Conveying map finesse: thematic map making essentials for today's university students

Schaab, G.[1,*], S. Adams[1] & S. Coetzee[2]

[1] *Faculty of Information Management and Media, Karlsruhe University of Applied Sciences, 76133 Karlsruhe, Germany*

[2] *Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria 0028, South Africa*

* corresponding author

Abstract

Maps have been used for centuries to depict the diverse facets of our environment. Thematic maps depict a specific theme and help in revealing geospatial patterns and relations. The study and practice of map making has led to established cartographic design rules. Ever increasing availability of high-quality geospatial data coupled with continuously changing technologies for map making imply that one has to find the right mix between age-old principles and state-of-the-art technologies and trends when teaching thematic cartography. This paper presents a proposal on how to stimulate the creativity of students' thematic map making by describing the teaching approach and results of a map assignment for a course presented to a group of postgraduate geoinformatics students. Based on a reflection of the teaching and learning experience and an assessment of the thematic maps produced by the students, recommendations are provided for teaching today's university students how to create convincing and appealing thematic maps. An infographics summarizes the most important guidelines. Additionally, the student maps, as well as the maps revised by a trained cartographer, are available and can be used by others for teaching.

Keywords: thematic cartography, multivariate data, complex analytical maps, good practice, infographics design, skills

1. Introduction

A map is a graphical representation of space that exploits artistic concepts to communicate thematic aspects of geography in an effective and efficient way. The extent to which maps proficiently communicate this geographical information is determined by their design and realization (Kriz, 2013). Maps have been used for centuries to depict our environment and its many different facets. Due to their aesthetic design, legibility, and the high degree of accuracy, analogue maps were considered to be authoritative (Buchroithner, 2016). The study and practice of making maps led to cartographic design rules that were typically conveyed through cartography education. However, nowadays it seems that anyone with access to the internet and time can make a map (Kraak et al., 2018). Nevertheless, following cartographic design rules remains important for effective communication (Schaab et al., 2009). When making maps that serve the purpose of orientation and reference (i.e. topographic maps), a trained cartographer follows conventions in the use of map symbols. For thematic maps, the appropriate use of visual variables, i.e. by applying cartographic representation methods, results in suitable map types that facilitate the revealing of geospatial patterns and relations (Kraak & Ormeling, 2003).

According to Friendly (2008), the onset of thematic cartography can be closely linked to the birth of statistical thinking, accompanied by a rise in visual thinking, i.e. the visual representation of statistical data on maps. Later, socio-economic data became more readily available through the establishment of official state statistical offices in Europe. Recognition of the importance of statistical data for planning and development led to a first explosive growth in statistical graphics and thematic maps also became more abundant. Such growth was experienced again in the mid-twentieth century, characterized by Friendly as the re-birth of visualization. This growth coincides with the emergence of a number of textbooks in the German speaking countries in the 1960s and 1970s, each dedicated to, or including a section on, thematic cartography (e.g. Arnberger, 1966, Hake, 1970, Imhof, 1972, Wilhelmy, 1962, Witt, 1970). Due to their extensive coverage of the wide array of principles that are of value for thematic mapping the books still provide a solid foundation for teaching thematic cartography. Among the many other cartographic textbooks in English and French, the textbook on thematic cartography by Slocum et al. (2010, 1st ed. 2003) stands out due to its depth and practical relevance.

In today's 'geoinformation society' maps and other geomedia are used to structure information and to construct spatial meaning (Vogler, 2016). In this context, statistical data and thematic map depictions of them make an important contribution. Increasingly, individuals, instead of experts, voluntarily contribute data and their own self-made maps (Cartwright, 2012). These are often quick-and-dirty map elaborations, which Buchroithner (2016) refers to as 'Micky Mouse cartography' due to the lack of knowledge or interest in proven cartographic principles and design rules. While there are ever increasing volumes of data available, as well as an increasing number of IT-savvy users, Smith (2016) points out that to date global data integration platforms have focussed overwhelmingly on topographic and remotely sensed data. This, despite the fact that Al Gore's original 'Digital Earth' vision included the global mapping of socio-economic data. Smith resumes that current trends are only now overcoming the long-existing barriers: the open data movement facilitates availability of high quality public sector data; technological advances and free open source software allow advanced thematic maps in standard web browsers; and today's data journalism triggers the aesthetics and techniques of thematic maps and related visualisations to become mainstream.

Fairbairn (2014) explores the question of how contemporary cartographic education, which should include thematic map making, addresses learning objectives, such as encouraging innovative flexibility, using the scientific method, developing creativity, and strengthening basic principles. University teaching changes constantly, even more so with rapid technological changes and ever shorter software life cycles. These lead to increasingly diverse and numerous opportunities demanding continual responses. Given the increasing breadth of methods applicable to geodata, the challenge is to find the "right" proportionate mix (Schaab, 2016) between teaching constantly changing and evolving map making tools and conveying long and well-established cartographic rules and conventions (Howarth, 2015). The wide range of available data, tools and processes calls for the setting of priorities in teaching (Fairbairn, 2013).

Cartography teaching approaches and the extent to which thematic cartography is included in higher education varies. For example, at Karlsruhe University of Applied Sciences (HsKA), thematic cartography has retained its status as a teaching focus since the inception of cartography-related study programmes in 1978/79 (Musall, 2003) and has been presented as stand-alone modules within the curricula ever since (Schaab, 2014a). In a different approach at the Charles University in Prague, a thematic cartography course was chosen to put particular emphasis on initiating creative thinking. Students had to produce a map by applying known artistic styles and techniques, or even completely new ideas as a counterbalance to the effects of uniform machine-aided solutions in the computer era (Bláha, 2009). In a third example from the Aristotle University of Thessaloniki, a thematic cartography course was developed as a common and fundamental basis for various engineering disciplines. The aim was to teach students how to elaborate and depict data individually selected and downloaded from a statistical data portal in a thematic map best suited for the spatial distribution. To produce the thematic map, the students had to use a suite of modular software tools, meant to reflect the real-world situation (Boutoura et al., 2016).

This paper aims to contribute towards demonstrating the recurring and growing importance of thematic map making, particularly focusing on what and how to teach today's university students in this regard. We do this by means of an example: a block course in thematic cartography presented with the idea of conveying map finesse. The paper starts with a literature review on changes in the map making environment and societal map appreciation, the purpose of thematic maps, and the relevance of teaching thematic map making today. Next, the teaching approach and the map outcomes of the block course are presented and assessed. The discussion reflects on the teaching approach and the need to teach thematic map making, as revealed by the student results and the teaching and learning experience. The paper concludes with guidelines for the most relevant considerations for making convincing and appealing thematic maps. As such it contributes to understanding how to develop an optimal approach for teaching thematic cartography.

2. Teaching thematic map making

2.1 Change in map making

Traditionally, maps were designed and produced by cartographic professionals. Due to technological advances, developers of software tools and their users, often without any cartographic expertise, are now in control of map making (Pillay et al., 2019). Already in 1997, Dorling and Fairbairn acknowledged that IT developments were leading to a diminishing importance of the craft skills required to understand map making when software tools for map making started to emerge. They

referred to the 'democratization' of cartography. However, limitations of map making software at that time often resulted in poor quality maps. The term, neocartography (borrowed from neogeography; Turner, 2006), was coined later and refers to empowered non-experts or lay individuals collecting data and producing maps (Cartwright, 2012). Haklay (2013) critically reflects on this development and acknowledges its confined democratic potential as it only includes the affluent, educated and powerful. Open data, open source software and cloud services have nevertheless expanded the user base of online cartographers who now have total control over the entire map design (Smith, 2016). Field & Demaj (2012) conclude, however, that the design of high-quality maps often remains difficult.

The wide availability of data, the global ICT network, and intuitive software facilitate and stimulate the universal nature of map making and map use for spatial communication (Morita 2005). There is no doubt that due to new tools, technology, data and approaches, map-making has become simpler (Roth et al., 2014). The web allows everyone with access to this medium and time to create maps (Kraak et al., 2018; Kraak & Ormeling, 2010). More generally, digital tools offer anyone the opportunity to become a cartographer (Waldt, 2008). This has led not only to a significant increase in maps, but also to an increasing number of flawed and misleading designs, which do not communicate the information in an efficient and accurate way. Kraak et al. (2018) therefore stress the need for proper cartographic data analysis skills or software, as well as awareness of and appropriate application of cartographic design guidelines. Otherwise, mapping is reduced to mere manipulation of data using online tools (Peterson 2013). Cartographers have to take responsibility for convincing the many potential map makers to stick to proven cartographic design principles when visualizing geospatial data (Kraak & Ormeling, 2010).

Although thematic map making has seemingly become simpler, the block course teaching approach put the focus on thematic cartographic design principles and aimed at developing an understanding of the challenges of designing meaningful maps.

2.2 Change in map appreciation

According to MacEachren (2013), our current era is marked by wide and general public interest in maps. Never before have maps experienced such a vast distribution. Increasingly, they are integrated into other disciplines, which makes them ubiquitous. However, this does not necessarily lead to better maps (Meng, 2008; cp. 2.1). Cartographers complain that the representation forms on thematic maps have been reduced to a few methods only (Schweikart & Domnick, 2013), while from the information design-side it is claimed that the old-fashioned virtue of design accuracy has to be rediscovered (Schwochoch, 2009). Cartography is, therefore, still best described as both art and science with a long tradition and history, but at the same time, cartography has become also very much a part of popular culture and new technology (Dodge, 2014, Dorling, 2013). In this context, Roth et al. (2015, p. 263) describe the pervasiveness of interactive maps as the "renaissance of 'geo' throughout popular culture and across professions".

Nowadays, infographics that impart knowledge seem to receive more attention than thematic maps. Infographics refers to graphical representations for communicating complex information in an aesthetically pleasant way. The closeness between the underlying data and its graphical depiction facilitates understanding. As infographics are based on the largely universal visual language, artistic freedom allows for unique and personalized results (Lee et al., 2013). While information design is considered to be almost entirely the domain of graphic designers, there seems

to be a common belief that maps can be produced by anyone (Schaab, 2014b). Thanks to today's trends, such as infographics and data journalism, we are currently experiencing a popularisation of online thematic mapping (Smith, 2016). However, creating complex thematic maps are still very much the interest and domain of trained cartographers. Due to the various technological advancements and as there are always different but valid ways of rendering the same reality, today's cartography can be considered even more versatile and thus indeed intellectually stimulating (cp. Ormeling, 2012).

The students of the course had the opportunity to develop an appreciation for the many different visualization options by discussing a variety of map examples. For the project work, the students rendered the same reality in two ways, as a thematic map and as an infographics.

2.3 The purpose of thematic maps

Spatial thinking is essential to all spatially dependent sciences, including geography. It comprises the spatial abilities of visualization, orientation and, likely also relation, although contested, (Bednarz & Lee, 2019). It employs the cognitive skills of knowing concepts of space, using tools of representation (e.g. maps), and applying processes of reasoning. When spatial thinking is applied, geographic thinking can address complex geographic concepts or problems. The required knowledge about space is widely captured in thematic maps, which enable the interpretation and understanding of spatial patterns and spatial relations they reveal (Metoyer & Bednarz, 2017).

Cartography and geographic visualization are uniquely placed to assist humans with visually discovering hidden content in geospatial data (MacEachren & Kraak, 2001). Maps do not only help to better understand geospatial relationships in data (Kraak & Ormeling, 2010), they remain one of the best ways to reduce complexity and to render complex spatial data sets (Robinson et al., 2017). Visualizations have the power to stir the imagination for exploration and problem solving and to facilitate pattern discovery in complex geospatial datasets (Dodge, 2014).

Havelková & Hanus (2018) state that thematic maps are becoming increasingly important to both the experts and the wider public in the current information age. They link this upsurge in popularity to the fact that thematic maps display important or interesting data about a specific topic. Cartographic practice is considered powerful, particularly for visualising complex spatial ideas, with maps being generally better suited to quantitative spatial data (Dodge, 2014). For illustrating a geographic phenomenon, the relationships between different mapping techniques or cartographic representation methods and the types of data are used (Tsorlini et al., 2017). Because vision is the most direct source of information as well as the one that supposedly offers the truth, thematic mapping serves inquiry and knowledge creation (Dodge, 2014). By meeting the communication goals and the needs of the intended audience, well-designed maps tell a story, which truthfully visualizes the data at hand (Kraak et al., 2018).

This purpose of thematic maps was repeatedly reinforced when students discussed their maps with the lecturer and received feedback.

2.4 What is of relevance when teaching thematic map making nowadays

Maps are particularly complex visualizations that require specialised skills to produce them (Dodge, 2014). Due to developments in the field of ICT and digital processes, new usage and consumer

behaviour and changes in the map medium itself, the tasks, methods and applications of cartography have become more diverse and complex (Harbeck, 2001). In this context, Fairbairn (2013) raises the question of how the daily increasing abundance of relevant content can be taught in higher education. What is the necessary scope? What is the right measure to satisfy all stakeholders: lecturers, students and potential employers? The consequence of having to cover more study content is likely to result in a shallower imparting of knowledge (Schaab, 2014a).

Apart from the obvious demand for creating knowledge and fostering the understanding of (thematic) mapping, other teaching demands or learning outcomes have also been postulated: the provision of real life experience and conclusions, and raising students' interest in cartography (Boutoura et al., 2016); the entrainment of today's digital natives through innovative teaching approaches (Harvey & Kotting, 2011); the motivation of students to reveal their versatile talents (Schaab, 2014b); and the stimulation of creative thinking (Bláha, 2009). Critical thinking, regarding both thoughts or ideas of others and self-reflection, is considered to be an essential outcome of higher education generally. The challenge of transferring critical thought is the greatest barrier to overcome (Goodsett, in press). Case studies, which ask students to make their own individual thematic maps, require the students to be critical, not only about the resulting map, but also about the data used (cp. Kerski, 2016).

Fairbairn (2014) underlines that the many fundamental cartographic concepts and ideas must still be learned by or instilled in students because of their relevance when producing maps, for understanding how maps work, or for finding solutions for maps on new devices. Original cartographic skills should not be neglected in the otherwise rather IT-focused training of the future generations of cartographers (Schaab, 2014b). It is the creation of effective information communication within an aesthetic and well-designed framework which Fairbairn (2014) lists as the last of eight essentials to be mastered by cartographers nowadays, and which matters especially in the field of thematic mapping where the wide public is increasingly engaged in participating in the volumes of data that are collected.

A teaching approach guided by proven thematic cartography design principles, while tackling also trending forms of data visualizations, served as a framework for the students. Starting with different statistical data on relevant topics, they were encouraged to think critically for succeeding in map visualizations which not only look appealing but also add to understanding the anthroposphere.

3. Teaching approach taken

The opportunity to teach thematic cartography as a separate course to students at the University of Pretoria (UP) was accommodated in a 'special topic' elective module of the Bachelor Honours (BScHons) in Geoinformatics. The course is designed to cover topics outside the fixed curriculum and is sometimes presented by guest lecturers. Students of the seventh semester followed a block course over two weeks in August 2017. At UP cartography is generally incorporated into geographic information systems (GIS) modules (Hodza et al., 2015) where thematic maps may be used to communicate spatial analysis results; however, there is no specific focus on teaching thematic cartography. Due to their previous three years of studies, they already had some background in cartography (first semester module of the BSc Geoinformatics programme), in working with thematic maps (four geography-related modules at Bachelor level), and in making thematic maps with GIS software (eight GIScience modules by then, with GIS-related courses accounting for the majority of credits earned during the undergraduate studies leading to an Honours degree). The curriculum at

UP is aligned with the academic framework of the South African Geomatics Council (SAGC, 2019), which specifies 24 credits (i.e. 240 notional hours or estimated learning time by a student) for the cartography and visualization knowledge area, i.e. 5% of the overall content of a three-year Bachelors degree. The lecturer who was invited to teach at UP has a first degree in cartography from a German university of applied sciences, several years of working experience as a cartographer, as well as extensive teaching experience in the subject at university level. However, it was the first time that the lecturer offered thematic cartography classes (student workload: 150 hours, 15 credits) condensed into a block course of 28 50-min. time slots within nine days. Coming from abroad, the lecturer was also not familiar with the curriculum at UP and only vaguely aware of the student background to be expected. However, two summer and winter schools on participatory sensing in which Geoinformatics Bachelor Honours students from UP and Geomatics Masters students from HsKA participated (Coetzee et al., 2018) provided a sense of the students' prior knowledge.

Consultations with the BSc Honours programme coordinator ahead of the course provided the basis for elaborating a course description (including content, objective, educational approach, learning activities, lecture schedule and assessment), which was required for informing the students half a year in advance. The learning objective focused on how to visualize statistical data in a correct, appropriate, as well as attractive, map with the aim of sensitizing those becoming experts in geodata processing to the need and value of allotting time for meaningful and appealing maps. The consultations further led to the decision to work with mixed teaching methods for teaching thematic cartography as block course (see figure 1 on the interleaved course structure):

(1) Theory classes with presentation slides offered as script covered ten time slots. Content ranged from basics in thematic map making (meant as repetition), cartographic representation methods and map types (the focus of the course), to analytical versus synthesis maps and less common thematic map solutions. Due to the lecturer's background, the study material included (translated) information from the German textbooks on thematic cartography.
(2) Group discussions (six slots): The course started with map reading exercises by the entire group based on a selection of mainly maps from print atlases. The various tasks required map analysis and map interpretation (Havelková & Hanus, 2018). This helped the lecturer to discern the students' cartographic knowledge and familiarity with thematic maps. The exercises served as the basis for a written assignment to be handed in by the end of week two. In addition, the differences between traditional maps and infographics (with a focus on those making use of the spatial reference, summarized in a table in Schaab, 2014b) were discussed as preparation for the student project.
(3) The map making project was handled in 12 time slots, of which one was used for the introduction to the task and the data, two for presenting student examples from a similar assignment at HsKA and the remaining nine for individually discussing the actual map making with the participants. The latter took place in a computer lab where students could make use of software (a spreadsheet and a vector graphics package).

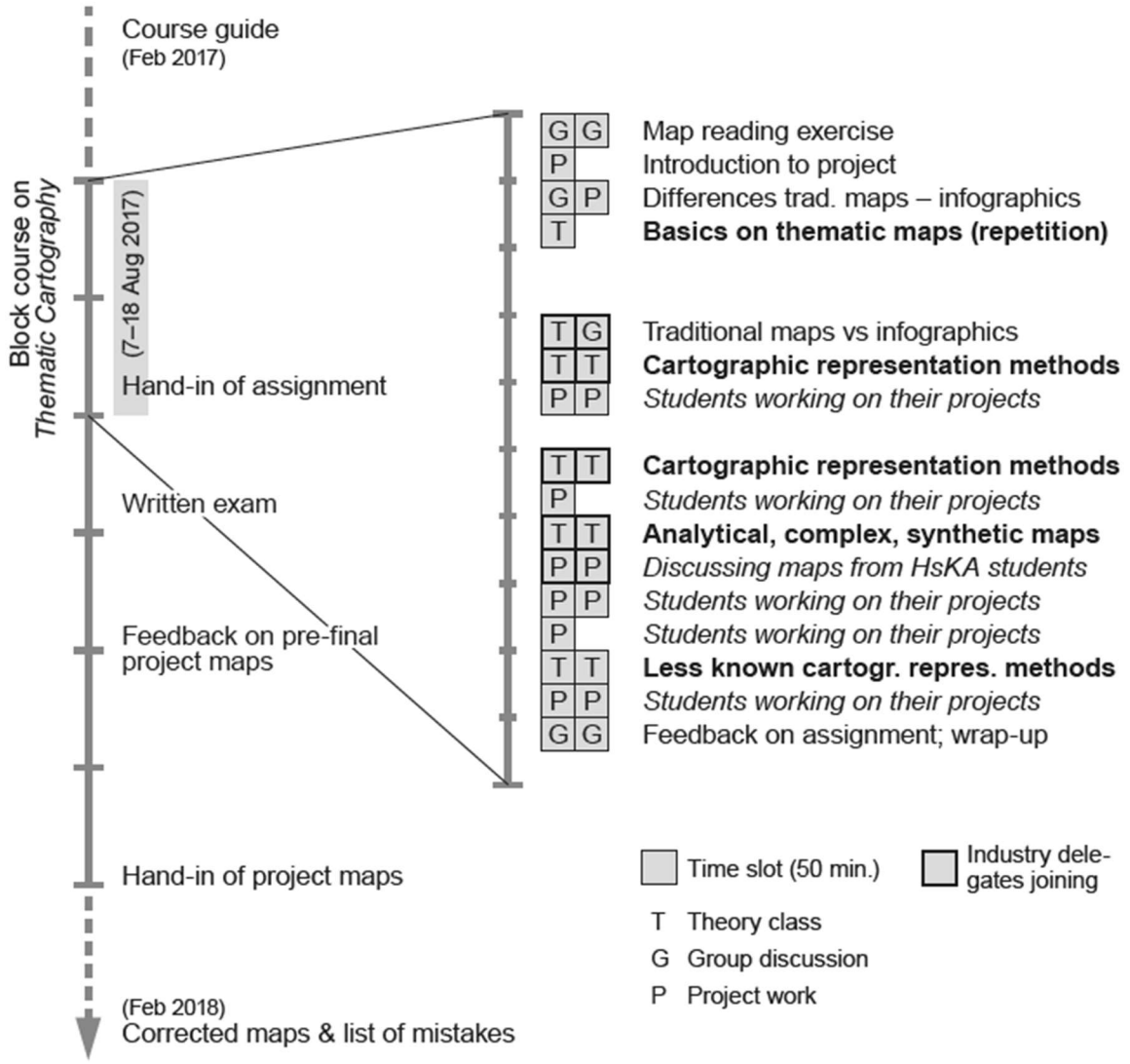


Figure 1. *The teaching approach design revealing the interleaved course structure based on three teaching methods, as well as the timeline on extended feedback provision for the project work.*

Industry delegates joined most of the theory lectures, an offer by the university towards continued professional development. This required careful planning to interweave the various active and passive learning components (McConnell et al., 2017), while still allowing the external participants to attend the course in a block within the block course. The written assignment on map reading accounted for 15%, the map making project for 35%, and the written examination for 50% of the final mark. The exam was written a week after the end of the block course.

The project borrowed from an assignment which at HsKA was successfully used to motivate students at the start of a major practical seminar and for the lecturer to discern students' skills and talents or, to the contrary, students' knowledge gaps (Schaab, 2014b). The approach was deemed equally suitable for conveying a wide range of skills related to thematic cartography to less-experienced students. For the project, the seven student participants (43% male / 57% female, all in their twenties) opted for seven different map topics out of ten options. The practical task was to create an appealing example for a (traditional) newspaper map and for an infographics based on the

same dataset, taking into account typical characteristics of each visualization medium. Statistical data of the 2011 Census (source: Statistics South Africa) for Northern South Africa was provided, as well as a ready-to-use basemap (an svg-file of the district municipality boundaries generalized for the scale 1:3.6m on A4-landscape paper suiting a scale range of about 1:2m to 1:10m). The area for which maps were to be created roughly matches the former Transvaal province, i.e. today's 17 district municipalities of the four provinces, North West, Gauteng, Limpopo and Mpumalanga. The statistical data (relating to people or households) covered the following topics: 1. Access to communication, 2. Highest education level, 3. Languages, 4. Source of water, 5. Population group, 6. Fuel for cooking, and 7. Refuse removal. Depending on the topic, two to twelve data fields were provided (most had four or five data fields).

Each student had to come up with two contrasting maps for printing on an A4 sheet: a black-and-white map following traditional cartographic map making rules versus a coloured map applying infographics elements or styles. A black-and-white map adds to the challenge of designing well-working maps and therefore allows students to further enhance their skills. Both maps had to be accompanied by appropriate text as an integral part of the map product, and thus also of the overall layout which was to make use of newspaper columns. All maps were created and designed using a vector graphics software package of the student's own choice (Adobe Illustrator, CorelDraw or Inkscape). It was assumed that the students would bring along sufficient knowledge in the use of such software and that they would help each other in its handling if necessary. GIS software was not used to ensure that thematic mapping principles were applied from scratch, instead of being limited by and relying on ready-available solutions which in addition would not necessarily be correct (cp. Boutoura et al., 2016). The submission deadline for two separate pdf-files was four weeks after the last class. The plans or concepts for the maps were discussed and feedback for the initial visualization was provided continuously during the nine time slots dedicated to the practical map making. Once the lecturer had returned to Germany, written summaries provided remote advice on what still had to be improved after handing in draft versions twelve days before the final deadline. Each student's final maps were assessed. The assessment was reviewed and moderated by an external examiner and the students could peruse the assessment on request. Finally, further guidance in skilful thematic map making was provided by correcting and polishing the final student versions, done by a cartographically well-trained HsKA university staff member. The accompanying texts were only corrected for obvious mistakes, or in one case, shortened due to irrelevant information about the map making process. The corrected maps, together with a list of common mistakes, were made available to the students in the online learning platform, albeit a full semester later. This was something we had not done before. The corrected map versions were a final feedback and learning opportunity because a group discussion about the strengths and shortcomings of their maps was not possible once the lecturer had returned to Germany. The timeline of the extended provision of feedback for the project work is visualized in figure 1, too.

The course was not evaluated when it was presented in 2017, as we initially did not plan to write a paper about the course. Instead, only now, three years after conclusion of the course (i.e. July 2020), five of the students (40% male / 60% female) agreed to participate in an online semi-structured interview, during which we asked them about their perceptions of the course: What did they like most or least about the course? What are the most important aspects of thematic cartography that they learnt and have they been able to apply this in their jobs? What did they learn from the enhanced versions of their maps? Did they have any suggestions for how the module could be improved in future? The online interviews with each student separately lasted between 20 and 40 minutes and differed in the number of additional questions required to guide the students to recall

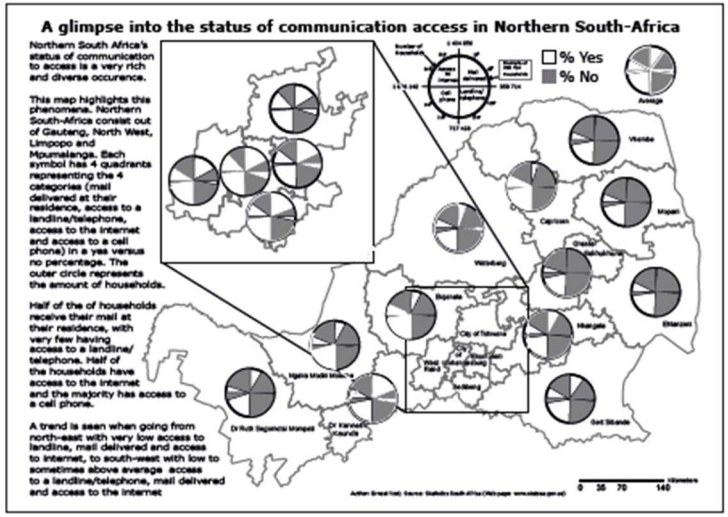
the study experience. Depending on the student, some questions triggered a shorter answer than others. Conducting interviews three years after completion of the course had its pros and cons: on the one hand, some details about the course had faded away, on the other hand, it became very clear how they had benefited in the long run. The results are reported in Section 5, including their perceptions about the mix of teaching methods and the feedback loops for the map making task.

4. Map outcomes

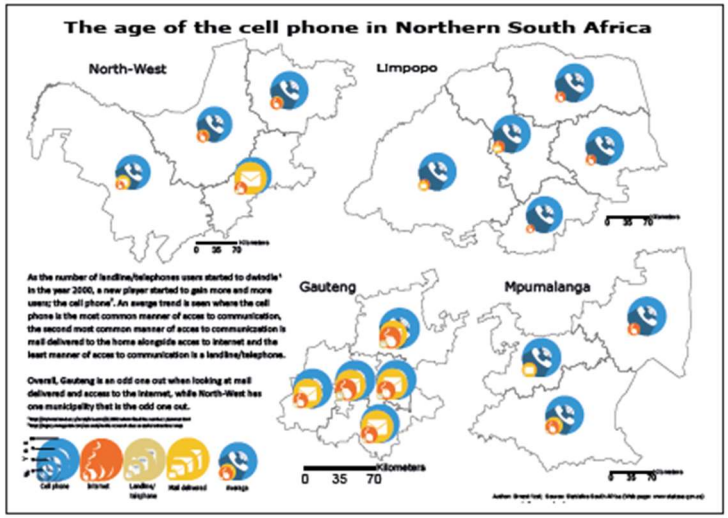
For each of the seven topics, four maps are now at hand: a black-and-white and a coloured student version, as well as an enhanced version of each (see http://hdl.handle.net/2263/75571 for online access). The maps show particularly high diversity in the representation methods applied. The students were hesitant to experiment with infographics elements or styles, i.e. the two maps are not always contrasting in this respect, but rather due to the difference between using colours or not, and due to the choice of the cartographic representation method selected. Elaborating text to accompany a map is more of a journalist's or geographer's task. Therefore, it posed a challenge, which not every student mastered (cp. Schaab, 2014b). The decision to only edit student texts, instead of rephrasing it to exemplify the two media styles, was made so that the polished map versions still reflect the student's work. The same applies to the overall layout, which was only changed into a more balanced design and corrected to be complete.

Due to space constraints, all 28 maps cannot be shown here. Instead, the maps depicting access to communication and cooking fuel types were selected for a) demonstrating the effects of the cartographic representation method, by juxtaposing the student versions with those corrected by cartographically experienced map makers; b) revealing the impacts of correctly applied cartographic principles.

Figure 2 shows the four resulting maps on access to communication: to the left the student versions, to the right the corrected versions; at the top the black-and-white depiction meant for an old-style newspaper and therefore sticking to established cartographic good practice, at the bottom the coloured version meant for a popular magazine and thus including elements of infographics. The student came up with two cartographically neat maps. During class, he presented many possible solutions for his data and found it difficult to decide which one to apply. The black-and-white version makes use of a uniformly sized circle symbol per enumeration unit, which in its quadrants reveals the percentage access to the four communication types. A ring diagram around the circle represents the number of households in the district municipality. The coloured map applies staggered proportional circle symbols in different colours with pictograms representing the communication type. However, the scaling of the symbols is incorrect, as is revealed in the legend (linear scale instead of considering symbol area).


A glimpse into the status of communication access in Northern South-Africa
Northern South Africa's status of communication to access is a very rich and diverse occurence.
This map highlights this phenomena. Northern South-Africa consist out of Gauteng, North West, Limpopo and Mpumalanga. Each symbol has 4 quadrants representing the 4 categories (mail delivered at their residence, access to a landline/telephone, access to the internet and access to a cell phone) in a yes versus no percentage. The outer circle represents the amount of households.
Half of the of households receive their mail at their residence, with very few having access to a landline/ telephone. Half of the households have access to the internet and the majority has access to a cell phone.
A trend is seen when going from north-east with very low access to landline, mail delivered and access to internet, to south-west with low to sometimes above average access to a landline/telephone, mail delivered and access to the internet
% Yes
% No
Average
Vhembe
Capricorn
Mopani
Waterberg
Greater Sekhukhune
Bojanala
City of Tshwane
Ekhurhuleni
Gert Sibande
Dr Ruth Segomotsi Mompati
Dr Kenneth Kaunda
0 35 70 140


The Status of Communication Access in Northern South Africa in 2011
The patterns of access to communication in northern South Africa reflect the diverse lifestyles and conditions across the region.
While access to cell phones is high across the entire region, use of landlines is low. The Gauteng province has a noticeable higher rate of access to landlines, likely related to the higher population and population density of the area.
Access to the internet and to mail delivery varies greatly across the region. While the municipalities of Gauteng, as well as one municipality in North West province, have relatively high rates of mail delivery (over 65%), in several other municipalities, less than 10% of households receive mail delivery. The spread in access to internet is not as pronounced, but relatively low across the region. Only one municipality, the City of Tshwane, has an internet access rate above 50%. However, the lowest rate, found in Greater Sekhukhune, is just below 20%.
City of Tshwane
Ekurhuleni
West Rand
Sedibeng
Waterberg
Vhembe
Capricorn
Mopani
Bojanala
Greater Sekhukhune
Ekurhuleni
Mangaung
Gert Sibande
Dr Kenneth Kaunda
Dr Ruth Segomotsi Mompati
0 50 100 km
Number of Households
Percent Access to Communication
Mail Delivery
Internet
Cell Phone
Landline Phone


The age of the cell phone in Northern South Africa
North-West
Limpopo
Gauteng
Mpumalanga
As the number of landline/telephones users started to dwindle in the year 2000, a new player started to gain more and more users; the cell phone. An averge trend is seen where the cell phone is the most common manner of access to communication, the second most common manner of access to communication is mail delivered to the home alongside acces to internet and the least manner of access to communication is a landline/telephone.
Overall, Gauteng is an odd one out when looking at mail delivered and access to the internet, while North-West has one municipality that is the odd one out.
Cell phone
Internet
Landline/ telephone
Mail delivered
Average
0 35 70
Kilometers

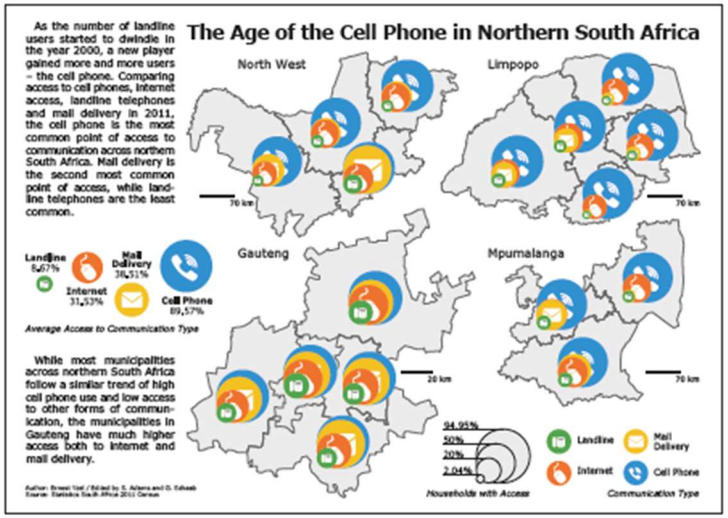
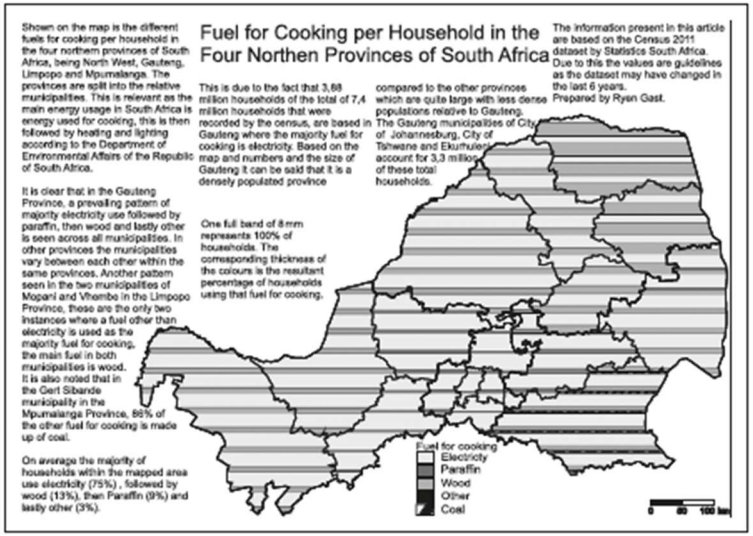
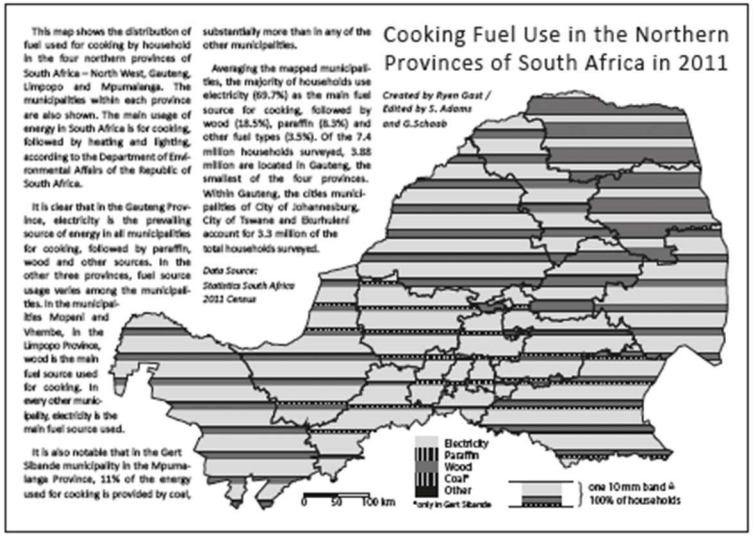
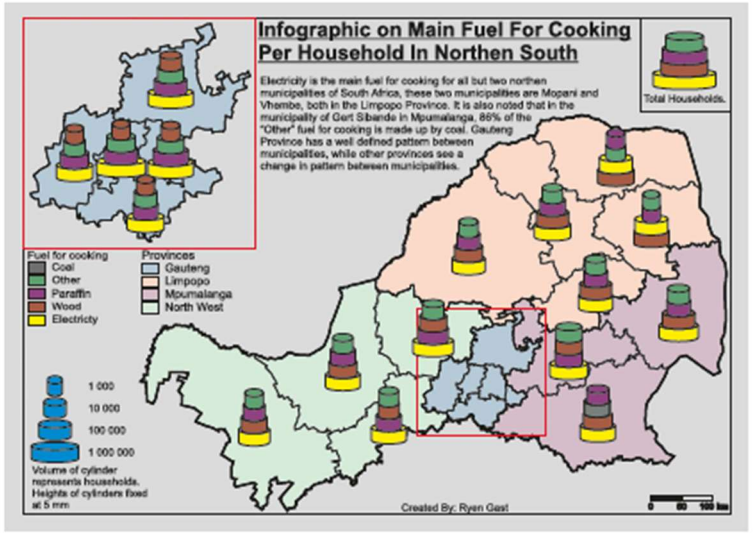

The Age of the Cell Phone in Northern South Africa
As the number of landline users started to dwindle in the year 2000, a new player gained more and more users – the cell phone. Comparing access to cell phones, internet access, landline telephones and mail delivery in 2011, the cell phone is the most common point of access to communication across northern South Africa. Mail delivery is the second most common point of access, while land-line telephones are the least common.
North West
Limpopo
Gauteng
Mpumalanga
70 km
20 km
Landline 6,67%
Mail Delivery 36,51%
Internet 31,53%
Cell Phone 89,57%
Average Access to Communication Type
While most municipalities across northern South Africa follow a similar trend of high cell phone use and low access to other forms of communication, the municipalities in Gauteng have much higher access both to internet and mail delivery.
94,95%
50%
20%
2,04%
Landline
Mail Delivery
Internet
Cell Phone
Households with Access
Communication Type

Figure 2. *Maps on communication access created by a BScHons Geoinformatics student as part of a module on thematic cartography at the University of Pretoria (left: student versions, right: enhanced and corrected versions, top: black-and-white map following established cartographic good practice, bottom: coloured map including infographics design elements)*


Fuel for Cooking per Household in the Four Northen Provinces of South Africa
Shown on the map is the different fuels for cooking per household in the four northern provinces of South Africa, being North West, Gauteng, Limpopo and Mpumalanga. The provinces are split into the relative municipalities. This is relevant as the main energy usage in South Africa is energy used for cooking, this is then followed by heating and lighting according to the Department of Environmental Affairs of the Republic of South Africa.
It is clear that in the Gauteng Province, a prevailing pattern of majority electricity use followed by paraffin, then wood and lastly other is seen across all municipalities. In other provinces the municipalities vary between each other within the same provinces. Another pattern seen in the two municipalities of Mopani and Vhembe in the Limpopo Province, these are the only two instances where a fuel other than electricity is used as the majority fuel for cooking, the main fuel in both municipalities is wood. It is also noted that in the Gert Sibande municipality in the Mpumalanga Province, 86% of the other fuel for cooking is made up of coal.
On average the majority of households within the mapped area use electricity (75%) , followed by wood (13%), then Paraffin (9%) and lastly other (3%).
This is due to the fact that 3,88 million households of the total of 7,4 million households that were recorded by the census, are based in Gauteng where the majority fuel for cooking is electricity. Based on the map and numbers and the size of Gauteng it can be said that it is a densely populated province compared to the other provinces which are quite large with less dense populations relative to Gauteng.
The Gauteng municipalities of City of Johannesburg, City of Tshwane and Ekurhuleni account for 3,3 million of these total households.
One full band of 8 mm represents 100% of households. The corresponding thickness of the colours is the resultant percentage of households using that fuel for cooking.
The information present in this article are based on the Census 2011 dataset by Statistics South Africa. Due to this the values are guidelines as the dataset may have changed in the last 6 years.
Prepared by Ryan Gast.
Fuel for cooking
Electricity
Paraffin
Wood
Other
Coal


Cooking Fuel Use in the Northern Provinces of South Africa in 2011
This map shows the distribution of fuel used for cooking by household in the four northern provinces of South Africa – North West, Gauteng, Limpopo and Mpumalanga. The municipalities within each province are also shown. The main usage of energy in South Africa is for cooking, followed by heating and lighting, according to the Department of Environmental Affairs of the Republic of South Africa.
It is clear that in the Gauteng Province, electricity is the prevailing source of energy in all municipalities for cooking, followed by paraffin, wood and other sources. In the other three provinces, fuel source usage varies among the municipalities. In the municipalities Mopani and Vhembe, in the Limpopo Province, wood is the main fuel source used for cooking. In every other municipality, electricity is the main fuel source used.
It is also notable that in the Gert Sibande municipality in the Mpumalanga Province, 11% of the energy used for cooking is provided by coal, substantially more than in any of the other municipalities.
Averaging the mapped municipalities, the majority of households use electricity (69.7%) as the main fuel source for cooking, followed by wood (18.5%), paraffin (8.3%) and other fuel types (3.5%). Of the 7.4 million households surveyed, 3.88 million are located in Gauteng, the smallest of the four provinces. Within Gauteng, the cities municipalities of City of Johannesburg, City of Tswane and Ekurhuleni account for 3.3 million of the total households surveyed.
Data Source:
Statistics South Africa
2011 Census
Created by Ryan Gast / Edited by S. Adams and G.Schaab
Electricity
Paraffin
Wood
Coal*
Other
*only in Gert Sibande
one 10mm band = 100% of households


Infographic on Main Fuel For Cooking Per Household In Northen South
Electricity is the main fuel for cooking for all but two northen municipalities of South Africa, these two municipalities are Mopani and Vhembe, both in the Limpopo Province. It is also noted that in the municipality of Gert Sibande in Mpumalanga, 86% of the "Other" fuel for cooking is made up by coal. Gauteng Province has a well defined pattern between municipalities, while other provinces see a change in pattern between municipalities.
Total Households.
Fuel for cooking
Coal
Other
Paraffin
Wood
Electricity
Provinces
Gauteng
Limpopo
Mpumalanga
North West
1 000
10 000
100 000
1 000 000
Volume of cylinder represents households. Heights of cylinders fixed at 5 mm
Created By: Ryan Gast

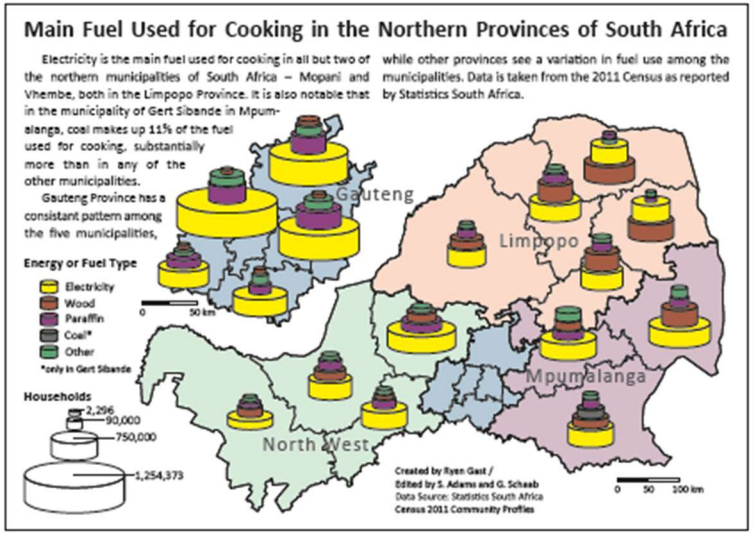

Main Fuel Used for Cooking in the Northern Provinces of South Africa
Electricity is the main fuel used for cooking in all but two of the northern municipalities of South Africa – Mopani and Vhembe, both in the Limpopo Province. It is also notable that in the municipality of Gert Sibande in Mpumalanga, coal makes up 11% of the fuel used for cooking, substantially more than in any of the other municipalities.
Gauteng Province has a consistant pattern among the five municipalities, while other provinces see a variation in fuel use among the municipalities. Data is taken from the 2011 Census as reported by Statistics South Africa.
Gauteng
Limpopo
Mpumalanga
North West
Energy or Fuel Type
Electricity
Wood
Paraffin
Coal*
Other
*only in Gert Sibande
Households
2,296
90,000
750,000
1,254,373
Created by Ryan Gast / Edited by S. Adams and G. Schaab
Data Source: Statistics South Africa
Census 2011 Community Profiles

Figure 3. *Maps on cooking fuel types created by a BScHons Geoinformatics student as part of a module on thematic cartography at the University of Pretoria (left: student versions, right: enhanced and corrected versions, top: black-and-white map following established cartographic good practice, bottom: coloured map including infographics design elements)*

In the corrected solutions (to the right), the black-and-white map is enhanced regarding 'figure-ground' distinction, i.e. working with visual hierarchy in the map face: the surrounding ring diagram is better visible, additionally absolute values are used (note the difference in household numbers per district municipality) to better illustrate the proportion of the population with access to communication. Also, it is not necessary anymore to provide a hint about the meaning of the grey section. The legend was also improved through its clear structure and captions. The selected map solution is clearly a map which requires reading for perceiving the information. In the corrected coloured map, the effect of correctly scaled area-proportional symbols is evident: differences in the percentages of households served with the four different communication types can be perceived directly from their visual weight. Thus, the differences between the provinces become apparent, and those district municipalities, which deter from the general patterns or are rather similar, can be observed. However, the proportional values are not as easy to grasp (i.e. circle sizes have to be compared against the examples in the legend). The coloured map draws attention by presenting a map per province (note different map scales), thus avoiding the workaround of an inset map, and by a map title, which is already an interpretation. In conclusion, with the cartographic principles and design rules properly applied, the black-and-white map is best at showing deviations from full coverage of access to the four communication types, while the coloured map is best at revealing similarities and differences at a glance, but without any information about the percentage of the population affected.

Figure 3 shows the maps on cooking fuel type, arranged in the same order as Figure 2. The student made a quick promising start but unfortunately later ignored further guidance from the lecturer. The black-and-white map makes use of the alternate band map method, which shows stripes of equal width across all enumeration units. For each district municipality, these stripes are divided proportionally according to the use of four different cooking fuels plus the class 'other'. In this way, only relative or standardized values are shown. The coloured map makes use of four non-proportional cylindrical symbols according to household numbers and stacked according to size. In the enhanced versions, the overall layout was improved (see arrangement of text), as well as the way in which the cartographic representation methods were applied. The alternate band method is now visually explained in the legend. The keys are ordered and touch each other, similar to their appearance in the map face. The special case of coal being used only in the Gert Sibande municipality is highlighted. Smaller proportions are expressed by more contrasting shades, additionally patterns are used due to the limitation when applying grey shades only. In the enhanced coloured version, the symbols are now truly proportional, representing household numbers as volumes due to the large range of values to be presented.

In the final solutions (to the right), the black-and-white map shows a pattern that calls for further exploration. Electricity is the major energy source used for cooking, except in the two most Northeastern municipalities where wood is the dominating source and paraffin used only to a tiny proportion. Only in the central part, wood seems not to be used as fuel for cooking, and Gert Sibane is the only district municipality where people use coal for cooking. The coloured map draws attention by its intriguing three-dimensional map symbols. Gauteng province depicted on an inset map can be easily related to its location on the main map by using the same colour. This map allows proportions to be compared based on the number of households. It becomes evident that a considerable number of households in the two Northeastern municipalities also make use of electricity for cooking. In this version, very small proportions are better visible and the importance of paraffin versus wood is easier to observe. Overall, the black-and-white map is best at showing proportions that are easily

read and interpreted, while in the coloured map solution the differences in household numbers is striking and their relation to cooking fuel sources easier to memorize.

Table 1. Shortcomings in student maps which required correction and enhancement, and their assessment (white bar: good results, black bar: failures, grey bar: okay or not necessarily required/possible, hatched bar: not of relevance; M stands for 'a Must' and provides a link to Fig. 4 in section 6)

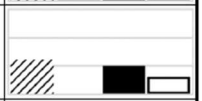
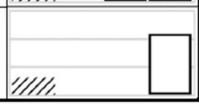
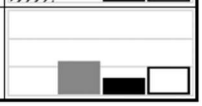
	Issues noted	Student maps assessment		Issues noted	Student maps assessment
1. General rules	Absolute (non-standardized) values must never be depict-ed by shading-in enumeration units (differing in size) **(M)**			Carefully select patterns for size of symbol (not too large)	
	Add absolute values to relative values to make the map more meaningful			Need of double checking calculations / mistakes in creating multi-part symbols	
	No point in presenting percentages among districts summing to 100%		3. Add. map elements	Precision on break values in legend	
	No legend needed for base map elements			Scale bar (was wrong for many of the maps)	
2. Map symbols	Use of area or volume proportional symbols (must be calculated; cannot use log scale) **(M)**		4. Map layout	Graphic design / layout, including positioning of text around map	
	Based on a symbol scale using a round value			Visual hierarchy / contrast (map face)	
	Classification by natural groups **(M)**			Fewer boxes and underlining opens up layout	
	Correlations and relations – finding a meaningful pattern			Completeness	
	One common symbol scale for related variables (for comparison) **(M)**		5. Text	Accompanying text should fit with the map	
	Common classes (choropleth or symbol size) among small multiples for comparison **(M)**			In text values, percentages must be calculated correctly	
	Symbols must be placed within the enumeration units where ever possible **(M)**			Use graphical legend and do not explain in/by text (legend headings?)	

Table 1 presents the results of an assessment of all versions of the student maps. The list is based on the shortcomings in the student maps that required correction or enhancement, and which had been made available to the student participants (see 3.). It is ordered in five categories: whether the student maps considered general cartographic rules, and how the students handled map symbols, additional map elements, map layout and text. Ideally, for all 22 issues, the white bar should be larger than the black or grey bars. The lightest grey bar refers to 'not of relevance'. Good results were achieved by not depicting absolute values per area (only one student failed, using wrong or misleading values), by placing symbols or diagrams within the enumeration units (not the case on

one student's pre-final version which had been created using an automated mapping tool), and by a high diversity in representation methods used (all maps differed). The data provided to the students included multivariate data for revealing meaningful correlations and patterns, and the basemap was already prepared in an equivalent map projection as required for maps showing distributions. However, the task of finding a meaningful pattern (correlations and relations) via the mapping could have been more convincing (in five maps not the case) and was clearly related to a poor application of the cartographic representation method. Partially successful was the use of proportional symbols, with mistakes in the calculations of areas or volumes, the adding of absolute values to relative values for being more meaningful, and the use of common symbol scales and common classes to allow for direct comparison. Despite the fact that natural grouping for data classification was emphasised in both theory lectures and feedback about the pre-final map versions, students did not apply natural grouping in their final maps. Many of the other shortcomings are related to a lack of thoroughness or lacking graphical design skills. These are genuine skills of experienced cartographers. Two students submitted misleading maps. Both still had major issues with their maps at the pre-final stage, one of them finally depicting values which did not make sense at all (i.e. percentages among district municipalities summing up to 100%).

5. Discussion on the teaching approach

5.1 Reflections on the teaching approach taken

The assessment of the student maps (Tab. 1) may seem disappointing but presents the view of what could have still been improved and in the form of a list it was meant to guide the students to further enhance their skills. For the lecturer, it discloses what one needs to pay more attention to in a next course, and it could also serve others as a basis for coming up with a more complete checklist for quality assurance. As the assessment is based on the outcomes of a student project followed by just seven students, it cannot provide a statistically sound analysis. Looking at the overall collection of the student maps, it becomes obvious that the students generally put a lot of effort into their projects: for the first time they elaborated complex thematic maps based on the wide variety of cartographically proven visualization options, which were presented to them during the accompanying theory lectures. The focus of the practical task was on the diversity of cartographic representation methods, on finding the best method for the data at hand, and on appreciating the effect of using different cartographic representation methods for the same data. When the students were asked what the most important aspect was that they had learnt about thematic cartography, some of them indicated that they realized there are many ways to present data and also different ways to present the same data. This is in agreement with Kraak et al. (2018) who emphasize that thematic cartography allows for different visual encodings with many choices to be made during the cartographic design process, i.e. there is no single unique correct map. Not all the student maps were successful in revealing a meaningful pattern or spatial relationships, which can be attributed to them still being beginners or, in a few cases, to a lack of diligence. By having added a set of corrected maps to the student versions (see http://hdl.handle.net/2263/75571 for accessing all maps), we now have a teaching tool at hand for conveying potential misinterpretations by map readers as a consequence of flaws in the map making process. It is in this regard that Kraak et al. (2018) demand mindfulness from cartographers.

The project work borrowed from an assignment which usually serves as a stand-alone appetizer at the start of a major practical seminar so that students are nudged to recall previously taught knowledge and skills (Schaab, 2014b). For the teaching at UP it was turned into a full project, interleaved with theory classes on advanced thematic cartography. The UP students, who were less experienced with thematic maps and applying vector graphics software, were asked to make more complex maps than required for the original assignment. To add to the challenge, teaching was compressed into a block course, which does not allow students time and flexibility for continuous progress as is possible with weekly teaching sessions. Apart from one student, all the students who were interviewed commented that the block course was packed to the brim with content and practical work. They agreed that spreading the content across a full semester would have allowed better internalization of the content and more time for improving their skills in using the software to create maps. Due to the short timeframe, feedback was extended to an enhanced version of the students' final maps, shared with them so that they could further improve their understanding of thematic maps. The changes or modifications added new insights: apart from the whole endeavour being more challenging for both the lecturer and students, good project results were achieved by the students and the map making was experienced as an enjoyable undertaking on both sides. All the students stated that they had learnt something from studying the enhanced versions. When using the set of 28 maps for teaching, the reader is referred to the description or explanations of the revised maps provided as supplement table in Schaab et al. (subm.).

The difficulty of teaching thematic cartography, including a major practical task, within a block course over two weeks clearly lies in the limitation of providing feedback about the maps to the students: only limited progress is possible between the time slots within a two-week period, compared to a course running over an entire semester. To counter this, one round of written feedback on pre-final versions was provided from abroad. However, written explanations cannot be considered to have the same effect as sitting next to a student, looking at the data and map, discussing issues in detail. Moreover, by then, some of the maps had not yet been elaborated enough, so that this final feedback could have helped to produce close-to-perfect maps. This experience added to the motivation for providing corrected, polished versions as an additional learning opportunity. From the interviews, it was evident that students appreciated the feedback sessions about their map designs with the lecturer in the lab. On the one hand, it encouraged them to explore different options and to be creative, while it also helped them stay on track for the final submission. The enhanced maps showed them what they could or should have done. Many of the shortcomings listed in Tab. 1 are related to lacking thoroughness by the students and missing graphic design skills. Whether a student possesses or develops a 'graphical eye' depends on both talent and training, the latter requiring repetitive practice and time to evolve. An overall appealing and effective thematic map composition is compiled of many skilfully combined singularities (Kriz, 2013).

Opting for vector graphics software for performing the practical task was based on the observation that many geoinformation technologies nowadays allow users to click through the map production process without considering cartographic principles which are nevertheless deemed necessary (Howarth, 2015). Indeed, one of the students mentioned that they now consider and apply cartographic principles when making maps with GIS software. According to Boutoura et al. (2016, p. 343) such technologies are useful tools for knowledgeable cartographers, who know the cartographic rules already and can thus take proper advantage of the tools. However, they are "not meant for a student's first compulsory educational acquaintance with thematic cartography". Although the group of students had little lecturing dedicated to thematic mapping before joining the block course, struggled to use vector graphics software and to come up with complex-analytical maps, the

resulting versatile student maps reveal that the task is also doable by students who are less experienced in cartography. More important seems to be that the students were already at an advanced level of their studies (7th semester).

Likely reasons for the success are that the task is fun, requires individual elaborations, uses up-to-date topics, ensures first-time depiction by students and, therefore, is motivating (cp. Schaab, 2014b). A similar experience when teaching thematic cartography was made by Boutoura et al. (2016) who point to the motivation created by portraying self-chosen data from the real life, whether social, political, economic or cultural. This measurably raised engineering students' interest in cartographic and geographic topics. For the lecturer teaching the module at UP, it was again fascinating to look through the versatile results instead of marking student assignments with very similar outcomes. Although this time, the student work did not serve the purpose of getting a picture of the available skills and talents of the students (for a complete list see Schaab, 2014b) before starting a larger project, the differences in students' talents across a wide range of the following skills and aptitudes relevant in thematic mapping also became apparent, such as map design, graphic design, text phrasing and geographic interpretation, apart from being interested and being informed, working thoroughly and creatively.

The block course covered a good mix of teaching methods, thus avoiding monotony, which is even more of a challenge when teaching an entire module in the course of two weeks. All students liked the switching between theory lectures and practical work because it helped them to understand the theory. The theory lectures provided the necessary background with a focus on the diversity of cartographic representation; conveying these requires showing and discussing many examples. Nevertheless, the passive learning approach tends to lack stimulation and engagement on the student side and does not necessarily lead to deeper thinking which active learning is known to achieve, e.g. engaging with data promotes active cognitive processing of spatial information (Schultz, 2012), which both the map reading exercises and the map making project supported. Bampton (2012) considers active learning to be particularly useful for counteracting misconceptions and subsequent under-performance. By intentionally applying threshold concepts (offering conceptual gateways), a qualitative shift in perspective can be achieved and thus new understanding of the material. In this context, so-called troublesome knowledge (where the transition to understanding proved troublesome) is considered of significant pedagogical importance. Besides being transformative and probably irreversible, its third component is integration, because the student needs to acquire the bits before integrating them. The troublesome transition to seeing the bits in a different way leads to real understanding (Meyer & Land, 2003). Creating complex analytical maps from scratch can definitely be troublesome, as it requires integration of various knowledge areas. It is also likely to act as a conceptual eye-opener for understanding what information can be read from thematic maps (compared to raw data) through map interpretation, a high-level map literacy skill (Havelková & Hanus, 2018). One of the students commented that the course taught them that there are many kinds of maps, not only topographic maps, and in addition, maps can be designed as infographics. As such, the map project also fulfilled the necessity of teaching students why certain ways of making maps actually work (Howarth, 2015).

5.2 Reflections on the need of teaching thematic cartography

The use of geographic information systems (GIS) may receive more attention from experts, but the 'normal' person still thinks of maps and not GIS (MacEachren, 2013). If the focus is on the visual

means (the map) and not the supporting technology, the map graphics is considered to be the most important medium for illustrating, communicating and analysing spatial relationships (Asche, 2003), whereas solving problems by means of maps depends largely on the cognitive information and the interpretation abilities of the map users (Wood, 2003). Dodge (2014, p. 302) attributes the power of maps to them being both a practical tool of information processing (analysis) and a persuasive rhetorical communication form (interpretation), which both require "thinking space into being" in the actual mapping process. Based on the interviews, students see maps differently after completing the course, e.g. one student told us that they were now much more alert about misleading maps or maps with potentially fake news. They also appreciate that one can discover a lot of information in a single map.

Today, the original focus on the map graphics in cartographic training at higher education institutes competes with the need to teach the use of constantly and rapidly developing or even new techniques (Schaab, 2014a). Howarth (2015) points to the recurring challenge in cartography education of adapting to the changing tools and techniques used for map making, while still holding onto established cartographic rules or conventions; the latter having the advantage of being timeless but challenged because they are considered to be old-fashioned traditions. Due to astonishing progress in the automation of map making, today it is easier to fascinate students via the technology used for map making than via the resulting maps. It is time again to put effort into ways in which students can be fascinated by artistic and scientifically sound maps which they can produce due to the wide availability of public open data and the many technologies at hand. Based on the interviews, the course achieved this, as all interviewees were intrigued by the many ways in which thematic maps can be used to represent data and also how the trained cartographer had been able to improve their maps. The surprisingly timeless list of generally accepted characteristics of cartographers by Fairbairn (2013), which sets targets for a successful training of today's students (Schaab, 2014a), excludes, probably on purpose, any reference to technologies, as the latter are vehicles only which change rapidly. For the student project described in this paper it is worth pointing out that all seven characteristics of trained map makers, except one, played a role when processing the map task.

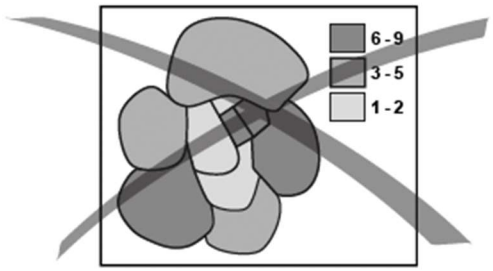
Roth et al. (2014) conclude in their paper on how best to learn and implement contemporary web mapping technologies in higher education that good design matters more than novel tools, as their finding showed primacy of representation over interaction in the web mapping workflow. Good map design and cartographic representation includes skills, which should not be neglected in our otherwise rather IT-focused training of cartographers (Schaab, 2014b). Creating maps based on statistical data is not necessarily the type of thematic maps whose compilation can be left to GIS users (as compared to cartographers) (see Medyńska-Gulij, 2010). Because "the availability of 'free' data and purportedly easy-to-use 'point and click' cartography tools" (Dodge, 2014, p. 299) does not guarantee appropriate and effective maps. Map making, in particular that involving multi-variate and/or time-dependent data, requires human engagement, i.e. skill and thought, as well as considerable effort for coming up with sound representations of space (ibid.). The student interviews revealed that after completion of the course, they appreciated that this is required. They also understood the importance of considering the target audience when designing a map. Those involved in map making in their jobs, confirmed that they were now applying what they had learnt during the course. Schwab (2016) predicts employment to grow in high-income cognitive and creative jobs as a result of the Fourth Industrial Revolution, and cartographers stand to benefit.

As a consequence of the many thematic mapping techniques or map representations available, data may be visualised inappropriately with the likelihood of resulting in a misleading map. This leads to the question how best to guide the selection of the (most) appropriate mapping techniques based on the data type (Tsorlini et al., 2017; cp. also Sibolla et al., 2018). Students need not only to be taught how to proceed in visualizing the important aspects of data, but also of how to avoid manipulation and how to avoid monotony (Ormeling 2003). The number of maps that contain serious flaws is on the rise, either due to insufficient cartographic knowledge of the map maker or due to intentionally distorted data. Based on this observation, Havelková & Hanus (2018) demand building students' ability during geography lessons to critically view and discuss information depicted in maps. Kraak et al. (2018) refer to map users in general, who need to be encouraged to show more awareness towards what is presented on maps. Map literacy or map use encompasses not only the knowledge of how to read a map, but also map analysis and finally map interpretation (Havelková & Hanus, 2018). The correct application of cartographic design principles, which are based on fundamentals of visual perception, strongly impact map interaction, communication and interpretation (Kriz, 2013).

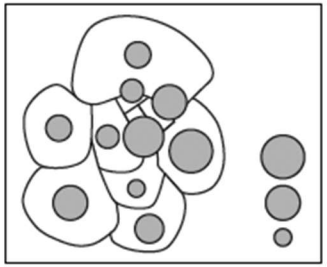
6 Concluding remarks for convincing and appealing thematic maps

Thematic map making follows many rules and principles. By studying textbooks (e.g. Slocum et al., 2010, the most comprehensive one in English), these can be apprehended and conveyed. Experienced lecturers are likely to list their guidelines in categories like 'a must', 'also important / recommended', 'for the sake of completeness' and 'not required'. Based on the teaching experience at UP, figure 4 visualises a subset of nine guidelines considered to be the most important points for making convincing and appealing thematic maps.

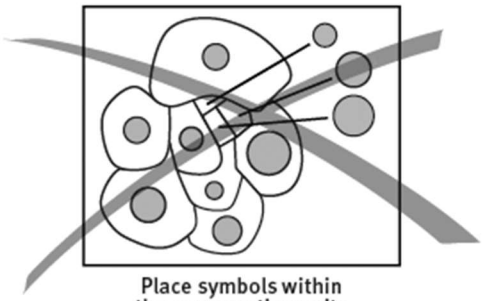
The following six guidelines are 'a must': 1) Absolute (non-standardized) values must never be depicted by filling enumeration units with different colours, shades or patterns. An exception is areas of the same size, which is the case in chorodot/gridnet maps (Friesen et al., 2018). In choropleth maps, the shading of administrative units of highly unequal size influences the map user's perception; Kraak et al. (2018, p. 12) call this "the most common error in thematic mapping". 2) Depict quantitative values by means of symbols reflecting differences in magnitude. For proportional symbols, the symbol scale for best readability should be chosen compromising maximum variation in symbol size and space available. The first option is area-proportionality, but if the value range is too large, volume-proportional symbols can be used instead. If this also does not work out, the coin chart method can be considered. 3) Place symbols within the enumeration units whenever possible so that spatial patterns can be revealed. 4) Use natural groups as the classification method. It works for most of the data distributions at hand. Election maps, which make use of equi-intervals to avoid suspicion of manipulating the map users, are an exception. 5) Use one symbol scale for related variables or common classes in order to allow for comparison of symbol sizes or between choropleth maps. 6) When showing distributions, an equivalent (i.e. equal area) map projection is a must. This poses a challenge nowadays because web services commonly serve readily rendered basemap tiles prepared in the WebMercator projection.



Absolute values must not be represented area-wise



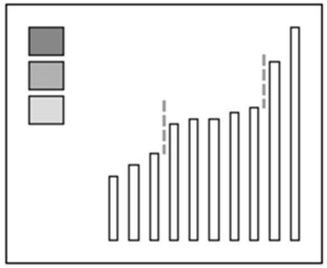
Represent quantities by symbols reflecting differences in magnitude



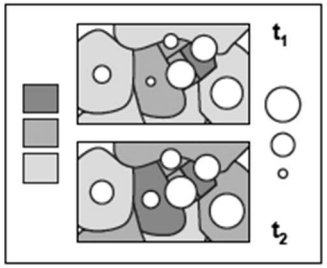
Place symbols within the enumeration units

Guidelines

for convincing & appealing thematic maps



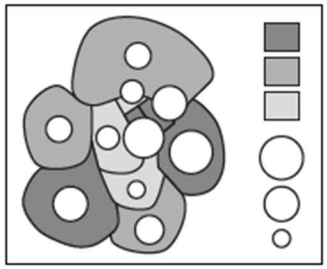
Use natural groups for classification



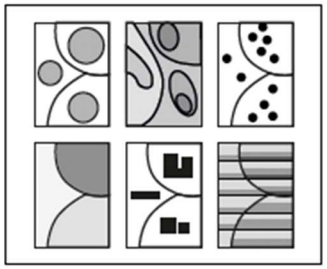
Common classes / one symbol scale facilitate comparison

Distribution maps require an equivalent map projection

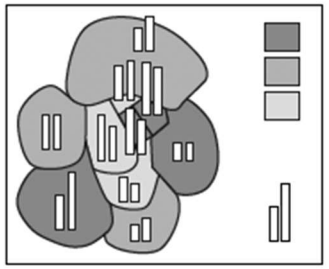
A Must



Enrich relative values by absolute values



Aim at diversity in representation methods



Use multivariate maps to reveal geospatial relations

Also Important / Recommended

Figure 4. *Nine most important points as guidelines for creating correct thematic maps*

An increasing number of cartographic papers express concern (Clarke et al., 2019, Battersby et al., 2014, Friesen et al., 2018, Kraak et al., 2018) because communication and interpretation of spatial patterns is hindered.

Under 'also important / recommended', three more guidelines are selected: 7) Always try to add absolute values to relative (standardized) values in order to make the map (more) meaningful. The advice of Witt (1970) is to enrich the areal depiction of the standardized variable by the related absolute figures represented by proportional symbols. However, counts can also be combined with standardized values for revealing correlations between the spatial distributions of phenomena in complex maps (Friesen at al., 2018). 8). In a collection of maps, aim at diversity in the cartographic representation methods applied. Finally: 9) Use several variables for revealing meaningful correlations or relations, i.e. produce multivariate and not just univariate maps. Although, for readability it is recommended not to choose too many attributes or variables to be displayed on the same map and to favour the combination of mapping techniques with different spatial dimensions (Tsorlini et al., 2017).

The list is intentionally limited and presents rules for thematic map making that are often either not known or not considered by today's map makers. The infographics of Fig. 4 might help in conveying and remembering them, specifically when teaching time is compressed into a block course and thus also the time for the students to internalize the important messages, but the aim is nevertheless to have convincing map outcomes based on multivariate data. Students need to be convinced of their importance, for which a student project like the one described in this paper can be used (see 'M' in Tab. 1, note: the map projection was an integral part of the basemap layer).

These days, experts in geodata handling readily adapt to new technologies but lack design skills (Gartner, 2014), even though the claim of cartography combining art, science, and technology has been adopted also for geomatics (Becek, 2014). The future will increasingly call for collaboration across disciplines and the integration of results in aesthetic and effective maps (Clarke et al., 2019; cp. Smith, 2016), because maps help to reduce complexity (Kraak et al., 2018). Neither map reading and interpretation, nor map making are universally available abilities. With more and more data becoming available, people, who besides mastering the handling of technology and tools have also been trained in how maps work, will make a considerable contribution to furthering the understanding of our planet. Instead of leaving map making to other disciplines, teaching in the field of geoinformation at institutes of higher education should consider rectifying the higher priority recently assigned to technological advancements towards an attractive and fruitful teaching of those principles, which are essential for skilful thematic mapping and thus for effective communication. Here our sets of thematic maps and the infographics can be valuable means for conveying the skills of map finesse.

Acknowledgements

The authors would like to thank the UP students of the BScHons Geoinformatics programme who participated in the Thematic Cartography course in August 2017 and made this publication possible through their maps and by participating in interviews. Gertrud Schaab is grateful for two visits to the Department of Geography, Geoinformatics and Meteorology as part of the University of Pretoria's Visiting Professor Programme.

References

Arnberger, E. (1966): Handbuch der thematischen Kartographie. Franz Deuticke, Wien.

Asche, H. (2003): Kartographie – quo vadis? In: Hermann, C. (Eds.), Entwicklungstendenzen der Kartographie. 25 Jahre Studiengang Kartographie und Geomatik, Fachhochschule Karlsruhe – Hochschule für Technik, Karlsruhe, 85-98.

Bampton, M. (2012): Addressing misconceptions, threshold concepts, and troublesome knowledge in GIScience education. In: Unwin, D.J., K.E. Foote, N.J. Tate & D. DiBiase (Eds.), Teaching Geographic Information Science and Technology in Higher Education, John Wiley & Sons, Chichester, 117-132.

Battersby, S.E., M.P. Finn, E.L. Usery & K.H. Yamamoto (2014): Implications of Web Mercator and its use in online mapping. Cartographica 49(2): 85-101.

Becek, K. (2014): The internet of things: Are we at the fringes of a paradigm shift in geomatics? In: Proceedings (digital) of the FIG Congress 2014 'Engaging the Challenges – Enhancing the Reality, 16-21 June 2014, Kuala Lumpur (Malaysia), TS01E.

Bednarz, R. & J. Lee (2019): What improves spatial thinking? Evidence from the Spatial Thinking Abilities Test. International Research in Geographical and Environmental Education 28(4): 262-280.

Bláha, J.D. (2009): Students' thematic maps as a result of creativity in cartography. In: Gartner, G & F. Ortag (Eds.), Proceedings of the 1st ICA Symposium for Central and Eastern Europe, 16-17 Feb 2009, Vienna (Austria), 1025-1031.

Boutoura, C., A. Kousoulakou & A. Tsorlini (2016): Thematic cartography: A key course in geospatial engineering. In: Gartner, G., M. Jobst & H. Huang (Eds.), Progress in Cartography. EuroCarto 2015, Lecture Notes in Geoinformation and Cartography, Springer, Berlin, Heidelberg, 339-355.

Buchroithner, M.F. (2016): Will paper maps remain smart apps? Kartographische Nachrichten. Journal of Cartography and Geographic Information 1/2016: 3-6.

Cartwright, W. (2012): Neocartography: Opportunities, Issues and prospects. South African Journal of Geomatics 1(1): 14-31.

Clarke, K.C., J.M. Johnson & T. Trainor (2019): Contemporary American cartographic research: A review and prospective. Cartography and Geographic Information Science, https://doi.org/10.1080/15230406.2019.1571441.

Coetzee, S., G. Schaab, V. Rautenbach, C. Stern & S. Adams (2018): Reflections on geomatics and participation summer/winter schools – Mobile map apps for nature conservation in Germany and for informal settlements in South Africa. In: Proceedings of the Academic Track of

AfricaGEO 2018, 17-19 September 2018, Johannesburg (South Africa), 78-91, http://africageoproceedings.org.za/wp-content/uploads/2018/11/655-2330-2-final.pdf.s

Dodge, M. (2014): Mapping and geovisualization. In: Aitken, S.C. & G. Valentine (Eds.), Approaches to Human Geography, 2nd ed., Sage, Thousand Oaks (CA, USA), 289-305.

Dorling, D. (2013): Cartography: Making sense of our worlds. The Cartographic Journal 50th Anniversary Special Issue 50(2): 152-154.

Dorling, D. & D. Fairbairn (1997): Mapping. Ways of Representing the World. Prentice Hall, Harlow.

Fairbairn, D. (2013): Issues in cartographic education: How and how many? In: Buchroithner, M., N. Prechtel & D. Burghardt (Eds.), 'Cartography from Pole to Pole' – Selected Contributions to the XXVIth International Conference of the ICA, Dresden 2013, Lecture Notes in Geoinformation and Cartography, Springer, Berlin Heidelberg, 461-470.

Fairbairn, D. (2014): Education in cartography. In: IMW Working Group of ICA (Eds.), The World of Maps, https://mapyear.icaci.org/the-world-of-maps-book/index.html, chapter 17.

Field, K. & D. Demaj (2012): Reasserting design relevance in cartography: Some concepts. The Cartographic Journal 49(1): 70-76.

Friendly, M. (2008): Milestones in the history of thematic cartography, statistical graphics, and data visualization. http://www.math.usu.edu/~symanzik/teaching/2009_stat6560/ Downloads/Friendly_milestone.pdf (17.10.2019)

Friesen, L., G. Schaab, S. Coetzee, V. Rautenbach, T. Marcus & J. Hugo (2018): Community oriented primary care (COPC) in the City of Tshwane (South Africa) – A web map application in support of responsive and dynamic health care. Kartographische Nachrichten. Journal of Cartography and Geographic Information 4/2018: 173-182.

Gartner, G. (2014): Challenges to cartography: The relevance of cartography, a cartographer's perspective. ArcNews Fall 2014: 29.

Goodsett, M. (in press): Best practices for teaching and assessing critical thinking in information literacy online learning objects. The Journal of Academic Librarianship.

Hake, G. (1970): Kartographie. Vol. II: Thematische Karten, Atlanten, kartenverwandte Darstellungen, Kartentechnik, Kartenauswertung. Sammlung Göschen, Walter de Gruyter, Berlin.

Haklay, M. (2013): Neogeography and the delusion of democratisation. Environment and Planning A 45(1): 55-69.

Harbeck, R. (2001): Kartographie: Vermittlung von Geoinformation. Zur Neuorientierung eines traditionsreichen Fachgebiets. In: Studiengang Kartographie und Geomedientechnik (Eds.), 50 Jahre Ingenieurausbildung für Kartographie in München. Festschrift, Fachhochschule München, München, 43-49.

Harvey, F. & J. Kotting (2011): Teaching mapping for digital natives: New pedagogical ideas for undergraduate cartography education. Cartography and Geographic Information Science 38/3: 269-277.

Havelková, L. & M. Hanus (2018): The impact of map type on the level of student map skills. Cartographica 53(3): 149-170.

Hodza, P., G. Schaab, S. Coetzee, F. van der Merwe & B. Vogt (2015): A comparison of the proportional composition of programs in geo(infor)matics / GIS&T at three universities in Europe, Africa and America respectively. South African Journal of Geomatics 4(3): 240-249.

Howarth, J.T. (2015): A framework for teaching the timeless way of mapmaking. Cartography and Geographic Information Science 42(S1): S6-S10.

Imhof, Eduard (1972): Thematische Kartographie. Lehrbuch der Allgemeinen Geographie vol. X, Walter de Gruyter, Berlin, New York.

Kerski, J.J. (2016): Critical thinking about elections maps and data. The Geography Teacher 13(3): 145-150.

Kraak, M.-J. & F. Ormeling (2003): Cartography: Visualization of Geospatial Data. 2nd ed., Prentice Hall, Harlow.

Kraak, M.-J. & F. Ormeling (2010). Cartography: Visualization of Spatial Data. 3rd ed., Prentice Hall, Harlow.

Kraak, M.J., B. Ricker & Y. Engelhardt (2018): Challenges of mapping sustainable development goals indicators data. ISPRS International Journal of Geo-Information 7, 482, https://www.mdpi.com/2220-9964/7/12/482.

Kriz, K. (2013): Maps and design – influence of depiction, space and aesthetics on geocommunication. In: Kriz, K., W. Cartwright & L. Hurni (Eds.), Mapping Different Geographies, Lecture Notes in Geoinformation and Cartography, Springer, Berlin, Heidelberg, 9-23.

Lee, B., R.H. Kazi & G. Smith (2013): SketchStory: Telling more engaging stories with data through freeform sketching. IEEE Transactions on Visualization and Computer Graphics 19(12): 2416-2425.

MacEachren, A. (2013): Cartography as an academic field: A lost opportunity or a new beginning? The Cartographic Journal 50th Anniversary Special Issue 50(2): 166-170.

MacEachren, A. M. & J.M. Kraak (2001): Research challenges in geovisualization. Cartography and Geographic Information Science 28(1): 3-12.

McConnell, D.A., L. A. Chapman, C.D. Czajka, J.P. Jones, K.D. Ryker & J. Wiggen (2017): Instructional utility and learning efficacy of common active learning strategies. Journal of Geoscience Education 65(4): 604-625.

Medyńska-Gulij, B. (2010): Map compiling, map reading, and cartographic design in “pragmatic pyramid of thematic mapping”. Quaestiones Geographicae 29(1): 57-63.

Meng, L. (2008): Kartographie im Umfeld moderner Informations- und Medientechnologien. Kartographische Nachrichten. Fachzeitschrift für Geoinformation und Visualisierung 1/2008: 3-10.

Metoyer, S. & R. Bednarz (2017): Spatial thinking assists geographic thinking: Evidence from a study exploring the effects of geospatial technology. Journal of Geography 116(1): 20-33.

Meyer, J. & R. Land (2003): Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines. ETL Project Occasional Report 4, Universities of Edinburgh, Coventry and Durham, https://www.colorado.edu/ftep/sites/ default/files/attached-files/meyer_and_land_-_threshold_concepts.pdf (25.10.2019).

Morita, T. (2005): A working conceptual framework for ubiquitous mapping. Proceedings (CD-ROM) of the International Cartographic Conference 2005 ‘Mapping Approaches into a Changing World,' 9-16 July 2005, A Coruña (Spain), theme 12 / session 3.

Musall, H. (2003): 25 Jahre Studiengang Kartographie und Geomatik. In: C. Hermann (Eds.), Entwicklungstendenzen der Kartographie. 25 Jahre Studiengang Kartographie und Geomatik, Fachhochschule Karlsruhe – Hochschule für Technik, Karlsruhe, 3-12.

Ormeling, F. (2003): Cartographic developments and their reflection in (academic) cartographic education. In: Hermann, C. (Eds.), Entwicklungstendenzen der Kartographie. 25 Jahre Studiengang Kartographie und Geomatik, Fachhochschule Karlsruhe – Hochschule für Technik, Karlsruhe, 77-82.

Ormeling, F.J. (2012): Exercises in cartography. In: Zentai, L. & J.R. Nunez (Eds.), Maps for the Future. Children, Education and Internet, Lecture Notes in Geoinformation and Cartography, Springer, Berlin, Heidelberg, 15-26.

Peterson, M. (2013): Taking cartography to the cloud. Kartographische Nachrichten. Journal of Cartography and Geographic Information 4/2013: 191-195.

Pillay, L., G. Schaab, S. Coetzee & V. Rautenbach (2019): A comprehensive workflow for automating thematic map geovisualization from univariate big geospatial point data. In: Proceedings of the 29th International Cartographic Conference, 15-20 July 2019, Tokyo (Japan), 2 – 100, https://doi.org/10.5194/ ica-proc-2-100-2019.

Robinson, A.C., U. Demšar, A.B. Moore, A. Buckley, B. Jiang, K. Field, M.-J. Kraak, S P. Camboim & C.R. Sluter (2017): Geospatial big data and cartography: Research challenges and opportunities for making maps that matter. International Journal of Cartography 3(S1): 32-60.

Roth, R.E., R.G. Donohue, C.M. Sack, T.R. Wallace & T.M.A. Buckingham (2014): A process for keeping pace with evolving Web mapping technologies. Cartographic Perspectives 78: 25-49.

Roth, R.E., K.S. Ross & A.M. MacEachren (2015): User-centered design for interactive maps: A case study in crime analysis. ISPRS International Journal of Geo-Information 4: 262-301.

SAGC (South African Geomatics Council) (2019): Registration – Geomatics Professional Information. https://www.sagc.org.za/4regnotesprof.php (27 Nov 2019).

Schaab, G. (2014a): 35 Jahre Kartographie-Ausbildung an der Hochschule Karlsruhe – den Wandel visualisieren. Kartographische Nachrichten. Journal of Cartography and Geographic Information 4/2014: 187-198.

Schaab, G. (2014b): Traditional map design vs. info graphics: motivating students to reveal their talents. Kartographische Nachrichten. Journal of Cartography and Geographic Information 1/2014: 22-29.

Schaab, G. (2016): Studienangebote im Umfeld Kartographie und Geomatik an den traditionellen Kartographie-Lehrstätten in Deutschland – ein Vergleich. In: Burghardt, D. (Eds.), Vom Gelände zur Karte ... . Festschrift anlässlich des 65. Geburtstages von Prof. Dr. Phil. Habil. Manfred F. Buchroithner, Kartographische Bausteine, vol. 40, 97-115.

Schaab, G., S. Adams & S. Coetzee (accepted): Drawing attention via diversity in thematic map design, as demonstrated by student maps of Northern South Africa. International Journal of Cartography.

Schaab, G., P. Freckmann, R. Stegmaier & S. Ortwein (2009): Visualizing Germany via maps in a magazine: “Fancy” graphic design as compared to “proper” cartography. In: Proceedings (CD-ROM) of the 24th International Cartographic Conference (ICC 2009) ‘The World’s Geo-Spatial Solutions’, 15-21 Nov 2009, Santiago de Chile (Chili), conf. theme 24 Art.

Schultz, R.B. (2012): Active pedagogy leading to deeper learning: Fostering metacognition and infusing active learning into the GIS&T classroom. In: Unwin, D.J., K.E. Foote, N.J. Tate & D. DiBiase (Eds.), Teaching Geographic Information Science and Technology in Higher Education, John Wiley & Sons, Chichester, 133-143.

Schwab, K. (2016): The Fourth Industrial Revolution. World Economic Forum, Geneva.

Schweikart, J. & I. Domnick (2013): Thematic mapping between individual issue and mass media product. Kartographische Nachrichten. Journal of Cartography and Geographic Information Sonderheft Juni/2013: 140-147.

Sibolla, B., S. Coetzee & T. Van Zyl (2018): A framework for visual analytics of spatio-temporal sensor observations from data streams. ISPRS International Journal of Geo-Information 7(12): 1-28.

Slocum, T.A., R.B. McMaster, F.C. Kessler & H.H. Howard (2010): Thematic Cartography and Geovisualization. 3rd ed., Pearson Prentice Hall, Upper Saddle River (NJ, USA).

Smith, D.A. (2016): Online interactive thematic mapping: Applications and techniques for socio-economic research. Computers, Environment and Urban Systems 57: 106-117.

Tsorlini, A., R. Sieber, L. Hurni, H. Klauser & T. Gloor (2017): Designing a rule-based wizard for visualizing statistical data on thematic maps. Cartographic Perspectives 86: 5-23.

Turner, A.J. (2006): Introduction to Neogeography. O'Reilly Media, Sebastopol (CA, USA).

Vogler, R. (2016): „Soziale Geokommunikation" durch Laier – (k)eine Frage der Tools? In: Hennig, S. (Ed.): Online-Karten im Fokus: Praxisorientierte Entwicklung und Umsetzung. Wichmann, Berlin, 105-123.

Waldt, A. (2008): Alles Karte. Mappen mit Sinn und Verstand. DE:BUG. Magazin für elektronische Lebensaspekte, Musik, Medien, Kultur, Selbstbeherrschung 124: 36-37.

Wilhelmy, H. (1966): Kartographie in Stichworten. III. Thematische Kartographie. Hirt, Kiel

Witt, W. (1970): Thematische Kartographie. Methoden und Probleme, Tendenzen und Aufgaben. 2nd ed., Veröffentlichungen der Akademie für Raumforschung und Landesplanung, Abhandlungen vol. 49, Gebrüder Jänecke, Hannover.

Wood, M. (2003): Future of cartography and geographic information science. In: Hermann, C. (Eds.), Entwicklungstendenzen der Kartographie. 25 Jahre Studiengang Kartographie und Geomatik, Fachhochschule Karlsruhe – Hochschule für Technik, Karlsruhe, 55-63.