sciendo

ORIGINAL PAPER

Problem-solving procedures in spatially explicit tasks: comparing procedures with printed and digital cartographic documents

Petr Trahorsch[1] ✉ — Jakub Reich[1]

[1]Department of Geography, Faculty of Science, J. E. Purkyně University, Ústí nad Labem, Czechia
✉ *petr.trahorsch@ujep.cz*

Abstract

The aim of this research study is to compare the procedures for solving geographical problems with printed and digital cartographic products. These documents are used in various areas of society, including regional development or visual communication in the media. A total of 27 probands participated in the research. Individuals were randomly divided into two groups, one group working with a printed atlas and the other with a digital atlas in the same version. Respondents were tested using stationary and wearable eye-trackers while completing a didactic test to determine different levels of map skills. The results of the research showed that although the procedures and the success rate for solving the different tasks did not differ between the two groups of respondents, the differences were mainly in the time needed for the solution and in the satisfaction in the use of a given type of cartographic work.

Highlights for public administration, management and planning:

- There are no differences in problem solving success between respondents working with a printed and digital cartographic documents.
- Problem-solving practices depend on individuals' internal assumptions rather than the type of medium.
- The level of satisfaction with the use of the title varied substantially, with respondents complaining about the lack of clarity and tediousness of handling the digital cartographic document.

Keywords

Digital atlas,
Printed atlas,
Eye-tracking,
Map skill

Received:
26 October 2022

Received in revised form:
25 March 2023

Accepted:
31 March 2023

1 Introduction

1.1 Rationalisation of research

Cartographic resources are seen as a key tool for geographical knowledge (Bláha 2021; Wiegand 2006). Due to the development of information technology, cartographic resources nowadays have many possibilities for their creation, editing and presentation (Dodge et al. 2008). Users themselves also have to get used to new ways of using cartographic resources, which may or may not be user-friendly for them (cf. Swienty et al. 2008). One of the key directions in the development of cartographic tools is online, digital or even interactive maps. Unlike traditional printed maps, the user can enter the interactive interface, change individual map properties (e.g. scale) or discover individual information about individual spatial units. The goal of using interactive cartographic products is usually, from the point of view of their creators, relatively simple data editing, reduced presentation costs and the potential to reach a wider range of users. On the other hand, for the users themselves, these cartographic resources represent a fast, cheap and above all universally usable tool for geographic knowledge. However, it is clear that the practices of using different forms of cartographic products may inevitably differ between users, as analogue and interactive cartographic presentations have several fundamentally different characteristics (O'Looney 2000; Solórzano et al. 2017).

© Jan Evangelista Purkyně University in Ústí nad Labem

GeoScape 17(1) — 2023: 34—46 doi: 10.2478/geosc-2023-0003 Available online at content.sciendo.com

In interpreting geographical phenomena and processes, users (in some cases, those responsible for making the right decisions on socio-economic issues in society) depend on the correct handling of cartographic products (Corbett & Keller 2003). Their decision-making thus depends on the level of their map skills (Wiegand 2006), but also on the characteristics of the cartographic work (cf. Havelková and Gołębiowska 2019; Jones et al. 2004; Swienty et al. 2008). Thus, decisions made by individuals and organisations about intentions regarding spatial change (e.g. in spatial planning processes) undoubtedly run up against the quality of processing of the same cartographic product in its different forms (printed vs. online, digital or interactive versions; O'Looney 2000), which may manifest itself in different accelerated regional development (MacDougalla et al. 2018).

One of the traditional cartographic tools that influence the perception of space and the development of geographical literacy is the (school) atlas. This didactic tool is very often referred to as the first comprehensive cartographic work with which an individual comes into contact and through which he or she forms geographical knowledge and perception of space (Trahorsch et al. 2020; Wiegand 2002). However, it is not only pupils who are users of this cartographic product; university students are also one of the key users, as are geography teachers. They use the atlas to prepare for and during geography lessons and can thus influence their students' geographic literacy and map skills (Bietlová et al. 2021).

Unfortunately, many research methods cannot very well and objectively identify how users of these cartographic products interact with or use school atlases (cf. Wiegand 1998; Blades et al. 1998; Trahorsch et al. 2020; Michaelidou et al. 2004, 2007 and others). In the past, traditional research methods such as interviews, didactic tests, questionnaires, observations, or methods originally based on other fields of science, such as the method of mental mapping (Bláha & Pastuchová-Nováková 2013), have very often been applied. However, these methods may be subject to error based on the respondent's answers, as the respondent may knowingly or unknowingly provide false information to the researcher (Cohen et al. 2008). However, some of the disadvantages of these methods are eliminated by the eye-tracking method, which has the potential to capture eye movements relatively accurately and identify which parts of the cartographic product the user is looking at and extracting information from, and which parts he is not. This method is often complemented by other research methods to ensure greater validity and reliability of the results (Duchowski 2007).

The comparison of user workflows with printed and interactive cartographic products can answer the question of how the processes and results (e.g. success rates) of using these cartographic products differ. To answer this question, we have chosen the field of geographic education as an example, since cartographic products are a traditional tool for geographic knowledge (cf. Sandford 1985; Rystedt 1995) and cartographic publishers publish school atlases in both forms: printed and interactive (Kartografie Praha 2021a,b). The aim of the study is therefore to compare the problem solving practices and success rates of users of printed and interactive cartographic products, using the example of a school atlas and a Geography trainee teacher as future users of the cartographic products under study. However, we assume that geographic education is chosen as an exemplary example and the results of the study will be transferable to other areas of geography, or the whole society. The results of our study can stimulate discussion or implementation of other research in the field of spatial planning, regional development, etc. (cf. Corbett and Keller 2003; O'Looney 2000). The results can indicate how users proceed when solving tasks with a spatial context, which can be fundamentally different from non-spatial ones (Jo & Bednarz 2009). The applicability of the findings there may be suitable for the field of visual communication in the media (Greyson et al. 2020), in self-government or in the development of the regions (De Graff et al. 2012; Kingston 2007). This can contribute to the creation of a more user-friendly concept of printed and digital cartographic documents for experts and the general public.

1.2 Using eye-tracking in geographic education research with a focus on working with cartographic products

The eye-tracking method has a long tradition in research on respondents' behaviour (Popelka 2018). Due to the development of these devices, along with the relative decrease in the associated cost and the variability of the models offered, eye-tracking is penetrating research in various fields, including geography (e.g., Beljaars 2020; Wang et al. 2021). Eye-tracking is very intensively used in the study of work with cartographic products (Havelková & Hanus 2019). Considering the benefits of eye-tracking, this method is primarily used to study the work with electronic versions of maps; the reason for this is, among others, the higher ac-

© Jan Evangelista Purkyně University in Ústí nad Labem

curacy of stationary eye-tracker compared to mobile (wearable) eye-tracking (Duchowski 2007). The results of the studies show sub-strategies of users when working with electronic resources, but these are not transferable to analogue resources (cf. Rockinson-Szapkiw et al. 2013).

Factors influencing map work can be broadly divided into three main categories (Havelková & Hanus 2019): user characteristics (age, cognitive abilities; e.g. Sun et al. 2020; Wang et al. 2021), cartographic product properties (thematic cartography methods, cartographic representation; e.g. Michaelidou et al. 2004; Ozcelik et al. 2009; Swienty et al. 2008) and other external factors (time of day, character of the environment, role of the teacher; reviewed by Gagné 1977). This study therefore focuses on the characteristics of a cartographic product, specifically a school atlas. Among the key features that will be considered in the interpretation of the results will be the form of cartographic presentation (interactive and printed form). As previous studies conducted on user strategies when working with these two forms of presentation in education have already shown, user strategies differ considerably. Solórzano et al. (2017) conducted a study conceptually similar to the one we present. Unfortunately, the cited authors did not test two identical works in printed and electronic form, but their research was focused on similar atlases (i.e. not identical atlases). The cited authors found that students had better problem-solving times and success rates with the electronic (interactive) atlas, but satisfaction and readability were better with the printed atlas. Although it was not the purpose of the study to investigate problem-solving strategies, some items of the research tool indicated that they used different problem-solving strategies as a result of the interactivity of the electronic atlas. Using topographic maps as an example, Incoul et al. (2014) addressed the differences in the use of printed and digital maps. The authors found that there were no differences in the distribution of attention between the two titles, but a higher number of fixations per second was recorded for the digital maps. The results of substudies looking at other learning materials are ambiguous in terms of preference for print and electronic resources; for example, Abuloum et al. 2019; Millar and Schrier 2015 and Woody et al. 2010 report that students prefer print-based learning resources rather than electronic ones because they are more convenient and they are used to them; in contrast, Gibbons (2001) reports that students would be more likely to use an electronic textbook when choosing a resource for their learning because they could access it more easily from anywhere. The difference in research design of the cited studies does not allow the results to be generalized.

User characteristics when working with maps have been the subject of a number of studies. In what follows, we will only focus on the relationship between student and teacher characteristics in schooling as this is the focus of the study. A key characteristic of users playing a role in map use is their cognitive level, whether conditioned by age or experience (Alhosan & Yagoub 2015; Blades et al. 1998; Hanus & Marada 2016) We can give an example related specifically to school atlases; Trahorsch et al. (2020) found that some cartographic features cannot be understood by primary school students because their abbreviations, e.g. the abbreviations of chemical elements used in these signs have not yet been taught in the classroom; on the contrary, teachers, as other users of these products, appreciate the abbreviations of chemical elements in the signs of mineral extraction for their clarity; this result shows the different requirements of pupils as objects of learning and teachers as facilitators of this process. A similar discrepancy between problem-solving strategies was found in a study by Bietlová et al. (2021), which highlighted differences in problem-solving strategies between students and their teacher; follow-up interviews revealed that the teacher used different strategies than her students as a result of her experience with a given cartographic data presentation. Thus, it is clear that although the teacher has his/her own conception of map skills and tries to apply this conception in teaching (Hanus & Havelková 2019), with regard to the intellectual abilities and previous experience, it is not possible to regard the problem-solving strategies of the student and their teacher with the school atlas as the same (cf. also Postigo and Pozo 2004; Ooms et al. 2014).

Unfortunately, other studies that deal with working with the atlas as a comprehensive whole are lacking, and studies focusing on working with sub-specific maps predominate. It is the work with the atlas as a whole that can give the user a more comprehensive picture of the phenomenon under study and a better understanding of the spatial context of geographical phenomena and processes. A significant limitation of monitoring work with the entire atlas is the complexity of the tasks, which limits the use of a larger sample of respondents due to time-consuming data analysis.

© Jan Evangelista Purkyně University in Ústí nad Labem

GeoScape 17(1) — 2023: 34—46 doi: 10.2478/geosc-2023-0003 Available online at content.sciendo.com

2 Methods

The aim of the research was to compare the methods of solving geography problems with the school atlas between respondents working with the printed atlas and students working with its electronic version. The group of respondents was randomly divided into two groups, with one group completing the tasks with the printed version of the atlas, and the other group completing the same tasks with its identical digital version. Subsequently, the results were analysed, collated and interpreted. When describing the methodology, we try to use the recommendations according to Holmqvist (2022).

2.1 Participants

A total of 27 trainee Geography teachers studying the first year of an undergraduate degree in Teaching Geography combined with another subject participated in the research. These were all students who were studying at the Faculty of Science of the Jan Evangelista Purkyně University of Ústí nad Labem in the academic years 2020/2021 and 2021/2022. A total of 14 respondents worked with the printed atlas (Kartografie Praha 2021a), and 13 respondents with its digital version (Kartografie Praha 2021b). Respondents were randomly assigned to the two groups via lottery. The age of respondents ranged from 23–26 years (M = 24.09; SD = .78). There are not many study participants, but this is a relatively common practice in studies using eye-tracking (Ooms et al. 2014; Keskin et al. 2019). Given the focus of their studies, this group of students is continuously being prepared for employment as geography teachers. The courses they have attended so far have focused on developing their map skills and working with the type of atlas with which the research was conducted. It can therefore be assumed that the participants have at least a basic understanding of the title and know its structure.

2.2 Research tool

The research tool consisted of a didactic test with complex geographical tasks. The test tasks were designed in such a way that the respondents had to use the cartographic work as a whole. In other words, they had to use different parts of the atlas (e.g. index, geographical grid, etc.) or different maps (physical, political, thematic maps of regions) to solve most of the problems. The design of the tasks also took into account the application of different map skills (following Hanus and Marada 2014); respondents demonstrated the ability to read map in the first tasks, in the next task they demonstrated the ability to analyse a map and in the last task they were asked to interpret the map. The different levels of map skills may have given the researchers feedback on which levels prospective teachers were failing at and whether this was due to faulty practices, and conversely which tasks the respondents were successful at. Given the relatively small number of respondents, most of the tasks were open-ended, which helped to better understand the reasons for incorrect answers when evaluating the responses, as well as to more accurately assess the degree of correctness of the answers (e.g. when interpreting the maps). The complete research instrument is located in the Supplement 1 of the article.

Respondents worked with the current edition of the school atlas from the publishing house Kartografie Praha in printed (Kartografie Praha 2021a) and digital version (Kartografie Praha 2021b), depending on which group they were assigned to. The digital atlas interface is shown in Fig. 1. The maps in the printed atlas are the same. These are the current versions of the atlases most commonly used in Czech education (Bietlová et al. 2021) and the research participants are thus familiar with them both from their studies and from their preparation for the teaching profession. With both versions of the cartographic product, the probands had experience in using them. They became familiar with electronic and printed atlases, among other things, as part of teaching geography education.

The didactic test method was complemented by the eye-tracking method. To measure eye movements, the Tobii Pro Glasses 2 eye-tracker (100 Hz) was used to record work with the printed atlas and the Tobii Pro X2 - 60 stationary eye-tracker (60 Hz) was used to record work with the digital atlas. The same instrument manufacturer is thus an added value. Both instruments were carefully calibrated for each respondent. The research was carried out in laboratories at the J. E. Purkyně University in Ústí nad Labem. The device was calibrated in the standard way recommended by the manufacturer, no other tools were used for calibration (e.g. GitHub - glassesValidator)

After the research and the didactic test was completed, a short reflective semi-structured interview was conducted with the respondent. The aim of the interview was to find out how he evaluates (reflects) his work with a given type of atlas and how he reflects on his solution of selected learning tasks from the didactic test.

© Jan Evangelista Purkyně University in Ústí nad Labem

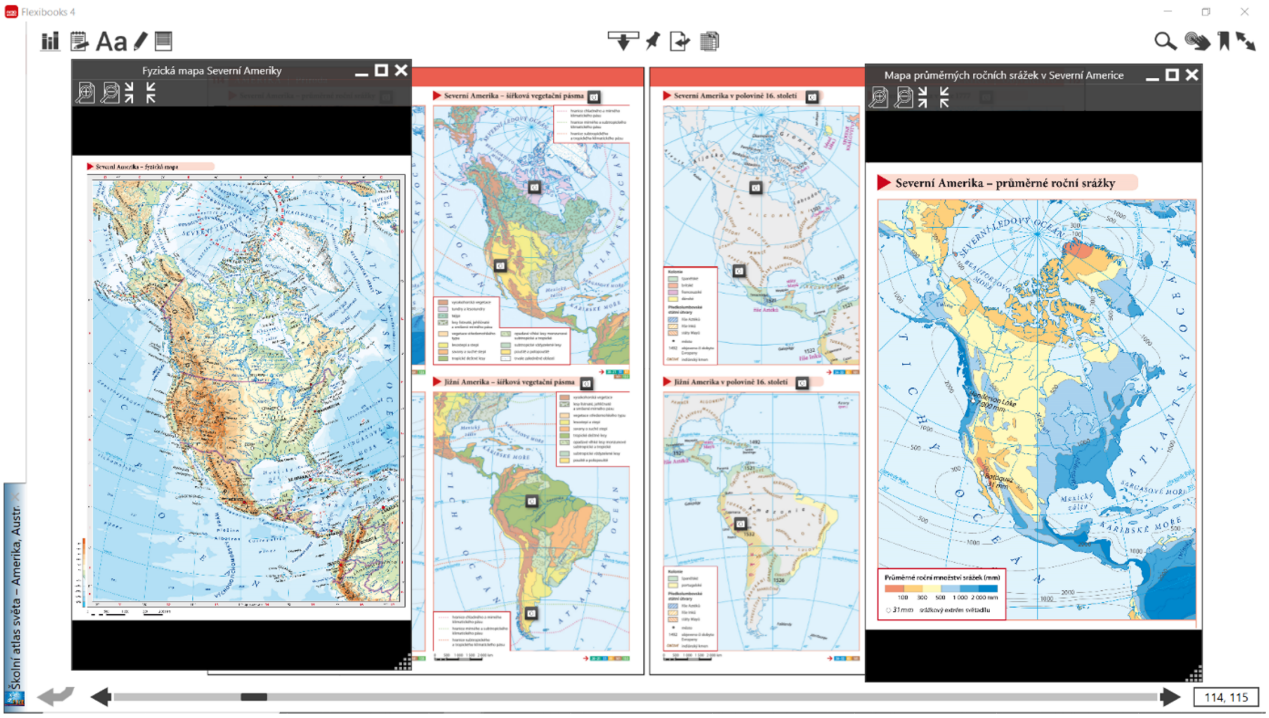


Fig. 1 Interface of the digital atlas (Kartografie Praha 2021b)

2.3 Data collection

Before each participant began working with the atlas, the individual was informed about the research process, its purpose and importance, and of course the nature of the eye–tracking method. The instrument (wearable and stationary) was calibrated for each participant, with the technology reporting correct calibration for all participants. Participants filled in their answers obtained from the atlas in an electronic form. In case of any uncertainties, a researcher was available to respond flexibly to respondents' questions. Taking into account the participants' experience of working with a school atlas as part of their preparation for the teaching profession, no time was given to familiarising themselves with the cartographic work before starting to solve the problems, as the participants were already familiar with this work. The mean of recorded data (tracking ratio) was 86.3% (SD = 4.9) and all records were in the tested areas, therefore none of them were excluded from the research set.

2.4 Data analysis

The collected data were processed qualitatively and quantitatively. Quantitative data analysis included the application of basic descriptive characteristics of the population (mean, mode, median, standard deviation, etc.) and the application of non-parametric statistical procedures. These methods are appropriate when the sample selection is not random, or the data do not show a normal frequency distribution (Hendl 2012; Chráska 2016). Specifically, the Mann-Whitney test and the ordinal correlation coefficient were used at a significance level of α= 0.05. The data were supplemented by the interpretation of the effect size, which indicates the applicability of the results in practice (Soukup et al. 2021). Attention was paid mainly to the scoring of the test or its sub-items (success rate of solving the tasks), the time needed for solving the tasks, which may indicate the ease (difficulty) of solving the tasks. In keeping with the aims of this study (and hence the considerable complexity of solving problems with such a large body of work), we did not focus on criteria such as Areas of interest tracking. Data analysis was performed in the software provided by the manufacturer, i.e. Tobii Pro Lab (1.123.22321).

To analyse the progress of the individual in solving the given tasks, the progress of the individual was primarily observed in the atlas as a whole and its subparts, not on individual maps. The researcher tracked which parts the individual used in solving the tasks, how they used them, and in what or-

© Jan Evangelista Purkyně University in Ústí nad Labem

GeoScape 17(1) — 2023: 34—46 doi: 10.2478/geosc-2023-0003 Available online at content.sciendo.com

der they proceeded. This analysis was carried out primarily at a qualitative level, with the recording of the parts of the atlas used in a pre-prepared form. Visualized heat maps are uniformly set to radius 12 px, opacity 100 %, absolute count, without set maximum value. The interview conducted with the research participants was transcribed verbatim and subsequently analysed using open coding (Švaříček & Šeďová 2014).

3 Results

3.1 Comparison of overall results of work with digital and printed atlas

First of all, it should be noted that the scores for the entire test are comparable for both groups of respondents. The group working with the digital atlas achieved a mean success rate of 8.1 points (SD = .90), while the group working with the printed atlas achieved a mean success rate of 8 points (SD = .81). The Mann-Whitney test showed no statistically significant difference between the two groups (p = .98). It can therefore be argued that both groups achieved identical results. The level of effect size according to Cohen's d is d = .11, indicating the practically no significance of the results. The results show that the form of the atlas does not play a role in the overall success rate of the didactic test. Respondents working with the digital version of the atlas took an average of 21.78 minutes, while the group of respondents working with the printed atlas took 18.64 minutes. However, the Mann-Whitney test showed no statistically significant difference between the groups (p = .77). Even the effect size shows their minimal practical impact (d =.10).

We also looked at the correlation between test scores and the time it took respondents to complete the didactic test. The Spearman's rank correlation coefficient is r = .62, indicating a medium level of dependence. Thus, the success rate in the test explains less than 40% of the variance in the length of problem solving. This result is statistically insignificant at the 5% significance level (p = .06). Table 1 compares the solution success rate and time between the two groups of respondents. It is clear from the table that the success rate for solving a given problem decreases and the time required to solve it increases when applying higher levels of mapping skills.

3.2 Comparison of individual strategiea for solving problems with digital and printed atlases

Qualitative analysis of the results, analysis of eye-tracker and interview data, identified different types of solvers at different stages of the didactic test. The first task focused on the use of different parts of the atlas. The eye-tracker identified two types of solvers. The first type were the solvers who proceeded in solving the problems more or less conventionally and were able to verify the searched for geographical terms and subtasks during the test. This group was characterized by the use of an index and tracing place names on a map. These individuals used the index and did not proceed to the next task unless they were sure they got the previous task correct. After memorizing the code from the index, the students found the appropriate map and did not return to the index, in both groups (printed and digital atlas). The average time to solve the task for this group was 2.2 minutes, but this group made far fewer errors (89% success rate). The second type of solvers were students who did not take much care and tried to solve the problems with only one map without checking the information in the index. These individuals searched for the desired locations only in the given map and had no motivation to use

Table 1 Comparison of success rates and solution times in the individual parts of the didactic test

Task	Applied Map Skills	Digital atlas		Printed atlas	
		Percentage of correct answers (%)	Time required to solve the task (in min)	Percentage of correct answers (%)	Time required to solve the task (in min)
1a	Reading	57	2.5	57	1.8
1b	Reading	92	4.0	93	3.0
2a	Analysis	92	2.6	71	2.4
2b	Analysis	38	3.5	29	3.1
2c	Analysis	61	2.9	79	2.3
3a	Interpretation	61	3.0	36	3.5
3b	Interpretation	31	3.7	29	3.0

© Jan Evangelista Purkyně University in Ústí nad Labem

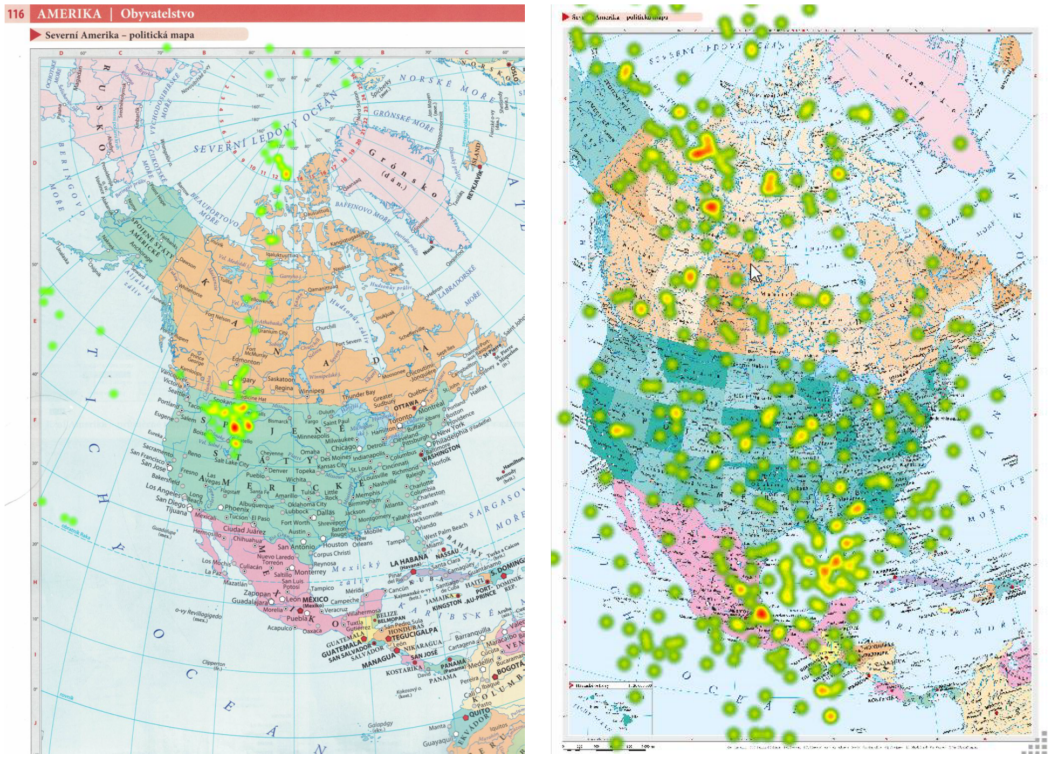


Fig. 2 Comparison of the procedures of individuals who used the index (left) and those who searched for cities on the map by trial and error (right)

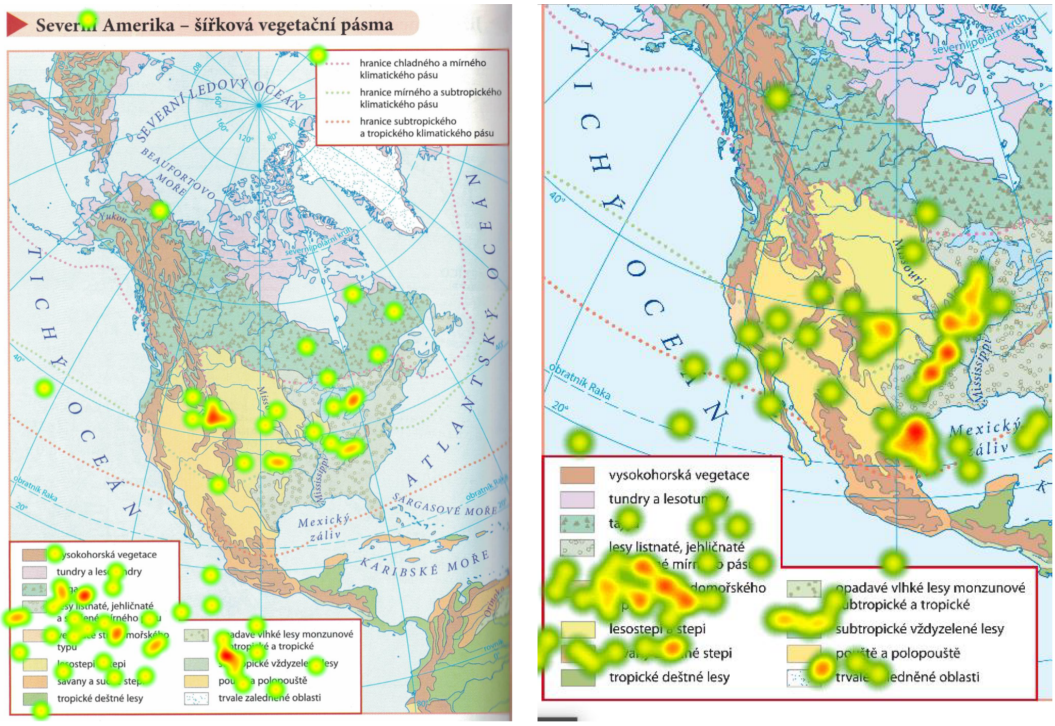


Fig. 3 Comparison of respondents' work with a printed (left) and digital (right) atlas

 © Jan Evangelista Purkyně University in Ústí nad Labem

GeoScape 17(1) — 2023: 34—46 doi: 10.2478/geosc-2023-0003 Available online at content.sciendo.com

other parts of the atlas. Although the average time to solve this task was better (1.8 min), the success rate was relatively low (59%), with the difference between the two groups of solvers being statistically significant ($p = 0.04$). Interestingly, the type of atlas did not play a role in the problem-solving procedures, because the number and ratio of users with a printed and digital atlas was very similar in both mentioned groups (9 : 6 and 7 : 6). A comparison of the sample heat maps of Task 1, in which they had to search for a less American city, is shown in Fig. 2. From the figure it is clear that the respondent, after using the index, orients himself according to the parallels and meridians and searches for cities in a relatively small area, while the second respondent without using the index uses the whole map area to search for a city.

The basis for solving the analysis tasks was the correct combination of the use of the legend, appropriate map orientation and the identification of the location of cities from general geographical or political maps (from task 1). The solution procedure among the respondents did not differ significantly, as they all followed a similar procedure, namely checking the location of the city on the map from task 1, orientation on the thematic map and reading the value from the legend (Fig. 3). Although the respondents working with the digital atlas took longer to solve tasks, there were no statistically significant differences in the results of this task between the two groups ($p = 0.41$). Respondents working with both atlases, however, consistently stated in interviews that they had problems locating cities on the map because there were no landmarks (e.g., state borders, rivers, etc.) on the thematic maps.

The last task focused on map interpretation. Respondents were forced to explain geographical phenomena and processes in space based on previous tasks and their knowledge. In this type of task, some respondents' unfamiliarity with the concept of population density was a limiting factor, as they confused it with data on agglomeration size (see also Fig. 4). As in the previous tasks, the procedures leading to the solution of the task were the same as in the previous tasks; students oriented themselves on the map, located the cities they were looking for and used a combination of the legend and the map box to answer, justifying their answer primarily on the basis of their own knowledge.

The interviews mainly revealed information regarding the user-friendliness for dealing with the tasks. Virtually all respondents who worked with the electronic atlas complained of poorer work efficiency. They were particularly bothered by the more demanding and slower handling of the cartographic work (e.g. turning pages, verifying information; *"...it was terribly difficult for me to click through the maps to see where they were growing the crops. And the handling of the index, where I almost couldn't read the terms, was terrible"*) or the less legible nature of some of the information in the index and on the maps (... *"I couldn't see the necessary data I needed to navigate to the correct meridian and parallel. That was a little less clear. And the colours were quite problematic because I couldn't tell them apart"*). Conversely, the ability to view some maps side by side is a definite advantage with a digital atlas, which was appreciated by three respondents (e.g.*"... what I need where I need it, and I just clicked where I had the pages open. So, it's not that I went as one question page, question page, but that I clicked it first to have it clear, and only then did I finish it."*). However, respondents' intrinsic factors influencing task success were very common; motivation was probably a key factor (e.g., answering the question why the respondent did not use the index even though his answer was incorrect: *"...I just know where the city is"*). Although the concept of both atlases is the same, the user interface of the digital atlas is not as easy to use as the printed version.

4 Discussion

The success rate for both groups, users of print and digital atlas, is comparable. Time needed to solve the problems was also not identified as a statistically significant factor underlying the differences in solving the problems with the printed and digital tools. This shows that the use of this tested cartographic title is ultimately free of major differences between the two versions. However, as the results of the interviews with both groups show, the printed atlas is more user-friendly for the future teachers to work on the tasks. This is probably due to the poorer user interface and control of the digital version of the atlas, as users had problems with page flipping, zooming in on maps, colour resolution on the computer display, etc.; on the other hand, students appreciated the ability to have multiple maps open side by side, which made it easier to compare data between multiple maps. In the case of a printed atlas, the key factor facilitating the use of this title is the personal experience of the respondent as well as the elimination of subtasks when working with the atlas compared to the digital version. Virtually the same results were obtained by Solórzano

© Jan Evangelista Purkyně University in Ústí nad Labem

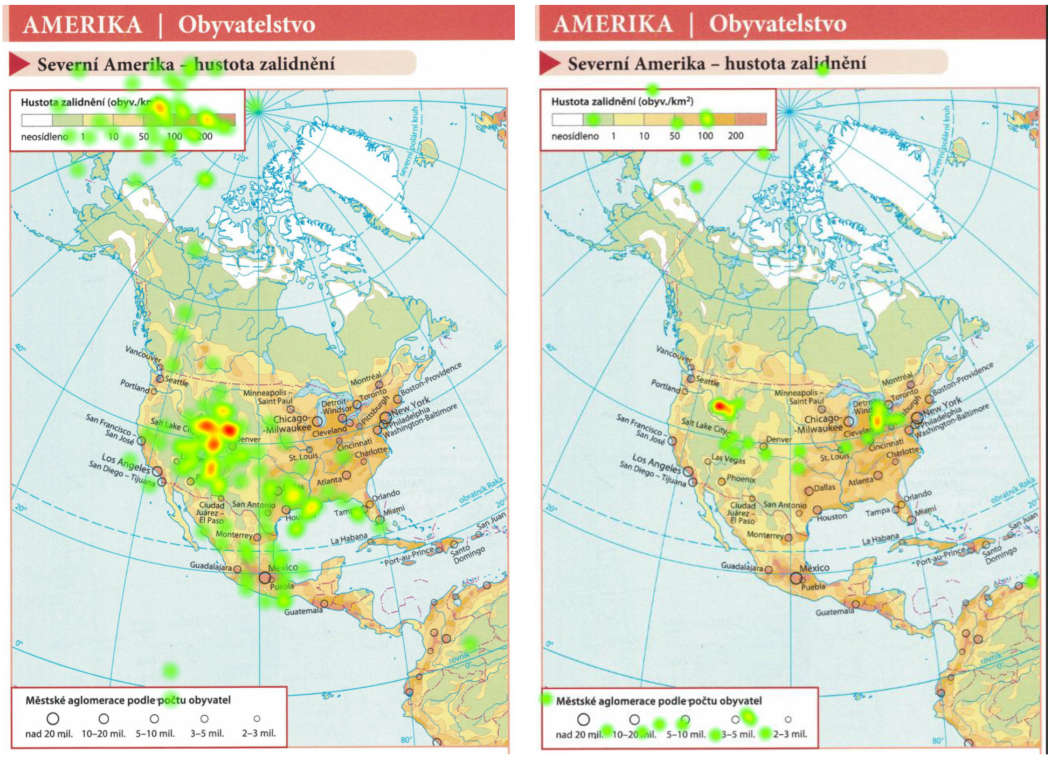


Fig. 4 Using the correct (left) and incorrect (right) legend when interpreting population density

et al. (2017), who also showed a higher level of satisfaction when working with a printed title compared to a digital one. When the results are confronted with other learning materials, printed textbooks are more user-friendly (Abuloum et al. 2019; Millar & Schrier 2015; Woody et al. 2010); however, an earlier study (Gibbons 2001) indicated the opposite result, which may be due to the advent of digital learning materials at the time of the study (cf. Gibbons 2001) Given the different type of media compared to the present study, this comparison must be viewed critically.

As noted, students working with the digital atlas spent significantly more time studying the maps. However, it was also interesting that they moved from one map to another much less in the atlas. Students working with the printed version flipped through the atlas much more. They returned much more to the maps they needed in previous tasks (e.g. in tasks 2a-2c alone, students working with a digital atlas returned to maps 21% more than students with a printed atlas, in case in task 1a, the difference was less than 4 %). This phenomenon could indicate a greater willingness of students to work with a printed atlas, due to its greater user friendliness and greater willingness to work with multiple maps.

The results showed that the individual's experience with the school atlas played a key role in the choice of problem-solving procedures. On the other hand, the type of cartographic medium (digital or printed) did not play a role in the chosen procedures and was comparable between the two groups. This result may indicate a complementary degree of efficiency in decision-making on regional development; digital maps may not be the only possible cartographic tool used in public administration, despite their undeniable advantages (see Introduction) – (cf. Corbett and Keller 2003). Respondents who indicated that they regularly work or have worked with the atlas solved problems using more efficient methods. Respondents with a low level of motivation or with a low level of cartographic skills used a trial-and-error strategy in some cases; for example, when searching for cities where the respondent did not know the location, they did not use the atlas index but searched for the city directly on the map. The time required to find a city was not always higher, as searching the atlas index is time consuming (especially in the digital version of the atlas). The role of experience in working with visuals (and therefore maps) has been discussed several times. In particular, Bietlová et al. (2021) have shown that although in some respects the conceptions of map skills of teachers and their

 © Jan Evangelista Purkyně University in Ústí nad Labem

GeoScape 17(1) — 2023: 34—46 doi: 10.2478/geosc-2023-0003 Available online at content.sciendo.com

students may be similar, they differ when solving specific learning tasks with an atlas, mainly due to the level of teacher experience (Bietlová et al. 2021). At this point, the question arises as to what level of map skills are achieved by those responsible for the management of regions, as this level can (see the results achieved) be reflected in the effectiveness of work with the cartographic product.

The results of the present study in relation to the cognitive difficulty of the tasks do not show major discrepancies with previous studies. The more cognitively demanding tasks (in this case focused on map interpretation) were characterized by longer solution times and lower success rates, whereas tasks focused on mere object localization were characterized by higher success rates due to at least a basic level of map skills (cf. Hanus and Marada 2016; Michaelidou et al. 2007; Wiegand 2002 and others).

The results of the presented study can be implied not only in the field of education. Map creators should choose user-friendly interfaces that do not hinder users from completing tasks. In this version of research tool, the desktop version of the program enabling the reading of the cartographic product, according to the users, made it difficult to solve the tasks. For example, in the case of a high-quality online map, the public can also enter into the process of regional development planning, which can lead to desirable changes in the region (Kingston 2007). Even more striking is the need for high-quality interactive maps in the field of media, in which online platforms using digital maps already completely prevail. Comparing the functionality of the map there can make it easier for the reader to understand the presented phenomena. In general, however, maps can be recommended for all areas of human activity that meet the basic usability criteria (e.g. presence of basic compositional elements, readability, etc.)

4.1 Limits of the study

The study has a number of limitations that must be considered when interpreting the results. First of all, it is necessary to point out the lack of initial diagnosis of both groups. Although the respondents were randomly divided into groups, it cannot be objectively ruled out that one group differs in some key factors of map skills (e.g. intrinsic motivation, level of cognitive ability, level of experience working with the atlas, etc.).

A significant limitation of the study that enters into the data obtained is the accuracy of the eye-trackers used. In the researchers' attempt to compare strategies with different versions of the atlas, it was necessary to use two different, but high quality and accurate, eye-trackers. Unfortunately, due to the different target orientation of the stationary and wearable eye-tracker and their functioning process (e.g. different recording frequency, mobility during task solving, etc.), it is necessary to take into account potential bias of the results from which we would like to obtain the most accurate results. On the other hand, it should be noted that the researchers' attention was primarily focused on the solution procedures and the sequence of individual tasks, rather than focusing on the sub-elements of the maps; thus, the varying accuracy of the eye-trackers did not play a key role in this study that could have biased the results.

The use of induction statistics to interpret the results may be debatable. Opinions on the use of these statistical procedures vary across authors (Chráska 2016; Soukup and Kočvarová 2016; Soukup et al. 2021 and others). In this study, we used non-parametric statistical tests, which some authors allow to be used if the research sample does not meet all the rules for the use of parametric tests (see Chráska 2016:63,64).

5 Conclusion

The study showed that it showed that the success of solving tasks with a printed and digital atlas is the same, but the procedures and especially the time are different for users using a printed and digital atlas. The choice of how to solve the given problems depends on other factors (especially individual factors related to the level of map skills) rather than just the form of the electronic and printed cartographic presentation. Of course, the study did identify partial differences in the use of the two titles; however, these differences can be seen as certain sub-outcomes that do not fundamentally affect the success of the use of the product. To some extent, the results also suggest that the digital cartographic information source has the potential to be very usable. However, users are likely to need to acquire additional competencies to operate the digital (in some cases even interactive) interface. To some extent, this may temporarily mean a reduced speed in solving tasks or a lack of satisfaction when using digital cartographic work. However, the success rate of problem solving, as this study has shown with the example of school atlases, is probably comparable with both versions of the same cartographic work.

© Jan Evangelista Purkyně University in Ústí nad Labem

This research has the potential to inform further studies in the field of geographic research. As working with cartographic products is a common part of local policies, it would be useful to focus future research studies on the problem-solving ability of those responsible for regional development (i.e. persons not studying geography) with cartographic materials, as well as on working with printed cartographic resources and their digital variants; for example, web map services (e.g. Google maps) are now increasingly used, which may require different working strategies from users than the digital atlas tested, which is in the nature of learning software.

Acknowledgements

The research was supported by the Smart City-Smart Region-Smart Community project OP VVV, PO1, N. CZ.02.1.01/0.0/0.0/17_048/0007435.

References

Abuloum AM, Farah A, Kaskaloglu E, Yaakub A (2019) College students' usage of and preferences for print and electronic textbooks. *International Journal of Emerging Technologies in Learning* 14, (7):80–97.

Alhosan NMD, Yagoub MN (2015) Geographic skills: a case study of students in the United Arab Emirates. *International Research in Geographical and Environmental Education* 24, (1):95–102.

Beljaars D (2020) Towards compulsive geographies. *Transactions of the Institute of British Geographers* 45, (2):284–298.

Bietlová M, Popelka S, Voženílek V, Fačevicová K, Janečková J, Matlach M (2021) The Importance of School World Atlases According to Czech Geography Teachers. *International Journal of Geo-Information* 10:8 504.

Blades M, Blaut D, Elguea S, Sowden S, Soni D, Spencer C, Stea D, Surajpaul R, Uttal D (1998) A cross-cultural study of young children's mapping abilities. *Transactions of the Institute of British Geographers* 23:269–277.

Bláha JD (2021) *Vybrané okruhy z geografické kartografie*. Univerzita J.E. Purkyně, Ústí nad Labem, .

Bláha JD, Pastuchová-Nováková T (2013) Mentální mapa Česka v podání českých žáků základních a středních škol. *Geografie* 118, (1):59-76.

Chráska M (2016) *Metody pedagogického výzkumu*. Grada, Praha.

Cohen L, Manion L, Morrison K (2008) The Methodology of Educational Research.

Corbett JM, Keller CP (2003) Speaking maps: use of digital maps and multimedia by local communities to influence decision making in west Kutai Indonesia. In: *Proceedings of the 21st International Cartographic Conference (ICC). Durban* pp. 13–22.

De Graff J, Romesburg H, Ahmad R, McCalpin J (2012) Producing landslide-susceptibility maps for regional planning in data-scarce regions. *Natural Hazards* 64.

Dodge M, McDerby M, Turner M (2008) The power of geographical visualizations. In: Dodge M, McDerby M, Turner M, (eds.) *Geographic visualization*. John Wiley & Sons, West Sussex, pp. 1–10.

Duchowski AT (2007) *Eye Tracking Methodology*. Springer, London.

Gagné RM (1977) *Be conditions of learning*. Rinehart and Winston, Holt.

Gibbons S (2001) E-books: Some concerns and surprises. *Portal: Libraries and the Academy* 1, (1):71-75.

Greyson D, O'Brien H, Shankar S (2020) Visual analysis of information world maps: An exploration of four methods. *Journal of Information Science* 46, (3):361–377.

Hanus M, Havelková L (2019) Teachers' concepts of map-skill development. *Journal of Geography* 118, (3):101–116.

Hanus M, Marada M (2014) Map skills: definition and research. *Geografie* 119, (4):406-422.

Hanus M, Marada M (2016) What does a map-skills-test tell us about Czech pupils? *Geografie* 121, (2):279-299.

Havelková L, Gołębiowska IM (2019) What went wrong for bad solvers during thematic map analysis? Lessons learned from an eye-tracking study. *International Journal of Geo-Information* 9, (1):9.

Havelková L, Hanus M (2019) Research into map-analysis strategies: theory- and data-driven approaches. *Geografie* 124, (2):187–216.

Hendl J (2012) Přehled statistických metod zpracování dat: analýza a metaanalýza dat.

Holmqvist K (2022) Eye tracking: empirical foundations for a minimal reporting guideline. *Behavior Research Methods* 55.

Incoul A, Ooms K, Maeyer P (2014) Comparing paper and digital topographic maps using eye tracking. In: Brus J, Vondráková A, Voženílek V, (eds.) *Modern Trends in Cartography*. Springer, Heidelberg, pp. 339–356.

Jo I, Bednarz S (2009) Evaluating Geography textbook questions from a spatial perspective: Using concepts of space, tools of representation, and cognitive processes to evaluate spatiality. *Journal of Geography* 108, (1):4–13.

Jones A, Blake C, Davies C, Scanlon E (2004) Digital maps for learning: A review and prospects. *Computers & Education* 43, (1–2):91–107.

Kartografie Praha (2021a) *Školní atlas světa*. Kartografie Praha, Praha.

Kartografie Praha (2021b) *Interaktivní Školní atlas světa*. Kartografie Praha, Praha.

Keskin M, Ooms K, Dogru A, Maeyer P (2019) EEG & Eye Tracking User Experiments for Spatial Memory Task on Maps. *International Journal of Geo-Information* 8, (546):1–17.

Kingston R (2007) Public participation in local policy decision-making: the role of web-based mapping. *The Cartographic Journal* 44, (2):138–144.

MacDougalla H, Tomosk S, Wright D (2018) Geographic maps of the impact of government incentives on the economic viability of solar power. *Renewable Energy* 122:497–506.

 © Jan Evangelista Purkyně University in Ústí nad Labem

Michaelidou EC, Nakos BP, Filippakopoulou VP (2004) The ability of elementary school children to analyse general reference and thematic maps. *Cartographica* 39, (4):65–88.

Michaelidou EC, Filippakopoulou VP, Nakos BP (2007) Children's choice of visual variables for thematic maps. *Journal of Geography* 106, (2):49–60.

Millar M, Schrier T (2015) Digital or printed textbooks: Which do students prefer and why? *Journal of Teaching in Travel & Tourism* 15, (2):166–185.

O'Looney J (2000) *Beyond maps: GIS and decision making in local government*. Esri Press, .

Ooms K, Maeyer P, Fack V (2014) Study of the attentive behavior of novice and expert map users using eye tracking. *Cartography and Geographic Information Science* 41,(1):37–54.

Ozcelik E, Karakus T, Kursun E, Cagiltay K (2009) An eye-tracking study of how color coding affects multimedia learning. *Computers & Education* 53, (2):445–453.

Popelka S (2018) *Eye - tracking (nejen) v kognitivní kartografii - praktický průvodce tvorbou a vyhodnocením experimentu*. Univerzita Palackého v Olomouci, Olomouc.

Postigo Y, Pozo JI (2004) On the road to graphicacy: the learning of graphical representation systems. *Educational Psychology* 24, (5):623–644.

Rockinson-Szapkiw A, Courduff J, Carter K, Bennett D (2013) Electronic versus traditional print textbooks: A comparison study on the influence of university students' learning. *Computers & Education* 63, (2):259–266.

Rystedt B (1995) Current trends in electronic atlas production. *Cartographic Perspectives* 20, (1):5–11.

Sandford HA (1985) The future of the school pupils' desk atlas. *The Cartographic Journal* 22, (1):3–10.

Solórzano LSG, Comíns JS, Sendra JB (2017) Atlas design: A usability approach for the development and evaluation of cartographic products. *The Cartographic Journal* 54, (4):343-357.

Soukup P, Kočvarová I (2016) Velikost a reprezentativita výběrového souboru v kvantitativně orientovaném pedagogickém výzkumu Pedagogická orientace 26.

Soukup P, Trahorsch P, Chytrý V (2021) Míry věcné významnosti s intervaly spolehlivosti a ukázky jejich využití v pedagogické praxi. *Studia paedagogica* 26, (3):131–166.

Sun Y, Lu X, Wang Y (2020) Using eye tracking to explore differences between high and low map-based spatial ability. *Journal of Geography* 119, (6):215–225.

Swienty O, Reichenbacher T, Reppermund S, Zihl J (2008) The role of relevance and cognition in attention-guiding geovisualisation. *The Cartographic Journal* 45, (3):227–238.

Trahorsch P, Bláha J, Kučerová S (2020) The usability of economic maps for students of various age groups: An example for a discussion of a multi-stage concept of teaching aids. *International Research in Geographical and Environmental Education* 29, (2):129–145.

Wang M, Wu J, An N, Lin M (2021) The effect of emotional experiences in fieldwork: embodied evidence from a visual approach. *Journal of Geography in Higher Education*. on-line first-.

Wiegand P (1998) Atlases as a teaching resource: findings from a national survey. *Geography* 83, (4):358–366.

Wiegand P (2002) School students' mental representations of thematic point symbol maps. *The Cartographic Journal* 39, (2):125–136.

Wiegand P (2006) *Learning and teaching with maps*. Routlege, London.

Woody WD, Daniel DB, Baker CA (2010) E-books or textbooks: Students prefer textbooks. *Computers & Education* 55, (3): 945–948.

Švaříček R, Šeďová K (2014) *Kvalitativní výzkum v pedagogických vědách*. Portál, Praha, .

© Jan Evangelista Purkyně University in Ústí nad Labem

Available online at content.sciendo.com GeoScape 17(1) — 2023: 34—46 doi: 10.2478/geosc-2023-0003

Supplementary material

Supplement 1: A complete research tool

1. a) Use the coordinates to determine which city on earth it is: 40°30’ N, 111°50’ E
   b) Use the index in atlas to find in which US state the city of Cleveland is located.

2. Using the thematic maps of North America, fill in the data for the cities from task 1 in the table.

City	Average annual precipitation in∼mm	Latitudinal vegetation zone	Agricultural crop

3. Using a map with population density in North America, find out what the approximate population density is around the cities of Provo and Cleveland, and using the answers from the previous question and the thematic maps, try to explain why this is so.

© Jan Evangelista Purkyně University in Ústí nad Labem