ADAPTATION OF QGIS TOOLS IN HIGH SCHOOL GEOGRAPHY EDUCATION

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ABSTRACT:

In the last decades, geography teachers have been trying to figure out how to adopt GIS (Geographic Information Systems) tools for their high school classes. Predominantly, teachers have come to use commercial versions. Lately, it has been QGIS getting more attention, especially in environments where teachers do not have access to sufficient funding. Nevertheless, there is a lack of ample research results and available teaching materials for geography teachers that want to give QGIS in their lessons a go. This paper presents our attempt to bridge this gap. We have set several goals in our search for the possibilities of adopting QGIS tools for high school geography lessons. The main one was to learn about the strategies that students have when they are learning about QGIS. Furthermore, we wanted to know what knowledge the students would demonstrate after attending a short course on QGIS basics and if their learning strategies during the lectures would impact their results. To find out, we created a set of 10 lessons and tested most of them on students from a high school in Brno, Czech Republic. The results of two pilot studies show that our research has not ended and that further investigation needs to be made about the circumstances that can affect a successful adaptation of QGIS tools in high school geography education.

1. ADAPTATION OF GIS TOOLS IN EDUCATION

Educators, backed up by years of research, believe that by collecting, displaying and analysing spatial data, students can solve local problems and foster and drive their learning process of geography phenomena. After using GIS, they are supposed to gain digital skills and extraordinary thinking that can be essential for their future careers and be motivated to pursue a career in science and engineering (Bednarz, 2004).

However, implementing GIS software into high school geography classes is a lengthy process that requires a lot of patience and confidence. A teacher may come across four major obstacles: 1) lack of hardware, software or data, 2) lack of teacher training and materials, 3) lack of support for innovations, and 4) lack of time to learn and teach GIS (Kerski, 2003). The biggest issue has come to be the insufficient pre-service and in-service teacher training in geoinformatics and its application. A recent systematic study (Bernhäuserová et al., 2022) has concluded that most of the limits were related to teachers and resources.

The implementation of GIS in teaching and the adaptation of its tools for the objectives of geographic education in secondary and primary schools can be carried out in several ways. Currently, five main ways are recognised: 1. teaching about GIS, 2. teaching with GIS, 3. learning about GIS, 4. learning with GIS, and 5. researching with GIS. The choice of each of these depends mainly on the desired learning outcomes and the teacher's capabilities. The most frequently discussed are learning with GIS and learning about GIS (Bednarz, 2004; Demirci, 2008).

The goal of learning about GIS is to acquire the technical skills required for manipulating the software. The most common form

of such learning is following instructions from a teacher in a step-by-step method (Whyatt et al., 2022). These can be found in various teaching manuals, referred to as Cookbooks (Mandel et al., 2016). In this way, students learn to use the program's analysis tools and manage geospatial data (Rød et al., 2010). In addition, they focus on the theoretical side of the issue and learn the basic terminology they operate with when working with the software. The conclusion of their learning is a conceptual understanding of GIS (Schulze, 2021), which can be manifested, for example, in the map they create. The main criticism of this approach is that it does not develop a deeper connection between GIS and geography (Argles, 2017), but rather computer science. On the other hand, other authors see this as a positive thing. According to them (Whyatt et al., 2022; Carlson 2008), the student must get familiar with the theoretical side at the beginning to move on to more cognitively demanding operations requiring independent work.

When learning with GIS, there is a focus on the geographical content of the curriculum. In this case, GIS serves as a tool (or rather process) that can convey geographical information and concepts on a particular topic, and develop geographical thinking (Buzo-Sánchez et al., 2022). Interactions with software, program or application are limited (Baker et al., 2015). The student primarily uses web-GIS, which does not require more excellent technical knowledge and skills (Rød et al., 2010). It is a learning method used in inquiry or project-based learning, where the learner is at the centre of the learning process and uses the GIS construct to understand the geographical phenomenon (Rød et al., 2010). According to several experts (Lloyd, 2001; Baker, 2005;), students should be introduced to GIS through this strategy. Their

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main arguments are the positive results long-term work with GIS can have on students. These include geographical and spatial thinking combined into the concept of geospatial thinking.

Based on an analysis of articles published between 2005 and 2014 Schulze (2021) concludes that the state of knowledge in the field of empirical research on GIS education is still inconclusive. The synthesis results proved that by 2015 the most common GIS software used in high school education was commercial software. Teachers used them for learning with GIS. On the other hand, the method of learning about GIS dominated in higher education. We have found no article that would suggest that these practices have changed. The results of another synthesis (Konstantaktos and Galani, 2022) prove that there is big heterogeneity in this research area. It corresponds with the findings of Baker et al. (2015), who publishes a call for a more complex study of implementing GIT into education.

One of the researchers that dived into the diversity of GIS learning strategies is Madsen and Rump (2012). They explored different learning strategies with GIS that their undergraduate geography students have in an introductory course to the software (in the academic year 2004/2005). Based on classroom observations and interviews with students during the semester, the authors compiled five types of strategies that students employed to approach their learning:
A: *Prioritise "doing the task "* – Students follow the assigned steps. They use GIS as a learning tool (learning about GIS). The cookbook format of lesson instructions is convenient for them.
B: *Focus on understanding* – Students follow the assigned steps but stop and try to understand the action they have just taken. Use GIS as a learning process (learning with GIS). They use a Cookbook but "read between the lines ".
C: *Play with the GIS programme* – Besides the specified approach, they are looking for other uses/ways. They use the Cookbook but also try different variations of the procedure for more profound understanding (also at home).
D: *Combine it with other subjects* – They understand GIS when they use it concerning the content of other subjects. They apply the Cookbook to other topics as well.
E: *Question whether they have learned GIS*
In their research sample (n = 47), most of the students were of type B (n = 18), slightly fewer were of type A (n = 17), half of those were of type C (n = 8), and a quarter of those were of both type D and type E (n = 2). For autonomous learning (type C), boys were predominant, and girls were mainly in the first two types (Madsen and Rump, 2012).

2. METHODS

To obtain answers to our questions, we have created a set of 10 lectures, which focus on the basics of working with QGIS software. Their piloting (i.e., testing or validation in a school setting) was guided by the principles of design-based research. Such research focuses on developing solutions to complex issues in pedagogical practice and on developing or validating theories about educational processes and their environments (van der Akker, 2006). This is to be done through developing learning and teaching materials (e.g. worksheets, teaching practices and curricula, educational courses and programmes) referred to as interventions. These different interventions result from a close collaboration between researchers and practitioners (i.e., teachers from preschool to tertiary education). Together, they develop, validate, modify and improve them until they eliminate all gaps.

This partnership has become a new paradigm for contemporary learning in education (van der Akker, 2006). Thus, the value of design research lies in its practical side, which builds on the initial theoretical values. These are complemented at the end by a new theory contributing to didactic knowledge about the pedagogical problem (i.e., design principles). Through their dissemination, the quality of teaching can be enhanced (Bakker, 2018). Three items result from design-based research: 1. a new curricular product (teaching material), 2. design principles (synthesis of discovered general didactic principles), and 3. the professional development of the participating teacher and researcher (McKenney and Reeves, 2019).

A major advantage of design research is that it employs quantitative and qualitative data collection and analysis methods. This offers the researcher a wide range of possibilities that can help him or her understand the pedagogical problem under investigation and find a more concrete solution (Cohen et al., 2011). In Table 1, we define which methods were chosen to answer the research questions we set out.

Research question	Method of data collection
How would students assess the piloted lessons?	Survey (feedback)
What learning strategies do students choose, when working with QGIS?	Observation Questionarre Interview
What knowledge do studnets aquire after their learning?	Test

Table 1. Methods of data collection paired with research questions of our study.

The main aim of the observation was to find out how the students coped with working with the software. In our observation notes, we tried to capture the work strategy of each pair in a scheme that corresponded to the students' seating arrangements. Subsequent analysis identified the main three situations. In the last stage, we related to the main three identified in the research by Madsen and Rump (2012), resulting in a matrix of nine categories of students in relation to their learning with QGIS (see Table 2).

Student during lectures	Description of their work		
	Faced no problems	Often faced problems	Worked individually
Focused on finishing the task	A1	A2	A3
Focused on understanding	B1	B2	B3
Played with the program	C1	C2	C3

Table 2. Matrix of nine categories of student learning strategies.

In our research, we used a questionnaire survey in the first case to get feedback from students on the lessons we piloted. Using Google Forms, we created an 18-item survey that students answered at school or at home for homework, if possible. The questionnaire consisted of two identification questions (name, class), eight closed dichotomous questions (yes, no), seven open-ended questions, and one scaled question with seven statements

(Likert scale). The number of questions for each respondent depended on the filter questions' answers (n = 7).

The second survey, in the form of a short questionnaire, was used to confirm our assumptions about students' attitudes towards working in QGIS, based on observation and submitted feedback. With two three-choice questions at the end of the piloting, before students sat the test, we asked them about their attitudes towards their work and how they would rate their work in class (Table 2). Students had the choice of circling only one option or choosing one dominant and one minor option to describe their situation in more detail.

For the purposes of our research, we included semi-structured interviews at the end of the piloting for both classes. Participation was voluntary. Through it, we wanted to gain a closer understanding of the students' attitudes towards their work with the software and their overall experience of the lessons. For this reason, three lists of questions were created, one for each strategy. These consisted of common questions (for the beginning and the end) and category-focused questions. The interviewees' responses were recorded on a mobile device with their permission and then transcribed into a selective protocol, as we did not need a verbatim transcript of the entire interview. We noted those responses that were particularly interesting to us; additional information around this was, if anything, merely summarised in notes.

The aim of our assessment test was to determine the level of understanding of basic terminology and procedures that students encountered during the piloting across lessons. This was to test technical (geoinformatics) rather than geographic knowledge. The test also sought to find differences between the performance of those who were actively working with the software in the lesson and those who were assisting or rather passively participating in the lesson. To differentiate between them, we included questions and tasks of dual difficulty, type (open, closed, to organise, etc.) and focus (defining, describing, justifying, etc.) in the test. Finally, we also included three questions that sought to elicit students' subjective feelings about the software they were working with. Since both classes did not cover the same lectures, we created two versions that were different only in three questions. The total scores of the tests are the same.

Before creating the materials for our research, we had no prior personal experience with a lesson in which students worked with QGIS. For this reason, we decided to test the sample lecture we had created a year ago. We labelled this phase as pre-research. After this experience, we looked up and studied available spatial data for the Czech Republic that we could use and with inspiration from already published Cookbooks we created a set of 10 lectures (see Table 3), which were compiled into a workbook for students.

For easy distribution of created study materials during the pilot testing, we decided to publish them on a page that we set up on the Google Sites domain. We chose this domain mainly because it is a free site that is linked to other Google services such as Google Drive and Google Form, which offer a repository suitable for submitting student work and feedback in digital form. For each lesson, we created a tab containing instructions, the necessary data required to complete the lesson, a place to upload maps and exercises, and a link to the feedback form. Below this, we inserted relevant theory as needed, a sample final map, and links to appropriate YouTube videos for those who didn't understand some of the tools or required further assistance to complete the map at home.

The link to the website that served as online support for the face-to-face and distance learning sessions: https://bit.ly/42byoMO.

Lecture (name)	Content of lecture
Lecture 1 (Basics)	Students download software, get to know the Graphic User Interface of the program, learn the geometry of vector layers and get to know the icons of essential tools.
Lecture 2 (Layout)	Students learn to set a coordinate system, add vector layers to a project, make a map layout, edit its components and export it.
Lecture 3 (Symbology)	Students learn to edit the symbology of the vector layers and style polygons according to the category. They get to know the Attribute table.
Lecture 4 (Relief)	Students learn to cut lines according to the selected area and display the profile of a chosen touristic route based on the DEM model of the area.
Lecture 5 (Labels)	Students learn to add labels to points and lines, revise the layout and export of map.
Lecture 6 (Category)	Students learn to graduate polygons according to the use of the area (woods, plains, cities etc.) and display four choropleth maps on one canvas.
Lecture 7 (Diagrams)	Students learn to make a thematic map combining a choropleth map with diagrams displaying the origin of tourists visiting Czech Republic.
Lecture 8 (Create)	Students learn to add underlying raster maps, create several new vector layers, add geometry and revise the edit of SVG symbology.
Lecture 9 (Compare)	Students revise learnt content, find differences between vector layers and the underlying map and fix them.
Lecture 10 (Finish)	Students reflect on what they have learnt and give feedback to created maps.

Table 3. Description of created lectures.

The lessons were tested at a grammar school (gymnasium) in Brno, Czech Republic. By agreement with school management, two classes were selected, students in the fourth and final year of a six-year course. During this course, students from the second to the last year have two Geography lessons per week. In total, we taught 62 students, 29 from the fourth year (11 boys and 18 girls) and 33 from the final year (13 boys and 20 girls). The testing took place during their Geography classes, under the supervision of their teacher, in the Geography classroom, which, however, is not equipped with computers. Because of this, a survey was conducted among the students in advance of the testing to

determine how many pieces of technology would be available in the classroom. It was found that at least one computer per pair should be provided. We could not equip the computer laboratory, so we were dependent on individual student equipment. This eventually saw to several technical problems that reflected the incompatible operating systems and diverse skills of the students involved.

The entire pilot testing took about three months. The first part was conducted in the senior year and focused on 5 lessons in November and December 2022. The first two lessons were assigned to students for individual study, and they were given instructions for those lectures at the initial orientation session. In January, students in Grade 4 participated in seven lessons. Table 4 displays which lectures were tested by which students.

Lecture	1st pilot	2nd pilot
1	individual study	2 lessons
2	individual study	1 lesson
3	1 lesson	1 lesson
4	1 lesson	wasn't tested
5	1 lesson + ½ lesson	wasn't tested
6	wasn't tested	wasn't tested
7	1 lesson + ½ lesson	wasn't tested
8	wasn't tested	2 lessons
9	wasn't tested	1 lesson
10	wasn't tested	wasn't tested

Table 4. Distribution of tested lessons among two pilots.

Each lecture follows a single pattern. The time allotment, difficulty and name of the lecture are indicated in the header. Below the number is a short description of the topic, what the students are tasked to do, and what they will learn from the lesson.

The progression of the work is listed in a logical order and is numbered. Instructions are written in complete sentences, in sufficient detail, but not too lengthy.

There is always an icon next to the tools mentioned to make it easier for students to find their way around. However, there are no other visual prompts in the procedure, so students are left to the teacher's demonstration or their own exploration. The process shown in this way is found only in the Teacher's Guide. The used tools and functions are highlighted in the text. At the end of each lecture, there are several exercises to revise and deepen the covered topic.

3. RESULTS

The two-phase testing of our lectures has shown us that several amendments in used spatial data and exercises are needed. However, the instructions for them required no changes. Only the time allotment and difficulty were updated. We have recognised that some lectures are more difficult and take longer time than we had assumed.

These findings are connected to the main issue that we faced – students in both classes had different needs. Our inexperience in teaching about and with QGIS has resulted in our incapability of fitting the content of lectures and style of lessons to the needs of all students. More students had technical problems than we were prepared for and more students (mainly in the first pilot) found small to no interest in the lessons we taught. Nevertheless, students from both classes did not have as diverse learning strategies as it first seemed to us. After each lesson, we marked the learning strategies we could recognise and, in the end, we drew a scheme which showed their distribution.

We were unable to compare our assumptions about students' strategies (for learning GIS) in 10 cases; for various reasons, students did not take an optional test that ended the piloting. Our estimates are consistent with all the strategies the students chose that we could verify.

After each lecture, students were assigned some homework exercises and were asked to give us online feedback on the last lecture. Along with that, students had to submit their final maps. Students that worked in pairs submitted only one map and one set of exercises. Results from their feedback and analysis of these artefacts give us a clearer picture of what students thought of the lessons and what they had learnt. Students from the first pilot were more reluctant with their feedback and on average, only 65 % of all students in the classroom filled out a form for every lecture. After this, we took some preventive measures and motivated students from the second pilot to help us more. As a result, on average 95 % of students filled out every feedback. Because of this, we decided to focus on the findings related to student strategies and scores on the final test.

After the first pilot, we also made minor changes in the style of the lessons. Students who did not bring a computer for the class no longer filled out the protocols (i.e., lab notes) and were asked to assist their partners. Occasionally, during the lessons, we checked if these students were taking their roles seriously and not slacking off. Luckily, the students paid attention to our demonstrations and helped their partners.

3.1 Student strategies for learning about QGIS

Already in the lessons of both pilots, we observed that most students fell into the A1 category, followed by A2 and least into B3. To verify our assumptions, we included a short questionnaire at the beginning of the didactic test that required students to match the corresponding letter and number. To avoid confusion, we gave them examples of all the categories.

Not all students participated in the questionnaire. The results represent 22 (66 %) students from the first pilot and 23 students (79 %) of the entire class from the second pilot. According to the results (see Table 6), we can see that in both classes, most students focused on completing the assignment and did not have major problems with their work. Six students (18 %) had periodically problems in the first piloting class, and four students (14 %) were in the second piloting class. In the first piloting class, four students (12 %) regularly worked independently based on the instructions on the website; in the second piloting class, half as many (6 %) did so. In the second piloting class, more students sought to understand the procedure rather than just follow it (20 % versus 9 %). Only one student learned to work with QGIS by playing with the program and working independently.

To further understand how students worked with QGIS in our classes and why they chose to adopt the given learning strategies, we invited all students to participate in a voluntary interview. Five students from the first pilot (see Table 5) and three students from the second pilot (see Table 7) accepted our invitation. We anonymised the students' names to preserve their identity, leaving only the initial letter of their names. For each, we report their learning strategy, their test scores, and whether they worked on the computer, assisted, or completed the protocol.

Also, to introduce them further, we indicate whether the students have a relationship with geography (whether they enjoy this subject more than others), whether they have had previous experience working in QGIS, and what they plan to pursue after high school.

For both groups, one student had previous experience with QGIS, both used it to write their high school research, and both are thinking about majoring in geography or a related field. The others have a largely positive relationship with geography, with only one student preferring other science subjects. In the first group, there are students of only two strategies (A1 and B3), in the second group, they are all significantly different strategies.

Initially, we gave students feedback on their maps, exercises and tests. We tried to create a friendly atmosphere for the students and help them recall the lessons, which we then talked about for about an hour.

3.1.1 Category A1 students: The most represented category in piloting in both classes was A1, with our eight interviews being no different. These students are defined by a focus on completing the assignment and a few problems that would slow them down as they work.

The students justify their trouble-free work through a systematic procedure that was demonstrated and explained to them step by step. All four agree that they were comfortable with the chosen pace, which not only allowed them to work out everything by themselves but also to help their classmates around them who might have been lost. Ema, Mary and Katherine also attribute their success to the cooperation that existed in their pairs. They did not forget to mention that motivation also played a significant role for them. Only Mary is considering studying for a degree in a field close to geography, but even the other girls do not feel they were wasting their time working in QGIS.

Cate-gory	1st pilot		2nd pilot	
	Absolut frequency	Relative frequency (%)	Absolut frequency	Relative frequency (%)
A1	11	33	14	48
A2	6	18	1	3
A3	2	6	1	3
B1	0	0	3	10
B2	0	0	3	10
B3	3	9	0	0
C1	0	0	0	0
C2	0	0	0	0
C3	0	0	1	3
SUM	22	66	23	79

Table 5. Strategies of students in both classes confirmed by a questionnaire at the end of the pilot.

All four of them felt an improvement in their work over the length of the course. Some of the procedures became natural to them and they already knew intuitively how to proceed, for example, when editing symbols. They did not rule out avoiding all problems, but they were always able to identify them and, even with our help, fix them. As Victoria said, most of the time, they called us in only for a quick check when they were unsure if they had set the tool's parameters correctly.

Even though they enjoyed those lessons, they would definitely change their form. They realise that those who did not work on computers were, as Ema said, *"deprived of so much"*. Katherine believes that if she had worked on the computer in class like Ema and Mary did, she would have done better on the test. She missed the practical side, which was not replaced by filling in the protocol.

3.1.2 Category B2 students: Category B2 covered fewer students, represented only in the second pilot. These students rather focused on comprehension and regularly had difficulty following the procedure. We could interview one of the three students who reported for this category. Thus, we cannot compare her answers with anyone else.

Viola assisted her peers at the beginning of the course and then in the second half, she worked independently on a laptop we lent her. Nevertheless, she was always paying attention and trying to understand why we had chosen a particular tool. During the lessons, she had problems that were of a technical nature. These were making her fall behind. Yet she enjoyed the content of the lessons and did not make a big deal of it if she failed to get something right on her first try.

Student	Thomas	Ema	Mary	Robert	Katherine
Category	B3	A1	A1	B3	A1
Prior experience	No	No	Yes	No	No
Activity	Computer	Computer	Computer	Computer	Protocol
Test score	14	15,5	11	15,5	4
Interest in geo.	Yes	Yes	Yes	No	Yes
Majors	IT	Physics	Cartography	Medicine	History, German

Table 6. Interview respondents from the second pilot.

Student	Victoria	Violet	Eve
Category	A1	B2	C3
Prior experience	No	No	Yes
Activity	Computer	Computer (+ Assist.)	Computer
Test score	15,25	12,5	16,5
Interest in geo.	Yes	Yes	Yes
Majors	Psychology	Pharmacy	Geography

Table 7. Interview respondents from the first pilot.

These problems she faced did not demotivate her and she was happy to complete the work at home on her computer. Like the students in the previous category, she noticed a steady improvement, gradually requiring less help from those around her. Viola believes that if she had worked on her own computer from the beginning, she would have been able to improve more and faster as well.

3.1.3 Category B3 students: Students who focused on comprehension of the QGIS and worked independently based on the provided online instructions appeared only in the first pilot. From these three students, we interviewed two.

After the first problems on our first face-to-face lesson have appeared and the pace of the instructions decreed, Thomas and Robert had decided with their partners that they would rather proceed on their own, at a faster pace. They maintained this strategy in all lessons. They always waited and found out which lecture we were going to cover in class and then got to work. Not once did Thomas consider changing this learning strategy.

Richard considered doing so only once, when he found out that we skipped a problematic part of the procedure that he had already completed. At that moment, he was quite angry (partly at himself) for doing extra work.

They both enjoyed the lessons but could certainly find room for improvement. Neither of them thinks their strategy strongly impacted their higher test scores and positive lesson evaluations. In their opinion, motivation is a more critical factor. Both did not mind that they were learning to work in QGIS instead of traditional lessons. They reminded us that some of their classmates were not interested because they were not planning to study geography or computer science. They both had the advantage of liking technology; otherwise, they would not have made a significant effort in their work either.

3.1.4 Category C3 student: During both pilots, we met only one student who, according to her words, played with the program during lessons and worked independently based on the instructions. Eve was in an exceptional situation compared to her classmates in the second pilot. She had already started to learn how to work with the program before the "course", as she wanted to use the program to produce her own maps. By the time the students in the first lesson were familiarising themselves with the program, she was already on the third lecture and had experience with tools that the others were just getting their first taste of. Because of this, she was rather playing with the tools during our lessons, figuring out how she could render the symbols of the vector layers or what other elements she could add to her final map.

However, if she was not in this situation, she believes that she would have followed B1 or B3 strategies, depending on the

pace of the lessons. She is confident that she would face no problems, because she is used to working in several graphic programmes. Several times she helped her classmates around her. Eve described her situation as *"they were learning, and she was advising "*.

3.2 Results of test

At the end of both pilots, a test was scheduled to assess students' understanding of QGIS. We created two versions of the test to match the content of the lectures that were covered during both pilots. Both tests were designed to have a maximum score of 17. Scoring depended on the difficulty of the question and the number of answers.

Due to organisational reasons, it was not possible for the students of the first pilotage to sit for our test immediately after the "course", but only one month after the last lesson. The second group sat for the test one week after the last class.

For both groups, the test was optional, and their scores were not included in their classification in the Geography course. In neither case did the entire class take the test. 20 students (60 %) from the first pilot participated and 22 students (75 %) from the second pilot.

No student scored with total points (see Table 8). On average, students in the first pilot scored three points less than those in the second. The minimum score was six full points higher for the younger students. The difference between the maximum and minimum scores for senior students was 14 points, while for fourth-year students, the difference was 9.25 points.

Students in the first pilot most often had scores of 11.5 to 9.5 (see Figure 1). The fewest had scores of 9 to 7.25 and 2 to 0. Students in the second pilotage most often scored 17 to 15 points, but some scored 11.5 to 9.5 points. The fewest students in this group ranged from 9 to 7.25 points.

	1st pilot	2nd pilot
Number of tests	20	22
Total scores	17	17
Average score	9,5	12,75
Maximum points	15,5	16,5
Minimum points	1,5	7,25
Median score	10	13

Table 8. Statistics of test results in both pilots.

In our thesis, we closely examine the success rate of all questions and explain it in the context of the different lessons. The main finding we can report is that the change of style in which we taught the lessons has positively reflected on the results of students from the second pilot. We decided to pay more attention to the details and explained a more advanced theory in more detail and with examples. Due to this, students no longer struggled with a question that asked them to describe the process of starting a new project in QGIS and remembered the rules for naming the maps.

In the second part of evaluating the test results from the two pilots, we looked at whether computer use, assisting, or writing protocols had any effect on them.
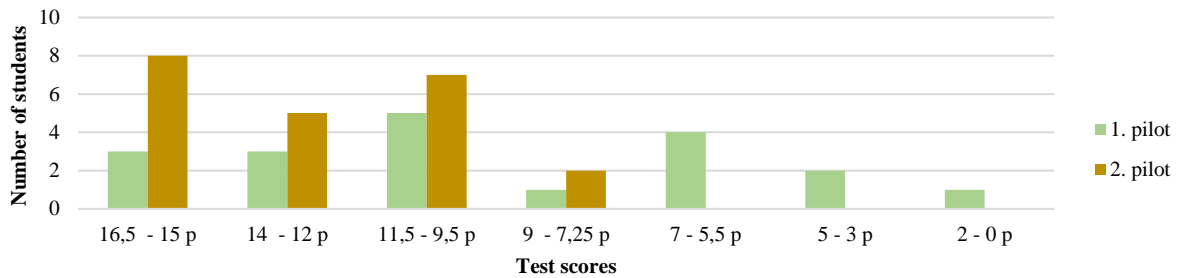
Figure 1. Scores of students from both pilotages on the final test.

Comparing the students in the first pilot (see Figure 2), we can see that the average score for computer users (11.2) was higher than for protocol writers (7.8). For computer users (55 %) the minimum score was 5 and for log writers (45 %) it was 1.5 points. However, the two students with logs scored 14 points, deviating from the trend of their group. Based on these findings, we could say that practical application plays a role in the outcome of the QGIS test. But that way we would neglect the other factors that played their role in it. One of them is the fact that shortly before the test, some students handed in their missing exercises and maps. This gave them an advantage over their classmates with protocols, who did not continue their work at home. They could revise some skills they might have forgotten a month into the "course". Another factor is the low participation of students in both categories. Of the 17 computer users, 11 (64 %) participated in the test, and 9 out of 16 (56 %) for the protocol writers. Thus, also, for this reason, it is not possible to speak of a clear impact of both classwork on the final result.
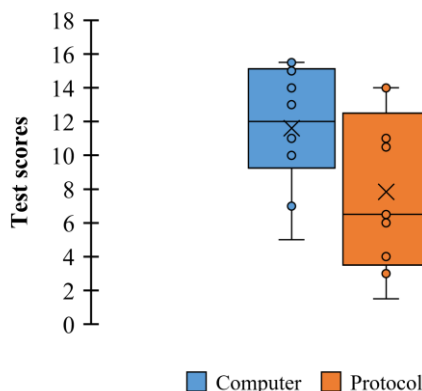

Figure 2. Differentiation of the test scores of those who worked on computer to those who did protocols (1st pilot).

In the second pilot, 17 of 21 (80 %) of those who worked on the computer and 5 of 8 (62 %) of those who assisted participated in the final test.

Even in their case, it is not possible to make general conclusions. Comparing their results (see Figure 3), we can see that the average of the two categories of students differs by 0.7 points. There is not much difference in the maximum and minimum scores either. It can be assumed that for the students in the second pilot, the different activities in class did not affect their results because they were all actively involved in some way in the computer work.

On the other hand, in the second pilot, there was a change in how we conducted the lessons – we focused on the quality rather than the quantity of the lessons. Learning from the first pilot's

experience, we emphasised explaining the steps and stronger integration of theory with practice. Finally, according to the interview results, the younger students were more motivated to actively participate in the "course" and more willing to learn something new than the final-year students, who had a lot of school responsibilities.
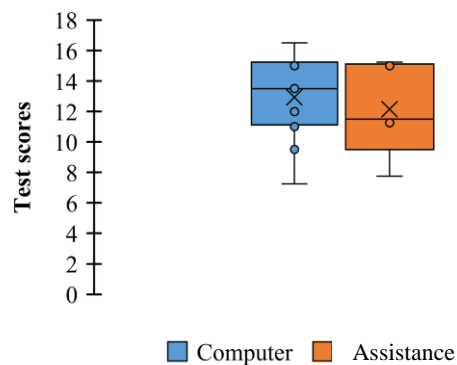

Figure 3. Differentiation of the test scores of those who worked on computer to those who assisted them (2nd pilot).

In the last part of the evaluation of the test results, we examined whether the learning strategies that the students had chosen had any effect on their test scores. Due to the strong imbalance in category representation in both classes (see Table 6) and the non-participation of all students in the questionnaire, it is impossible to suggest generally valid conclusions. The only finding that would be valid for both the first and pilot students is related to students who regularly had problems and we able to keep up with the rest of the class (A2, B2). It turns out that they were able to achieve higher minimum scores than those who did not have problems while working (A1, B1) or independently followed the instructions (B3, C3). Assistance

4. CONCLUSION

After the two-part testing of our set of 10 lectures, we can conclude that they should be in a ready-to-use state. Student assessment has shown us that after the first pilot, we had to make some amendments. After the second pilot, we made no changes. Yet there is still room for improvement. We believe that the lectures' content is fit for learning the basic tools and functions of QGIS software. On the other hand, the form of the lectures could use some improvement from the hands of a professional designer. Our goal is to offer our lectures to more high schools in the Czech Republic that could provide us useful feedback from their attempts to adapt them to their needs. Secondly, we are considering making it more universal for the wider world and translating the lectures into English.

On a personal level, after delivering 12 lessons on QGIS, we feel more confident in choosing a more appropriate teaching style suitable for this technology. The experience from teaching and the analysis of student feedback has shown us that GIS such as QGIS has a rightful place in Geography lessons. It depends on the teacher what purpose this technology will have in their classroom. Their students can learn about GIS and know its technical side or they can learn with GIS and discover patterns in geographic phenomena. In both options, the students are gaining a hands-on experience of a real geographer using spatial data to understand the surrounding world.

Due to unforeseeable problems such as the lack of technology resources, the unsolvable technical problems, the lower return rate of feedback and an insufficient number of test results and verified student learning strategies, we could not form universally applicable design principles. We could not prove whether learning strategies had any impact on the test score. We could see that using a computer in classes resulted in a higher score, but the given circumstances could give us a different perspective on the issue. On the other hand, with this paper, we can offer a case study of research that attempted to learn more about the possibilities of adopting QGIS tools. We could, however, offer teachers a few pieces of advice for their GIS classes: book an ICT laboratory, motivate your students, do not rush them, thoroughly explain the theory behind GIS and maps and most importantly, let them work together and let them learn from each other, make your QGIS lessons as enjoyable as possible.

REFERENCES

Argles, T., 2017. Teaching practical science online using GIS: A cautionary tale of coping strategies. *Journal of Geography in Higher Education*, 41(3), 341–352.
doi.org/10.1080/03098265.2017.1315531.

Baker, T. R., Battersby, S., Bednarz, S. W., Bodzin, A. M., Kolvoord, B., Moore, S., Sinton, D., Uttal, D., 2015. A Research Agenda for Geospatial Technologies and Learning. *Journal of Geography*, 114(3), 118–130.
doi.org/10.1080/00221341.2014.950684.

Bakker, A., 2018. *Design research in education: a practical guide for early career researchers*. Taylor & Francis Group, London.

Bednarz, S., W., 2004. Geographic information systems: A tool to support geography and environmental education? *GeoJournal*, 66, 191-199.
jstor.org/stable/41147881 (20 April 2023).

Bernhäuserová, V., 2022. The Limits of GIS Implementation in Education: A Systematic Review. *International Journal of Geo-Information*, 11, 592-617.
doi.org/10.3390/ijgi11120592.

Buzo-Sánchez, I. J., Mínguez, C., De Lázaro-Torres, M. L., 2022. Expert perspectives on GIS use in Spanish geographic education. *International Journal of Digital Earth*, 15(1), 1204-1218.
doi.org/10.1080/17538947.2022.2096131.

Cohen, L., Manion, L., Morrison, K., 2011. *Research methods in Education*. 7. edition. Routledge, Abington.

Demirci, A., 2008. Evaluating the implementation and effectiveness of GIS-based application in secondary school geography lessons. *American Journal of Applied Sciences*, 5(3), 169–178. doi.org/10.3844/ajassp.2008.169.178.

Kerski, J. J., 2003. The implementation and Effectiveness of Geographic Information Systems Technology and Methods in Secondary Education. *The Journal of Geography*, 102(3), 128-137. doi.org/10.1080/00221340308978534.

Konstantakatos, G., Galani, L., 2022. How is the use of GIS in geographical and environmental education evaluated? Findings from a systematic review. *International Research in Geographical and Environmental Education* (online).
doi.org/10.1080/10382046.2022.2138167.

Madsen, L. M., Rump, C., 2012. Considerations of How to study Learning Processes when Students use GIS as an Instrument for Developing Spatial Thinking Skills. *Journal of Geography in Higher Education*, 36(1), 97–116.
doi.org/10.1080/03098265.2011.576336.

Mandel, A., Ferrero, V., Graser, A., Bruy, A., 2016. *QGIS 2 Cookbook*. Pack Publishing, Birmingham.
oiipdf.com/qgis-2-cookbook (20 April 2023).

Mckenney, S., Reeves, T., 2019. *Conducting Educational Design Research*. 2. edition. Routledge, Abington.

Rød, J. K., Larsen, W., & Nilsen, E., 2010. Learning geography with GIS: Integrating GIS into upper secondary school geography curricula, *Norsk Geografisk Tidsskrift–Norwegian Journal of Geography*, 64(1), 21–35.
doi.org/10.1080/00291950903561250.

Schulze, U., 2021. "GIS works!"—But why, how, and for whom? Findings from a systematic review. *Transactions in GIS*, 25, 768–804. doi.org/10.1111/tgis.12704.

van der Akker, J. (Ed.), 2006. *Educational design research*. Routledge, Abingdon.

Whyatt, D., Davies, G., Clark, G., 2022. Going solo: students' strategies for coping with an independent GIS project. *Journal of Geography in Higher Education*, online.
doi.org/10.1080/03098265.2022.2065668.