holds true for nearly all questions: consistent large grey bars. This significantly better performance of the students can be attributed to combinations of several factors: (1) all students have completed their secondary education; (2) the students are older than the pupils; (3) the students have a higher interest in geography and cartography (as they are enrolled in geography courses at the university); (4) the average IQ of university students might be higher than this of the pupils that were tested.

More detailed information on the different map reading skills was obtained by studying the results on the different questions in relation to the subsequent sub-tasks the participants had to solve to find the answer. It was found that, on the one hand, the complexity of the questions attributes significantly to the results: number of subtasks and complexity of the map reading tasks involved. Navigation is more complex than measurement, and visualization is most straight forward. However, this does not hold true in all cases. Not all objects can be located with the same efficiency, which is linked to participants' knowledge on the symbolization or geography in general: a river, police office, swimming pools or (pedestrian) pad are more difficult to locate, especially by pupils. The higher level of complexity creates a clear distinction in the results of the students and pupils. Nevertheless, some questions were too complex to be completed correctly within the available time frame. Reading altitude information was one of the problems that pupils were faced with.

The number of sub-tasks is a good indicator of the level of complexity of a certain question or tasks, but it is not the only factor which reflects the difficulty the participants experienced to solve a question. A very simple task – without many subtasks – can be very difficult for pupils/students when they do not remember or understand what a certain symbol means. This corresponds to mastering the thinking skills on the lowest level. Consequently, the level of thinking skills that need to be addressed is not necessarily linked with the overall score on a certain question. If pupils or students had never heard before of a certain topic or did not recognized a certain symbol (e.g. supermarket in Q15), they could not solve the question. The highest level of thinking skill related to a certain question might be set to four, but the problem in solving the task may already be situated on a lower level. For example in Q9, the participants have to be able to recognise multiple schools, a roofed public school and compare their mutual distances. This is latter assignment requires Level 4 thinking skills (comparing things, which corresponds to analyzing). However, if they cannot distinguish the pool on the map (Level 2 thinking skill) the task cannot be solved. This 'complex symbol knowledge' is indicated with an asterisk in the table with the sub-tasks in the attachments. Therefore, it can be concluded that complexity is not the only predictive factor in the pupils'/students' outcomes.

Conclusion and Future Work

Although a rising trend in the popularity of maps and map use is observed, very little is known regarding the map reading skills of young people. Pupils and students had to solve a number of map reading tasks, with different levels of difficulty. This was implemented in the questions, on the one hand, through a number of sub-tasks that had to be completed to be able to solve the main task. On the other hand, different types of sub-tasks could be identified (visualization, measurement, navigation). These tasks are also linked to Bloom's Taxonomy to identify the highest level of thinking skills the participants should address to solve a question.

The geography students' performed, as should be expected, much better (about 70% correct answers): they are older than the pupils and maps and geography are situated in their field of interest and expertise. This expertise can also be situated in the region that is depicted: better results were obtained for pupils who indicated that they knew the region. Therefore, education in geography itself is also an important element that should not be neglected. The age of the pupils also turned out to be a determining factor on their map reading skills, which can be linked to education in cartography they receive in secondary education. In basic education and the subsequent grades in secondary education, attention is given to different learning outcomes that pupils should obtain.

Both male and females gave a similar number of correct answers, but both user groups used a different strategy to solve the questions, which could be related to the introduced time pressure. Females worked more efficiently and could thus solve more questions. Males had a significant higher ratio of correct answers and thus solved the questions more effectively. The difference between both groups was not found in the results of the students. More research is needed to investigate the influence of the time limit on the obtained scores of both user groups. More detailed research is needed to verify the influence of these different factors on the map readings skills of young adults (students in geography, other science related studies, non-related studies and persons who do not take any further education) and other age groups.

In the light of cartographic communication, there are two paths that can be followed in order to improve this process. The first path focusses on the map maker, who should create cartographic products that can be understood by non-experts in cartography. This often entails a simplification of the content of the map which means that information will be lost. The level of simplification depends on the level of cartographic expertise of the map reader. When the map reader does not possess any cartographic knowledge or map reading skills, the amount of information that can be communicated is reduced.

Therefore, it is of major importance that the second path is also considered: cartographic education of the map reader. The positive relation between age and scores, and the distinctive break between pupils and students give a hint regarding what should be done to overcome the perceived map reading difficulties. The key word is education and practice There is still some work to be done to improve the pupils final learning outcomes regarding their map reading skills. If the pupils would use the maps more often, they would become more familiar with how objects are visualized and symbolized on the maps. This feeds the lower level thinking skills, but they are the essential basis to be able to solve the more complex tasks. This basic level of understanding is the essential starting points if these young people have to able to understand the vast amount of visual information that is nowadays communicated through all sorts of cartographic products.

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Attachments

Table: Sub-tasks for each question that have to be solved to be able to answer it correctly

	Question	
	Sub-tasks	
Map 1	**1. The roads are depicted in different colors. What do they stand for?**	
Map 1	1. Distinguish roads on the map 2. Distinguish different colors on these roads	3. Derive meaning of colors
Map 1	**2. What is the name of the district of Chimay, depicted on the map?**	
Map 1	1. Read labels 2. Distinguish difference in typography	3. Select correct label
Map 1	**3. The original scale of the map is 1 : 20 000. What does this mean?**	
Map 1	1. Read scale correct 2. Know 1cm = 20 000cm	3. Recalculate cm to km
Map 1	**4. What is the equidistance on this map?**	
Map 1	1. Know meaning of equidistance 2. Find altitude lines on the map	3. Read height information 4. Determine difference in altitude between subsequent lines
Map 2	**5. What is the name of the river that runs through Forges?**	
Map 2	1. Locate Forges (find label) 2. Locate river (symbology)	3. Read label
Map 2	**6. From the chapel St-Quirin, can I see the church of Forges?**	
Map 2	1. Locate chapel (symbology + label) 2. Locate Forges (read label) 3. Locate church (symbology)	4. Compare altitude information a. Find altitude lines b. Read height information c. Compare height information d. Analyze visibility
Map 2	**7. I would like to play soccer and meet my friends at the church. How do I have to walk starting from the church? (a direction is indicated at every crossroads)**	
Map 2	1. Locate church (symbology) 2. Locate soccer field (symbology)	3. Find route (navigation) a. Distinguish roads b. Analyze roads between start and end point c. Derive route instructions (left, right, etc.)
Map 2	**8. If you go from the chapel St-Quirin via the orange road to the chapel situate somewhat more to the north then… (up/down/same height)**	
Map 2	1. Locate chapel (symbology + label) 2. Find North direction	3. Read altitude information a. Find altitude lines b. Read height information c. Compare height information
Map 3	**9. Which school is situated closest to the roofed public pool?**	
Map 3	1. Locate pool a. Determine correct symbol* b. Find symbol on map	2. Locate schools a. Determine correct symbol* b. Find symbol on map c. Repeat multiple times 3. Compare distances a. between each school and the pool
Map 3	**10. Which N-way does not run through Chimay?**	
Map 3	1. Locate Chimay (label) a. Determine Chimay = city b. Read label	2. Locate N-ways a. Know N-way is a road b. Distinguish roads c. Distinguish N-way among roads d. Find label of N-way
Map 3	**11. What is the highest point on the map?**	
Map 3	1. Read altitude information	

	a. Find altitude lines b. Read height information c. Compare height information	
	12. What does the dark green color on the map mean (eg. Upper left corner)?	
	1. Locale area with dark green color	2. Derive its meaning (symbology)
Map 4	**13. Is there a police office on the map?** *(indicate associated road number in answer)*	
	1. Derive symbology of police office* 2. Recognize abbreviated label Pol. 3. Locate office	4. Link names (N5, N99) to roads 5. Find & read label road where office is located
	14. This picture is taken from which position on the map?	
	1. Recognize objects in picture a. River, bridges, row of houses, church (located at an higher point), …	2. Find objects in map a. Derive symbology of recognized objects b. Find symbols on map c. Analyze locations (map vs. picture) d. Determine viewpoint of picture
	15. How many supermarkets are there in the city?	
	1. Determine symbol of supermarket* 2. Locate symbols on map	3. Count number
	16. At which height is the camp site situated?	
	1. Determine symbol camp site 2. Locate symbol	3. Read altitude information a. Find altitude lines near symbol b. Read height information c. Compare height information
Map 5	**17. In which direction is the river flowing?**	
	1. Locate river a. Distinguish symbology of river b. Find symbology on the map 2. Know that rivers flow from high to low altitude	3. Read altitude information a. Find altitude lines that cross river b. Read height information c. Compare height information 4. Know NSEW-directions
	18. What does the section of the river's valley look like?	
	1. Locate river a. Distinguish symbology of river b. Find symbology on the map	2. Read altitude information a. Find altitude lines along the river b. Read height information c. Compare height information d. Estimate steepness based on distance e. between altitude lines 3. Estimate width of riverbed
	19. I organize a hike. To avoid traffic and walk in a calm environment, it would be best to walk on the … (color and shape of the lines).	
	1. Distinguish roads on the map 2. Distinguish different colors on these roads	3. Distinguish different patterns on these roads 4. Derive meaning of colors & patterns 5. Select appropriate
	20. Which slope is most steep?	
	6. Read altitude information 7. Find altitude lines that intersect with line a. Read height information b. Compare height information c. Estimate steepness based on distance between altitude lines	8. Compare steepness between slopes