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The impact of using Google Earth Pro on the development of geography-specific competencies in different educational contexts

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Abstract

The purpose of this research is to analyse the impact of using the Google Earth Pro application on the development of Geography-specific competences among lower secondary school students. The experiment on teaching geography with Google Earth Pro was conducted simultaneously in two different educational environments, in Belgium and Romania. The study was designed as an experimental model with a pre-test and post-test applied to the entire sample, which consisted of an experimental group and a control group.
The research follows a mixed-methods approach, as the data were analysed both qualitatively and quantitatively. The statistical analysis involved the application of nonparametric tests to compare the median distribution (Mann-Whitney U test), frequency, and means between groups, as well as the calculation of the effect size (Cohen's *d*) for each item.
The statistical tests validated all three research hypotheses: (1) the use of Google Earth Pro produced a significant change in the formation of Geography-specific competences; (2) Google Earth Pro had a significant impact on the development of geographical competences among lower secondary students; and (3) the effect size of the intervention—teaching geography with Google Earth Pro—was statistically significant in shaping these competences.Google Earth Pro influenced the development of competences such as the interpretation of graphic representations, the ability to construct explanatory arguments, and spatial skills in both samples (Belgian and Romanian). The comparative analysis of the two samples from Belgium and Romania, belonging to different educational contexts, revealed some differences regarding the level of spatial skill formation—Belgian students encountered greater difficulties in developing this ability. The competence of constructing explanatory arguments was better developed within the Romanian experimental group.
Keywords: *geography, GIS, Google Earth Pro, competences, argumentation, spatial skills*

Introduction

In every national education system, the general educational goals of school Geography are explicitly stated in the curriculum for both lower and upper secondary education. These curricula establish and require the development of a set of general and specific competences. It is up to the teacher to determine the didactic strategies to be employed in order to achieve these competences. Geography, as a science, has a dual character—being both a natural and a social science. The issues of the contemporary world, the methodology of investigating reality, and the thematic approaches common to both dimensions support the unitary character of Geography (MEN, 2021). Geography involves the knowledge and understanding of spatial phenomena and processes, as well as the analysis and interpretation of spatial units—from the global scale to the micro-local one (Jackson, 2006; NRC, 2006). Geography emphasises the creation of interconnections both at a global level (Allen & Massey, 1995; Hardwick & Holtgrieve, 2013) and among its numerous subfields, which include disciplines such as transport (Hay, 1977), geomorphology (Cantón et al., 2011), economics (Dicken, 1986), hydrology, demography, and ecology.

With the emergence of the *digital earth* (Goodchild, 2008) and Geographic Information Systems (GIS), these interconnections between the Earth's geospheres can now be studied in a new context—through the use of GIS tools and geo-browsers. GIS has been recognised among the 25 most important technological innovations that influenced the development of humanity in the 20th century (Demirci, 2008) and has been acknowledged as the most effective technology that can be implemented in teaching geography (Lam et al., 2009; Lateh & Muniandy, 2010). Geography, as a school subject, provides an ideal framework for GIS integration because it establishes the foundation for these interconnections (Kemp et al., 1992). Teaching basic geographical concepts such as water, climate, and natural disasters is particularly well suited to GIS tools, since they use real-world data that help students think critically and solve authentic problems related to different locations on Earth (Kerski, 2023).

Buzo et al. (2022) conducted a study among experts and teachers of geography at the university and high school levels, which revealed a consensus that GIS helps to understand territory in an experiential and non-memorising way and supports the development of spatial thinking. GIS has begun to be used even in primary schools as a didactic tool because it provides valuable map resources for students of all ages (Kerski, 2003; Jo et al., 2016). GIS offers diverse datasets and tools that assist teachers in delivering fundamental content and concepts—such as change, scale, ratios, historical events, and biomes—in line with national educational standards (Kerski, 2023).

Google Earth uses GIS technology to create 3D images of the entire planet based on high-resolution satellite imagery. The latest version, Google Earth Pro, offers several benefits, such as the import of thematic maps from QGIS and ArcGIS, shape and GeoJSON files, kmz/kml files, and ESRI MapInfo tables. It also allows for surface measurements, drawing of circles and polygons, viewing of historical imagery, printing and saving of high-resolution maps, and the creation of collaborative maps. Although Google Earth does not provide as many tools or capabilities as a full GIS, it enables students to explore spatial examples and develop spatial thinking (Alfatikh et al., 2020).

Since its introduction, Google Earth has been used in academic teaching (De Paor et al., 2017) and in numerous research studies. In recent years, the use of geospatial technologies, including Google Earth Pro (GEP), in secondary education has become a global trend (Avdić et al., 2020), possibly because of their user-centred design (Hong, 2018). Alfatikh et al. (2020) argue that no other science benefits more from the use of Google Earth than the geosciences. Whereas in the traditional model students needed multiple printed thematic maps to conduct geographical investigations, digital tools such as Google Earth Pro now offer a more interactive interface, allowing multiple maps to be overlaid and queried simultaneously. These tools are easier to use than traditional maps and more effective when used as teaching materials (Pickles, 1997).

The benefits of Google Earth are numerous. Palmer (2013) asserts that Google Earth has significantly influenced students' learning of landforms and their acquisition of spatial perception skills; it allows for instant collection of information from various sources (Goodchild, 2008), helps understand natural and cultural events (Guertin & Neville, 2011), supports critical thinking and spatial analytical operations, stimulates student-centred learning and motivation (Awada & Diab, 2018), and provides opportunities to observe and interpret natural changes, enhancing understanding of complex environmental structures (Xiang & Liu, 2017). Alfatikh et al. (2020) also found a positive correlation between the use of Google Earth and students' participation in task completion, showing increased engagement in classroom activities. A previous study highlighted students' interest in learning geography using Google Earth Pro; the main benefits cited by students were: an opportunity to discover places on the Earth's surface that otherwise would never be seen, spatial orientation, real-time visualization of the Earth's surface, analysis of geospatial data for educational purposes, and assistance in everyday life, not just for school (Pascu & Duroisin, 2026).

In the United Kingdom and other countries, there is growing pressure for schools to teach GIS as part of their curriculum, and Google Earth Pro provides this opportunity by functioning as a "simple" GIS system that introduces basic concepts such as data formats (e.g., vector—point, line, polygon; raster—a matrix of pixels, such as an image). These are already present in the software package (e.g., satellite imagery, road networks) and can be customised by users to create their own resources (Mather et al., 2015).

The development of argumentation skills is a goal of geographical education as defined in national educational standards and curricula (DGFG, 2014). Studies have shown that students often struggle to formulate complete, technically correct, and convincing arguments (Budke & Kuckuck, 2020; Chase, 2011; Lytzerinou & Iordanou, 2020; Uhlenwinkel, 2015) or to generate valid evidence to support their claims (Sampson et al., 2013). Researchers have emphasised the need to implement didactic strategies that help teachers integrate tools and instructional methods to develop students' argumentation skills (Chen et al., 2017).

Geographical argumentation is usually written with the help of supporting materials (Budke, 2021)—maps, diagrams, texts, and images. To improve the quality of arguments, students should be provided with supporting elements that enable them to produce more coherent reasoning during argumentation. Visual representations can facilitate students' understanding of argument structure (Akpınar et al., 2014) and increase their awareness. Google Earth Pro offers all these resources—maps, images, visual representations, and data—that can support the development of students' argumentation skills.

Based on Toulmin's model (1990), Google Earth Pro is an extremely useful information source in directly supporting two of the model's components: it provides the necessary *data* (in the form of satellite images, thematic maps, altitudes, geographic coordinates, etc.) and additional *backing* (through thematic layers and extracted measurements).

Indirectly, Google Earth Pro supports the remaining components of Toulmin's model by providing information that helps students interpret data and formulate the *claim*, *warrant* and *qualifier*. Out of the six components of Toulmin's model, GEP directly supports two, indirectly supports three, while the last one—*rebuttal*—remains the student's own creation.

Methodology

The purpose of this research is to analyse the impact of using the Google Earth Pro application on the development of geography-specific competences among lower secondary students (aged 14–15).

Research Questions:

• To what extent has the use of the Google Earth Pro application influenced the formation of Geography-specific competences among lower secondary students?

• How effective has the use of Google Earth Pro proven to be in developing Geography competences in lower secondary education?

• How significant was the impact of introducing Google Earth Pro on the formation of Geography-specific competences?

• To what extent do the research results on the effectiveness of Google Earth Pro in developing geographical competences differ between the two educational contexts—Romanian and Belgian?

The sample consisted of a total of 86 students from two different educational environments, Belgium and Romania. The Belgian sample included 43, S3 students, of whom 29 formed the experimental group and 14 formed the control group. The Romanian sample also included 43 ninth-grade students, of whom 20 formed the experimental group and 23 the control group. Students were selected based on availability. In Romania, the implementation stage of the research was carried out by two Geography teachers from different educational institutions, while in Belgium, the experiment was implemented by the researcher in two different educational institutions, assisted by the Geography teachers teaching those classes. Before starting the experiment, the researchers prepared the course materials for the *Hydrosphere* chapter, lesson plans for teachers, worksheets for students, a blog page with all the teaching resources required for the experiment, as well as thematic files in KMZ and Shape file formats for use with Google Earth Pro.

Figure 1. Teaching hydrography using Google Earth Pro

Before implementing the didactic scenario of teaching and learning Geography with Google Earth Pro, a student knowledge questionnaire was administered (Fig. 1).

The experiment took place between April and May 2025 and lasted three weeks (6 hours in total). During these three weeks, students learned Geography content using the Google Earth Pro application. The study was designed as an experimental model with a pre-test and a post-test applied to the entire sample, consisting of both an experimental and a control group. The experiment was conducted simultaneously in two different educational contexts, in Belgium and Romania. Both target groups — the Romanian and the Belgian students — had previously studied some general aspects of the hydrosphere, as well as fundamental elements related to it. Therefore, it was assumed that students already possessed certain knowledge, skills, and competencies specific to Geography, which had been progressively acquired in previous years. Consequently, a pre-test was administered to determine the students' initial level of knowledge and competence related to the *Hydrosphere* chapter.

At the end of the three weeks, a post-test was applied in order to identify changes that occurred after the experiment, as well as to evaluate the impact of using Google Earth Pro on the development of specific Geography competencies: interpreting graphical representations, constructing explanatory arguments, and developing spatial abilities. The post-test aimed to determine the effectiveness of this digital tool in fostering these three specific geography competencies. The research used an identical structure for both the pre-test and post-test, with only one modification applied to the evaluation of the *Interpretation of a graphical representation* competence — the diagram/image used was slightly adjusted in the post-test (the order of numbers and the position of some elements were changed). Educational research often employs pretesting to rank participants based on their test scores, to create teaching materials suited to students' current levels of knowledge, and to identify what they already know or what deficiencies they have (Kim & Willson, 2010). Prior knowledge occupies a central position in three major learning theories: schema theory, mental models (Johnson-Laird, 1983), and constructivism (Roth & Roychoudhury, 1992; Von Glasersfeld, 1989). The pre-test aimed to identify the initial level of development of the specific Geography competencies before the experiment was applied. The three competencies were assessed in both the pre-test and post-test through three items.

Willson & Putnam (1982) reported that pretest effects on cognitive outcomes are generally greater than on affective measures. Furthermore, it was observed that the effects of pretesting vary depending on the characteristics of the participants (e.g., age and ability level) as well as the characteristics of the testing (e.g., the time interval between the pre-test and post-test;

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Gunasekera, 1997; Willson & Putnam, 1982). Students' responses to each of the three items were evaluated using a scoring grid on a scale from 0 to 10 points. The level of competence development was coded on a four-point scale (1–4).

Use of Google Earth Pro. The first lesson was of a mixed type, with time resources allocated both to a brief presentation of the content related to *running waters* and to the introduction of the Google Earth Pro application. Students were introduced to the program, its menu, and its main functions. They were divided into teams of 2–3 students, each team having access to a laptop. Several exercises were conducted to practice searching for, identifying, and locating different places, in order to familiarise students with the local and regional scales, the transition from the 3D virtual globe to Google Street Map, and the 3D physical map of the world — all while maintaining north–south orientation and developing geo-visualisation skills of the Earth's surface.

The second lesson focused on reviewing previous content related to *running waters* and conducting collaborative learning activities using Google Earth Pro. The learning tasks involved: importing into Google Earth Pro the map *The Major River Basins of the World* and importing KMZ and GeoJSON files of selected river basins (Amazon, Nile) (Fig. 2). Using these materials, students were asked to identify and locate the river basins of the world's major rivers (Mississippi, St. Lawrence, Colorado, Amazon, Congo, Nile, Niger, Ganges, Indus, Huang He, Chang Jiang, Ob, Yenisei, Danube, Murray–Darling). With the help of thematic layers, they learned about the components of a river (drainage basin, tributaries, confluences, source, flow direction, etc.) and completed a worksheet focused on the Nile River. Students worked on the worksheet by investigating the thematic KMZ file from Locations with *Primary Data* (boundaries, limits, and water sources). Google Earth Pro was used as a tool for gathering information, exploring, and developing spatial orientation.

Figure 2. Sequence from the teaching scenario based on the use of Google Earth Pro, Belgian target group

The third lesson focused on learning about *fluvial landforms* and *flooding*. The same method was maintained — collaborative learning using Google Earth Pro. The tasks involved identifying and locating regions at risk of flooding and analyzing and interpreting landforms as a contributing factor to the occurrence of floods.

Research Hypotheses

• The use of Google Earth Pro produced a significant change in the development of Geography-specific competencies.

• The Google Earth Pro application had a significant impact on the development of geographical competencies among lower secondary students.

• The effect size (r) of teaching Geography using Google Earth Pro was statistically significant in the formation of these competencies.

To validate the research hypotheses, the SPSS 28.0 software was used. The statistical analysis involved the application of nonparametric tests for comparing: the Mann–Whitney median distributions (to verify whether the distributions of a variable were similar in the two groups — experimental and control), the means between groups, the frequency, and the effect size (Cohen's *r*) for each of the three items. The research adopted a mixed-methods approach, with data analysed both qualitatively and quantitatively.

Results

In the first stage, the data were statistically (according to the nationality criterion) and later comparatively analysed.To ensure that both samples were homogeneous and comparable in terms of students' knowledge, skills, and competencies, the Independent-Samples Mann–Whitney U Test was applied to the pre-test results. Both samples (Belgium and Romania) obtained Mann–Whitney U test values (Table 1) above the significance threshold of 0.05 for all three items, which means there were no differences between the scores obtained by students in the two groups (control and experimental) at the pre-test stage. This demonstrates that the groups were homogeneous and comparable in terms of their initial knowledge and skills.

Table 1. The Mann–Whitney U test values at pre-test

The Belgian sample		
	Test	Sig.
Interpreting graphical representations	Independent- Samples Mann- Whitney U test	0.376
Constructing an explanatory argument/ Argumentation	Independent- Samples Mann- Whitney U test	0.466
Spatial abilities	Independent- Samples Mann- Whitney U test	0.829
The Romanian sample		
Interpreting graphical representations	Independent- Samples Mann- Whitney U test	0.478
Constructing an explanatory argument/ Argumentation	Independent- Samples Mann- Whitney U test	0.970
Spatial abilities	Independent- Samples Mann- Whitney U test	0.127

For the Belgian sample, the Mann–Whitney U test recorded the following values for the three items: $p = 0.376$, $p = 0.466$, $p = 0.829$. A similar situation was observed for the Romanian sample, where $p = 0.478$, $p = 0.970$, $p = 0.127$. These values indicate that there were no statistically significant differences between the groups, confirming their eligibility for a comparative analysis of post-test results after implementing the teaching experiment using Google Earth Pro.

First Research Hypothesis: *The use of Google Earth Pro produced a significant change in the development of Geography-specific competencies*. To validate or invalidate this hypothesis, the t-test for independent samples was employed. Given that in both countries the groups were small and unequal in size, the students' post-test results were statistically analysed using the nonparametric Independent-Samples Mann–Whitney U Test.

The statistical results show that for the Belgian sample, the Independent-Samples Mann–Whitney U Test (Table 2) recorded values below the significance threshold of 0.05 for all three post-test items: $p = 0.005$, $p = 0.031$, $p = 0.001$, indicating statistically significant differences between the two groups. These differences may be attributed to the use of the Google Earth Pro application. Thus, for the Belgian sample, the research hypothesis is validated — the use of Google Earth Pro produced a significant change between the two groups. The differences observed in the post-test are a consequence of introducing this digital tool in Geography learning and in the formation of the three competencies. The groups started off with similar scores (pre-test), supporting baseline equivalence. After the intervention with Google Earth Pro, their scores differed significantly (post-test), indicating that the treatment likely had an impact.

Table 2. Mann–Whitney U test values at post-test

The Belgian sample		
	Test	Sig.
Interpreting graphical representations	Independent- Samples Mann- Whitney U test	0.005
Constructing an explanatory argument/ Argumentation	Independent- Samples Mann- Whitney U test	0.031
Spatial abilities	Independent- Samples Mann- Whitney U test	0.001
The Romanian sample		
Interpreting graphical representations	Independent- Samples Mann- Whitney U test	0.647
Constructing an explanatory argument/ Argumentation	Independent- Samples Mann- Whitney U test	0.414
Spatial abilities	Independent- Samples Mann- Whitney U test	0.922

For the Romanian sample, all Independent-Samples Mann–Whitney U Test values were above the 0.05 significance threshold, indicating no statistically significant differences between the two groups for any of the three post-test items. Therefore, the research hypothesis was invalidated — the use of Google Earth Pro did not produce a statistically significant change in the development of geography-specific competencies among the Romanian students.

Although the statistical analysis did not show a significant difference between the experimental and control groups, a statistically significant change could still be observed *within* the experimental group using the Paired Samples Test (Table 3). This test indicates whether students' results improved between the pre-test and post-test, and whether a significant change occurred between the two measurements. The research hypothesis can therefore be validated through the paired samples test.

The Paired Samples Test (Table 3) showed that within the experimental group, significant differences were recorded between the pre-test and post-test for all three items ($p = 0.036$, $p = 0.048$, $p < 0.001$). These results demonstrate that Google Earth Pro positively influenced students' performance, producing a significant change. The hypothesis is thus validated.

Considering that other factors could have influenced students' results between pre-test and post-test — such as motivation, teacher experience, and teaching style — a Paired Samples Test was also calculated for the control group to determine whether their performance changed between the two tests. The Paired Samples Test (Table 4) showed values above the significance threshold of 0.05 for all three items (*p = 0.117*, *p = 0.278*, *p = 0.676*). Consequently, students in the control group did not show progress; no significant change occurred between pre-test and post-test. In this context, it can be concluded that the Google Earth Pro application played an important role in the formation of competencies among students in the experimental group.

Table 3. Paired samples test results for the Romanian experimental group

Paired Differences	Mean	t	df	One-Sided p	Two-Sided p
Interpreting graphical representations : pre-test – post-test	-2.14550	-2.251	19	.018	.036
Constructing an explanatory argument/ Argumentation : pre-test – post-test	-1.18750	-2.111	19	.024	.048
Spatial abilities : pre-test – post-test	-2.71500	-5.792	19	<.001	<.001

Table 4. Paired samples test results for the the Romanian sample, control group

Paired Differences	Mean	t	df	One-Sided p	Two-Sided p
Interpreting graphical representations : pre-test – post-test	-1.02071	-1.680	13	.058	.117
Constructing an explanatory argument/ Argumentation : pre-test – post-test	.62500	1.132	13	.139	.278
Spatial abilities : pre-test – post-test	.06000	.428	13	.338	.676

Second Research Hypothesis: *The Google Earth Pro application had a significant impact on the development of geographical competencies among lower secondary students*. To validate this hypothesis, statistical tests comparing means (Table 5) and frequencies (Table 6) of the results obtained by students in the two groups (experimental and control) were used for the three items at pre-test and post-test.

Table 5. Mean Comparison test results

Skills/items	Control group	Experi-mental group
The Belgian sample		
Interpreting graphical representations - Pretest	*N= 14**	*N=29**
	4.4	3.9
Interpreting graphical representations - Posttest	5.4	7.9
Constructing an explanatory argument/ Argumentation Pretest	3.0	2.5
Constructing an explanatory argument/ Argumentation Posttest	2.5	4.2
Spatial abilities Pretest	0.5	1.1
Spatial abilities Posttest	0.4	2.3
The Romanian sample		
Interpreting graphical representations - Pretest	N= 23	N=20
	3.65	4.06
Interpreting graphical representations - Posttest	6.26	6.21
Constructing an explanatory argument/ Argumentation Pretest	5.59	5.68
Constructing an explanatory argument/ Argumentation Posttest	5.97	6.87
Spatial abilities Pretest	2.41	3.51
Spatial abilities Posttest	6.59	6.22

Table 6. Results of the frequency comparison test

The Belgian sample		Control		Experiment	
		PRE_POST		PRE_POST	
Skills		Pre test	Post Test	Pre test	Post Test
Interpreting graphical representations	Level	*14**	*14**	*29**	*29**
	Insufficient	71.4	50.0	75.9	10.3
	Satisfactory	7.1	14.3	13.8	10.3
	Good	21.4	28.6	10.3	62.1
	Very Good	0.0	7.1	0.0	17.2
Constructing an explanatory argument/ Argumentation	Insufficient	85.7	92.9	93.1	72.4
	Satisfactory	7.1	7.1	0.0	10.3
	Good	7.1	0.0	6.9	17.2
	Very Good	0.0	0.0	0.0	0.0
Spatial abilities	Insufficient	100.0	100.0	96.6	89.7
	Satisfactory	0.0	0.0	0.0	6.9
	Good	0.0	0.0	3.4	0.0
	Very Good	0.0	0.0	0.0	3.4
The Romanian sample					
Interpreting graphical representations	Level	*23**	*23**	*20**	*20**
	Insufficient	69.6	30.4	80.0	35.0
	Satisfactory	17.4	8.7	10.0	15.0
	Good	13.0	60.9	10.0	20.0
	Very Good	0.0	0.0	0.0	30.0
Constructing an explanatory argument/ Argumentation	Insufficient	30.4	26.1	45.0	10,0
	Satisfactory	30.4	30.4	20.0	50,0
	Good	30.4	13.0	10.0	25.0
	Very Good	8.7	30.4	25.0	15,0
Spatial abilities	Insufficient	82.6	8.7	70.0	30,0
	Satisfactory	8.7	47.8	20.0	25.0
	Good	8.7	30.4	10.0	35.0
	Very Good	0.0	13.0	0.0	10.0

In the Belgian sample, statistically significant differences were observed between the two groups in post-test results:

For *Interpreting graphical representations*, the experimental group's mean score (7.9) was much higher than that of the control group (5.4).

For *Constructing an explanatory argument*, the experimental group scored 4.2, higher than the control group's 2.5.

For *Spatial abilities*, the experimental group's mean (2.3) exceeded that of the control group (0.4).

In the Romanian sample, the test comparing means indicated significant differences between groups for Item 2 of the post-test: the control group had a mean of 5.97, while the experimental group scored slightly higher, at 6.87.

However, the difference in mean scores between pre-test and post-test does not fully reflect the impact of using Google Earth Pro in geography teaching, nor does it capture students' actual progress, given that the items were evaluated on a 0–10 point scale. To clarify this, students' results for the three items were classified into four performance categories — *Insufficient*, *Sufficien*t, *Good*, and *Very Good* — and their frequencies were calculated and compared (Table 6).

The Belgian sample showed that experimenting with learning Geography using Google Earth Pro had a significant positive impact on the experimental group (Figure 3). The proportion of students who scored very poorly on the pre-test, with an insufficient level (75.9%) of competence in interpreting cartographic representations, decreased significantly to 10.3% in the post-test.

Figure 3. Doing some exercises during geography class—the Belgian target group

We also observe that the frequency of students who achieved scores corresponding to the Good performance level increased substantially — from 10.3% on the pre-test to 62.1% on the post-test — while 17.2% of students reached a Very Good performance level. Google Earth Pro had a very strong impact on this competence. Google Earth Pro also appears to have influenced the level of development of the Argumentation competence. The proportion of students in the experimental group who had an Insufficient performance level on the pre-test decreased from 93.1% to 72.4%; 20.7% of students improved to Satisfactory (10.3%) and Good (17.2%) levels. However, no student achieved a high level of performance. The use of Google Earth Pro produced modest progress at the post-test, while the control group recorded a regression. The most difficult competence and task seemed to be the spatial ability. The impact of the Google Earth Pro application was not as great as in the case of the first competence. A slight improvement was observed, with the proportion of students at the Insufficient performance level decreasing from 96.6% to 89.7%, and a slight increase in those at Satisfactory (6.9%) and Very Good (3.4%) levels.

At the level of the Romanian sample, the experimental group recorded an improvement in the Interpretation of graphic representations competence. The proportion of students with an Insufficient level at the pre-test (80%) decreased considerably; at the post-test, it was 35%. A positive evolution was also found in the improvement of performance at the Satisfactory, Good, and Very Good levels. Google Earth Pro also had a major impact on the performance level of students in developing the Argumentation of an explanatory approach competence. Compared to the pre-test, the share of students with an Insufficient level decreased from 45% to 10%; the proportion of those at a Satisfactory level increased from 20% to 50%, and those at a Good level from 10% to 25%. Students' performance level in the third competence — spatial abilities — improved after using Google Earth Pro. The proportion of students with a very low performance level decreased from 70% to 30% at the post-test. Moreover, the proportion of students with a Good level increased to 35%, and those with a Very Good level to 10%. For both samples, the research hypothesis is confirmed: the Google Earth Pro application had a significant impact on the level of development of the three geography-specific competences. The third hypothesis, concerning the effect size of the intervention (Cohen's d) of teaching geography with Google Earth Pro, was statistically significant in developing geography-specific competences.

The Cohen's d values (Table 7) recorded for the Belgian experimental sample show that the effect size of the Google Earth Pro intervention for item 1 is d = -1.444, demonstrating a substantial impact on developing the competence *Interpretation of cartographic representations*; for item 2, d = -0.576, indicating a moderate impact on *Argumentation of an explanatory approach*; and for item 3, d = -0.766, indicating a large impact on Spatial ability development.

For the Romanian sample, the effect size of the Google Earth Pro intervention indicates that the application had a significant impact in developing all three competences. The obtained Cohen's d coefficients are significant: for *Interpretation of cartographic representations*, d = -0.503; for *Argumentation of an explanatory approach*, d = -0.472; and for *Spatial abilities*, d = -1.295. The use of Google Earth Pro had a medium effect on competences 1 and 2, and a very large effect on competence 3.

The Cohen's d values validate the research hypothesis for both samples: the effect size (Cohen's d) of teaching geography with Google Earth Pro was statistically significant in developing geography-specific competences.

Table 7. Paired samples effect sizes (Cohen's *d* coefficients)

Paired Samples Effect Sizes		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
The Belgian sample					
Interpreting graphical representations pre-test – post-test	Cohen's d	2.76541	-1.444	-1.961	-.914
	Hedges' correction	2.84234	-1,405	-1.908	-.889
Constructing an explanatory argument/ Argumentation pre-test – post-test	Cohen's d	2.91769	-.576	-.965	-.178
	Hedges' correction	2.99887	-.561	-.939	-.173
Spatial abilities pretest – post-test	Cohen's d	1.60453	-.766	-1.176	-.346
	Hedges' correction	1.64917	-.745	-1.144	-.336
The Romanian sample					
Interpreting graphical representations pre-test – post-test	Cohen's d	4.26193	-.503	-.964	-.031
	Hedges' correction	4.43992	-.483	-.925	-.030
Constructing an explanatory argument/ Argumentation pre-test – post-test	Cohen's d	2.51558	-.472	-.929	-.004
	Hedges' correction	2.62064	-.453	-.892	-.003
Spatial abilities pre-test – post-test	Cohen's d	2.09624	-1.295	-1.885	-.687
	Hedges' correction	2.18379	-1.243	-.1.810	-.659

Comparative analysis of the research results in the context of the two educational systems: Romanian and Belgian

Similarities: Both samples consist of homogeneous and comparable groups, and the research hypotheses are validated for both samples.

Differences: A statistically significant change after the experiment involving teaching–learning geography using the Google Earth Pro application was demonstrated for the Belgian sample using the Mann–Whitney U test, while for the Romanian sample, it was validated using the paired sample test. The frequency comparison test indicates a more pronounced improvement in the performance level of the *Interpretation of graphic representations* competence for the Romanian sample, as the proportion of students at a Very Good level (30%) is higher than in the Belgian sample (17.2%). However, the Belgian sample has a higher proportion of students at a Good level (62.1%) compared to the Romanian sample (20%) and a lower proportion of students at an Insufficient performance level (10%). The Argumentation of an explanatory approach competence is better developed in the Romanian experimental group, which recorded a lower proportion of students at an Insufficient performance level (10%) compared to 72.4% in the Belgian group. Also, the proportion of students at a Very Good performance level (15%) is higher than in the Belgian group (0%). Spatial abilities are much better developed in the Romanian sample at all performance levels: 30% of students have an Insufficient level compared to 89.7% in the Belgian group; 35% have a Good level compared to 0.0%, and 10% a Very Good level compared to 3.4%.

After the experiment using Google Earth Pro for geography teaching, at the post-test, the Belgian experimental group achieved a higher performance level than the Romanian group only for the competence *Interpretation of a cartographic representation*, and lower values for the other two competences (*Argumentation of an explanatory approach* and *Spatial abilities*). The effect size (Cohen's d) shows that Google Earth Pro had a very strong impact in the Belgian sample for developing the competence *Interpretation of cartographic representations*, while in the Romanian sample, the impact was very strong in developing *spatial abilities*.

Discussion

To what extent has the use of the Google Earth Pro application influenced the development of Geography-specific competencies among lower secondary education students?

Considering that the research was conducted in two different national educational contexts with very few similarities in the geography curriculum for Grade 9 (Romanian system) and S3 (Belgian system), demonstrating that Google Earth Pro (GEP) produced significant changes in the development of competencies in the experimental group was possible through different statistical methods, while the purpose and effect remained consistent under research conditions using different methods. Our objective was to determine whether the research hypothesis was validated in both educational contexts. Although both samples (Belgian and Romanian) consisted of two groups, experimental and control, homogeneous and comparable in terms of students' initial competencies, skills, and knowledge of the hydrosphere, the validation of the first research hypothesis could be achieved through different but complementary statistical methods. Unlike the Belgian sample, in the Romanian sample, the significant change produced by Google Earth Pro in the development of Geography-specific competencies could not be statistically demonstrated using the same method (by comparing it to the control group and calculating the Independent-Samples Mann-Whitney). Another statistical method, the Paired Sample Test, was required to show a change as a result of using GEP. The research hypothesis was validated in both educational contexts.

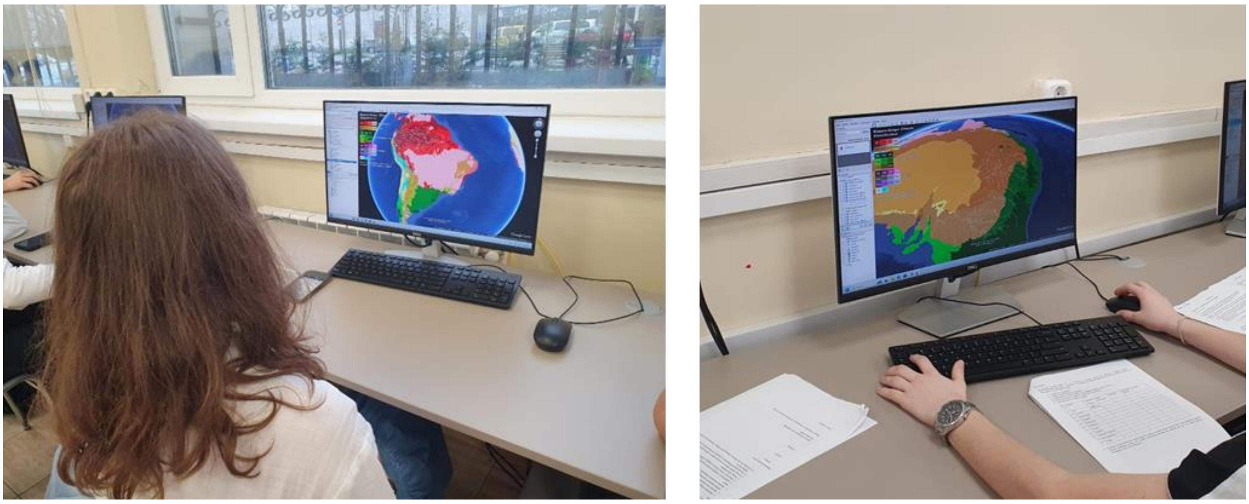

Figure 4. Developing specific skills using Google Earth Pro—the Romanian target group

The introduction of the Google Earth Pro application into the educational process was a novelty for students in both samples, as they had not previously experienced learning geography content with this digital tool. In the teaching-learning-assessment process of geography, both samples had previously experienced learning through games, and teachers typically assessed and reinforced new knowledge and skills using quizzes, online encyclopaedias, and websites, which were the only digital resources used. The introduction of Google Earth Pro changed students' learning styles because learning activities involved observation and analysis of rivers based on thematic layers imported into GEP. Traditional graphical representations from textbooks were replaced by a 3D geo-visualisation of the Earth's reality, requiring students to conduct investigations of terrestrial surfaces and establish correlations and connections between physical Geography elements.

Hydrography content taught with Google Earth Pro, such as river components, river analysis, and factors influencing flow and fluvial relief, required students to observe, think, and reason more extensively. They had to manipulate and operate multiple information sources simultaneously, including temporary locations (imported thematic layers such as drainage basins, major landforms, climate maps) and primary databases (Fig. 4). GEP influenced the development of competencies in interpreting graphical representations, arguing an explanatory approach, and spatial skills in both samples (Belgian and Romanian).

How effective was the use of Google Earth Pro in developing geography-specific competencies among lower secondary students?

Studies have shown that students who develop geographic competencies and acquire specialized knowledge will be able to adopt solid geographic perspectives and strengthen their capacity to become change agents in the future (Kerski, 2023). Numerous documented examples in pre-university settings (Fitzpatrick, 2020) and community colleges (Kerski, 2019) show that many students already fulfill this transformative role during their studies, before graduation.

The effectiveness of Google Earth Pro in teaching and learning geography had a very significant effect on Belgian students. The proportion of students with very poor results (Insufficient) decreased, as they moved to the category of passing grades (Satisfactory), thereby reducing the percentage of students at high risk of academic failure and low motivation to learn. Introducing GEP into geography lessons positively affected Belgian

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students' attitudes toward geography lessons, particularly among students with very low or low results.

Teaching geography with GEP was highly effective in the Belgian sample in developing the competency of interpreting graphical representations. In the pre-test, this competency had a very low performance level, with 75.9% of students at an Insufficient level and only 10.3% achieving a Good score. After the experiment, the post-test showed a considerable increase in performance, with 62.1% of students at a Good level and 17.2% at a Very Good level.

This competency was assessed through an item requiring students to know and identify seven elements of a drainage basin based on an image. The increase in performance can be attributed to multiple factors that complemented and supported GEP's effectiveness. Pre-test effects are sometimes explained as motivational factors or as serving a direct teaching function (Gunasekera, 1997). GEP's effect may have been reinforced by increased student motivation and interest in geography lessons, which became more interactive and engaging due to the introduction of a new digital tool that captured their attention. Pre-testing may also increase excitement or attention toward upcoming events, such as the treatment and post-test (Sime & Boyce, 1969), especially since the experiment was conducted by researchers who taught the content and worked with students using the application. The presence of these new figures as "teachers" in the experimental pedagogical scenario stimulated student attention throughout the lessons, creating a novel learning context both in terms of the teaching tool and the facilitator.

GEP was highly effective in developing the competency of arguing an explanatory approach in the Belgian sample when considering Cohen's d coefficient. However, performance-level analysis shows that students did not fully progress between pre-test and post-test; 72.4% of students did not reach a satisfactory level of this competency. While the percentages of students achieving Satisfactory (10%) and Good (17.2%) levels increased compared to the pre-test, students still struggled to develop this competency. Teachers should focus more on remedial plans and personalised learning to improve competency.

Cohen's d indicates a high effect of GEP in developing spatial skills in the Belgian sample. This efficiency is reflected in the decrease of students at the Insufficient level (89%), with slight increases at Satisfactory (6.9%) and Very Good (3.4%). Despite these statistical results, the fact that 89% of students have not developed spatial skills is alarming, as this competency is fundamental in geography. No student reached a Good level, and only 3.4% reached Very Good. These results should prompt geography teachers to reflect on methods and teaching tools to improve spatial skills. The same situation is observed in the Romanian sample. GEP had a medium effect on interpreting graphical representations and arguing an explanatory approach, and a very high effect on spatial skills. Cohen's d indicates effect size, but performance-level analysis is needed to determine whether students progressed from Insufficient to Satisfactory, Good, or Very Good. Teachers must be aware of the proportion of students at Insufficient and Satisfactory levels, as these students are vulnerable and at high risk of failing or dropping out. The effect of GEP on interpreting graphical representations is evident in a 30% increase in students at the Very Good level and a 45% decrease in students at the Insufficient level. However, students at Insufficient and Satisfactory levels still constitute 50% of the total, requiring teacher reflection to improve outcomes. GEP had a medium effect on the argumentation competency, reducing the Insufficient level to 10% post-test, but 50% of students remained at Satisfactory. In spatial skills, GEP had a very high effect, improving students at Good and Very Good levels; still, 55% of students remained at Insufficient or Satisfactory.

How relevant was the impact of introducing Google Earth Pro in developing Geography-specific competencies?

Although the impact of introducing GEP was significant (Cohen's coefficient), the level of development of the three competencies is still not very high in any sample—neither in the Belgian nor in the Romanian sample—despite the fact that these competencies are developed over several years. One possible explanation for this situation could be the general evaluation approach used by teachers in class: if the teacher is more lenient and overestimates students, they become accustomed to this style, put less effort into learning geography, and when faced with standardised assessments using a 0–10 grading scale, they achieve much lower results than they normally do.

The research highlighted the relevance of GEP in teaching content and developing subject-specific competencies. However, the mere introduction of a digital tool into the geography teaching–learning process cannot guarantee sustainable long-term results with substantial improvement in argumentative and spatial skills. If the tool is not integrated into the teaching strategy alongside the teaching methods used by the teacher, educational resources, content, and learning activities adapted to the digital tool, it is difficult to achieve performance in developing students' competencies.

The curricular context, the marginalisation of Geography as a science within the curriculum, and the emphasis placed on mathematics, the native language, modern languages, and other sciences could equally explain the results of this research.

How much do the research results regarding the efficiency of the Google Earth Pro application in developing geographical competencies differ in the two educational contexts: Romanian and Belgian?

The research results differ between the two samples in terms of improvement in performance levels and the development of the specific competencies analysed. The findings highlight that in the educational process, the mere use of a digital tool is insufficient to guarantee an increase in students' academic performance through a significant improvement in the development of fundamental geographical competencies. Students' learning characteristics, the national educational context, school curricula, student motivation, and the teaching methods used by teachers in the teaching–learning–assessment process support the achievement of performance in developing students' competencies through the use of a digital tool. These factors play a complementary role, supporting the digital tool.

This conclusion was reached by analyzing the results of the two samples. Although statistical analysis indicated that Google Earth Pro produced a significant change with considerable impact on competency development, the proportion of students with an insufficient level in Argumentation of an explanatory process and Spatial Skills is very high in the Belgian sample. By comparison, the Romanian sample shows a lower proportion of students with insufficient levels, raising important questions regarding the causes behind the different results observed in the Belgian sample.

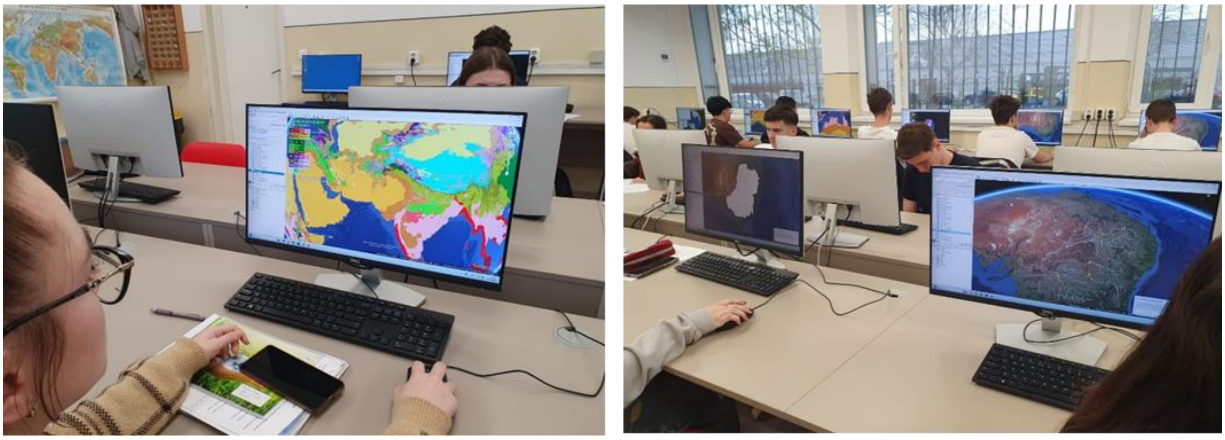

Figure 5. Teaching scenario focused on developing specific skills using Google Earth Pro—Romanian target group

The Romanian sample (Fig. 5) showed improvement in all three competencies analysed, while the Belgian sample improved only one. The Romanian sample achieved better results than the Belgian sample in Argumentation of an explanatory process. The "Insufficient" grade indicates very poor results, placing students in a non-passing situation. From this perspective, the non-passing rate in the Belgian sample is very high at 72.4%—this is the proportion of students who have not developed this argumentative competency. In contrast, the non-passing rate in the Romanian sample is much lower at only 10%. The absence in the Belgian sample of students with a Very Good level of argumentative competency indicates serious issues related to academic performance.

Although these competencies are developed over several school years, the very high proportion of students with an insufficient level raises multiple questions regarding students' motivation, interest in Geography, quality of teaching, and the methods and tools used in the teaching process. Among the possible causes explaining this situation are: the short duration of piloting the teaching scenario (three weeks were insufficient for students to acquire digital learning skills with GEP), the precarious level of prior knowledge in argumentation (students need to draw on previous knowledge, but their background is weak), and the practice of content-focused teaching rather than competency-focused teaching. Teachers face difficulties implementing student-centred teaching, and students are not accustomed to learning activities during geography lessons, which explains the lack of attention to experimental activities.

Other causes explaining the difficulties students encountered in argumentation include: lack of specialised vocabulary or a limited vocabulary, incorrect use of specialised terminology, and insufficient knowledge and skills to explain, justify, reason, and support arguments.

The results are concerning, especially since argumentation is a cross-disciplinary competency. Students solve argumentative tasks in many other subjects within the curriculum: native language, history, geography, civic education, etc.

In the Romanian sample (Fig. 6), the results are better: the proportion of students with a Good or Very Good level of argumentative competency is high at 40%. This performance may result from the combination of Google Earth Pro with other factors such as: the structure of the school curriculum (this competency is

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progressively developed from 7th grade, and students had previously engaged in learning activities requiring argumentation, even if with other tools), the evaluation system (periodic and systematic evaluation in the Romanian system provides faster feedback and allows teachers to identify learning issues), and the higher competitiveness of 9th-grade students, motivated by university admission criteria.

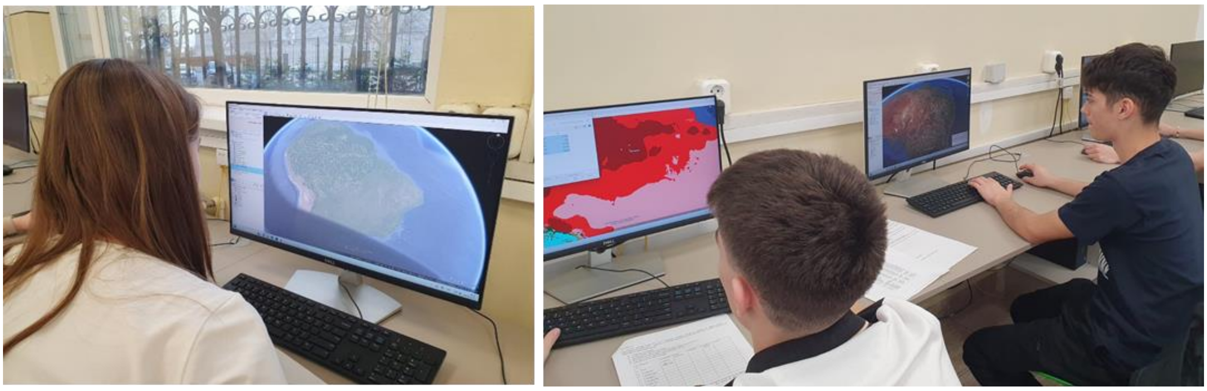

Figure 6. Piloting the teaching scenario—the Romanian target group

Significant differences were observed between the two educational contexts regarding the development of spatial skills. Belgian students face major difficulties, with 89.7% at an insufficient level, indicating they have practically not developed this competency. Equally worrying is the very small proportion of students at Good and Very Good levels (3.4%). Spatial skills are included in the primary school geography curriculum, and working with maps, locating, and identifying fundamental geographical elements are among the most frequent tasks students should practice. The failure to develop these skills can be partly attributed to the curriculum in Belgium, which is not clear and concise, gives teachers significant freedom in content selection, and does not encourage the development of spatial skills from a global to regional and local scale. Students' geographical thinking is mainly developed at local and national scales. In this context, it is difficult to develop global-scale spatial skills within a three-week experiment if students are not accustomed to learning activities that require developing this competency, motivating students, and helping them gain a global perspective.

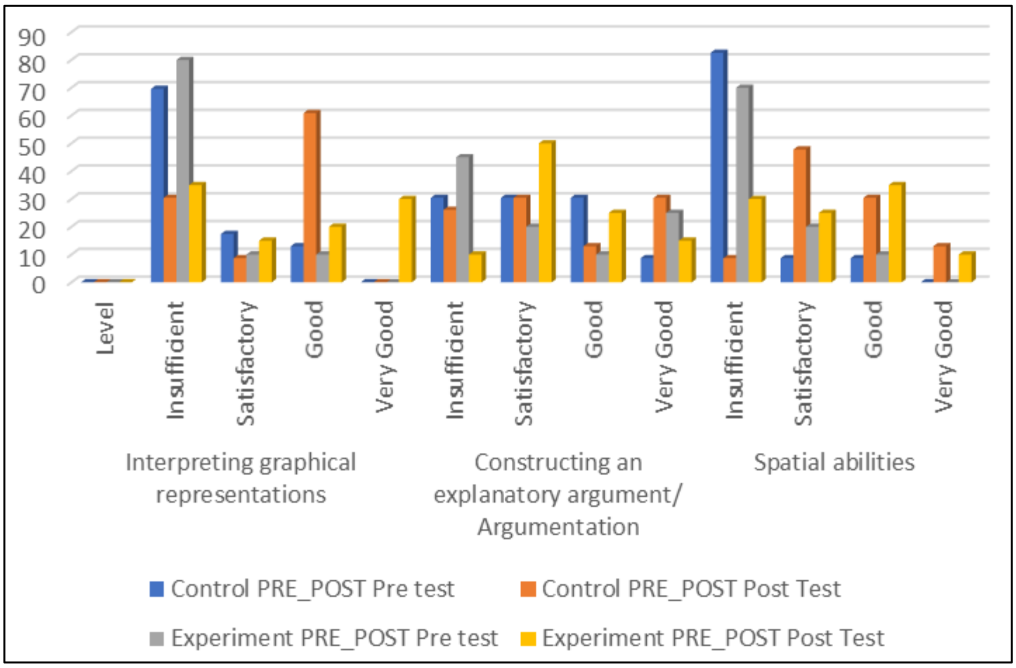

Figure 7. A graphical representation of the development of proficiency levels in the three competencies analyzed for the two groups (control and experimental) within the Romanian target group

In the Romanian sample (Fig. 7), students show a much better level of spatial skills: only 30% are at an insufficient level, while 45% are at Good or Very Good levels. Google Earth Pro contributed to these results, but its effect cannot be separated from complementary factors: the geography curriculum emphasizes spatial skill development from local to global scales from 5th grade onward (VI, VII, VIII, IX). This fundamental competency is continuously assessed, and educational reforms require teachers to integrate it into learning activities using digital tools.

Poorer student results and lack of performance may also stem from a lack of social awareness regarding geography's capacity to solve problems and an inadequate understanding of the subject's importance in education (Kerski, 2023). In the Romanian experimental group, there was a significant improvement in the competency of Graphical Representation Interpretation, with a sharp decrease in students at the Insufficient level (by 45%), an increase in Satisfactory (5%) and Good (10%), and the emergence of Very Good (30%). The Argumentation competency showed significant improvement, with a 35% decrease in students at Insufficient level, a 10% increase in Very Good, and increases in Satisfactory (30%) and Good (15%). Students also made substantial progress in the third competency, Spatial Skills, with a 40% decrease in Insufficient level, increases in Satisfactory (5%), Good (25%), and emergence of Very Good (10%).

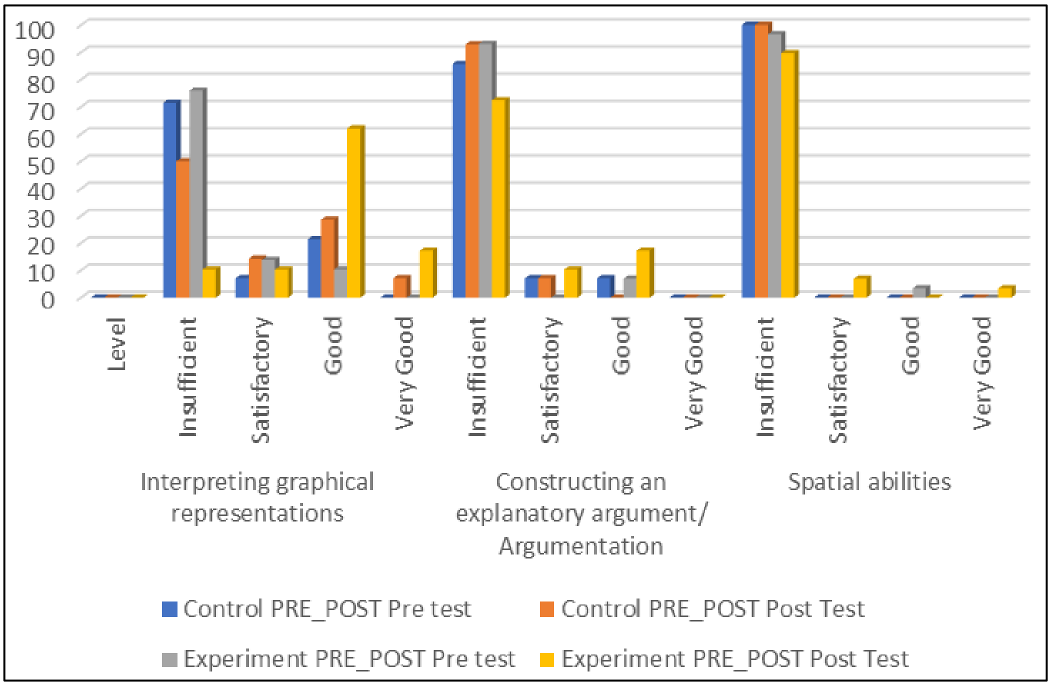

Figure 8. A graphical representation of the development of proficiency levels in the three competencies analyzed for the two groups (control and experimental) within the Belgian target group

The Belgian experimental (Fig. 8) group recorded a significant improvement in Graphical Representation Interpretation, with a massive decrease in Insufficient level (65.3%), and increases in Good (51.8%) and Very Good (17.2%). There was modest improvement in Argumentation: although the Insufficient proportion decreased by 20.7%, it remained very high at 72.4%, with the Satisfactory segment at 10.3% and Good at 10.3%. A slight improvement was also observed in Spatial Skills, with a 6.9% decrease in Insufficient, disappearance of Good (3.4%), and increases in Satisfactory (6.9%) and Very Good (3.4%).

Limitations

Experimental research based on analyzing the evolution of pre-test and post-test results highlights the need to consider several additional aspects. Kim & Willson (2010) also point out that pre-testing can alert subjects to relevant topics and may direct their attention selectively toward what the researchers intend to analyse, with the possibility of memorising pre-test questions.

The similarity between pre-test and post-test encourages content-focused learning rather than competency-focused learning. In the case of experimenting with the teaching of Geography using digital tools such as Google Earth Pro, it would be more appropriate to design pre-tests and post-tests focused on evaluating competencies. This would involve including in the post-test images and datasets downloaded from Google Earth Pro to observe how students handle cartographic materials used during the experiment.

Designing competency-focused pre-tests and post-tests means that only the evaluated competencies remain identical, while the questions and tasks are similar in model and expression but not identical. This ensures that we are truly assessing a competency developed through Google Earth Pro.

Using the same didactic illustrations in pre-tests and post-tests—depicting river components that do not correspond to geographic reality—does not prove that a student successfully completed the item in the post-test due to the Google Earth Pro experiment. Only by integrating in the post-test an image downloaded from Google Earth Pro that corresponds to a real geographic basin can we directly evaluate the impact of the digital tool on competency development. Didactic images and conceptual models are visual, often artistic representations that explain geographic elements visually. The main challenge arises when students must transfer and apply this information, knowledge, and skills to a cartographic support that corresponds to geographic reality. The level of difficulty is perceived as slightly higher: students may easily identify simplified hydrological elements such as tributaries, confluences, and deltas in didactic illustrations but may not be able to do so in Google Earth Pro.

The use of a digital tool such as Google Earth Pro requires careful supervision by the teacher. Students seated in front of the tool tend to act freely, sometimes ignoring the teacher's instructions, wasting valuable time exploring Google Street View, or searching for answers on Wikipedia or ChatGPT instead of investigating the virtual globe. This risk increases, especially if students are not accustomed to analyzing, observing, locating, and working with cartographic supports in general.

Another limitation is the small sample size, which requires cautious interpretation of the obtained results.

It is also necessary to discuss the difficulties encountered in identifying common elements between the Geography curricula of the two education systems, including the subject-specific competencies outlined in the programs and the theoretical content studied in Grade 9 (Romanian system) and S3 (Belgian system). The two educational systems approach hydrosphere content differently. In the Romanian Geography curriculum, students learn about the fundamental elements of the hydrosphere in Grade 5 (middle school cycle), focusing on general aspects and characteristics. In Grades 6 and 7, these topics are further developed for all continents, while in Grade 8 students study the hydrography of Romania. By Grade 9, students are expected to have acquired certain subject-specific competencies, general knowledge, and information about the hydrosphere from previous grades, alongside revisiting theoretical concepts and developing new knowledge.

Experimental research often focuses on differences between control and experimental groups and between experimental groups. From our perspective, comparative analyses between the two control groups (Belgian and Romanian) should not be neglected, as their evolution from pre-test to post-test can influence the statistical results at the level of the experimental groups.

The frequency analysis of students' results (Table 6) shows that the Belgian control group achieved moderate progress in developing the competence Interpretation of Cartographic Representations, with a 21.4% decrease in students at the Insufficient level and increases in the Satisfactory (+7.2%), Good (+7.2%), and Very Good (+7.1%) levels. For the competence Argumentation of an Explanatory Approach, a regression was observed, with an increase in students at the Insufficient level (+7.2%) and a complete disappearance of students at the Good level. Regarding Spatial Abilities, the situation remained constant between pre-test and post-test, with all students at an Insufficient level.

The Romanian control group showed major progress in both competencies. For Interpretation of Cartographic Representations, the percentage of students at the Insufficient level decreased by 39.4%, at the Sufficient level by 8.7%, while the proportion of students at the Good level increased significantly by 47.9%. For Argumentation of an Explanatory Approach, progress was recorded with a decrease of students at the Insufficient level by 4.3% and an increase in those at the Very Good level by 21.7%. A very large improvement was also observed for Spatial Abilities, with a significant reduction in students at the Insufficient level (-73.9%) and increases at Satisfactory (+39.1%), Good (+21.7%), and Very Good (+13%) levels.

Conclusion

The data confirmed the research hypotheses for both samples, showing that the digital tool Google Earth Pro was effective in teaching Geography, capable of producing significant changes with a positive impact on the development of the analysed subject-specific competencies. The Mann-Whitney U test results indicated that, prior to the intervention, there were no statistically significant differences between the groups for variables S1, S2, and S3 ($p > 0.05$). However, at post-test, significant differences were observed between groups for all three variables: S1_post test ($p = 0.005$), S2_pos ttest ($p = 0.031$), and S3_post test ($p = 0.001$). These findings suggest that the intervention had a substantial impact on participants' performance, clearly differentiating the groups after the treatment.

Once differences between the two groups were established—differences attributable to the use of Google Earth Pro in teaching Geography—it became important to measure the effect size of this experimental intervention and assess the impact of Google Earth Pro. Cohen's d values (Table 6) for the Belgian experimental sample indicate that the effect size of the Google Earth Pro intervention for item 1 was $d = -1.444$, demonstrating a substantial impact on the development of the competence Interpretation of Cartographic Representations. For item 2, d = -0.576, indicating a moderate impact on Argumentation of an Explanatory Approach, and for item 3, d = -0.766, reflecting a large effect on the development of Spatial Ability.

For the Romanian sample, the effect size of the Google Earth Pro intervention showed that, in the experimental group, the application had a significant impact on the development of all three competencies. The Cohen’s d values were significant: for competence 1 (Interpretation of Cartographic Representations) d = -0.503; for competence 2 (Argumentation of an Explanatory Approach) d = -0.472; and for Spatial Ability, d = -1.295. The use of Google Earth Pro had a moderate effect on competencies 1 and 2, and a very large effect on competence 3.

The effectiveness of Google Earth Pro in teaching and learning Geography had a strong positive effect on the Belgian students. The proportion of students with very poor results (Insufficient grade) decreased, as after the experiment, these students moved to the passing category (Satisfactory grade), reducing the percentage of students at high risk of academic failure and with low motivation to learn. Introducing GEP into Geography lessons positively influenced Belgian students’ attitudes toward the subject, particularly among those with very low and low initial results.

However, the observed improvement in Geography learning with Google Earth Pro—primarily reflected in the progression from Insufficient to Satisfactory and only slightly to Good or Very Good—suggests that the level of knowledge, competencies, and skills remains limited. Students either face learning difficulties or lack sufficient motivation to engage with Geography, highlighting the need for remedial measures, personalised learning, and adaptive teaching strategies to optimize learning outcomes and enhance student competencies.

The study emphasised the relevance of GEP in teaching content and developing subject-specific competencies. Nevertheless, the mere introduction of a digital tool into the teaching-learning process of Geography cannot guarantee sustainable long-term results or substantial improvements in argumentative and spatial competencies. Effective integration of the tool into the teacher’s instructional strategy, alongside appropriate teaching methods, resources, content, and learning activities, is essential to achieve sustainable improvements in students’ competencies.

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Author contribution

Conceptualization, MP and ND; methodology, MP and NP; validation, MP; formal analysis, MP; investigation, MP and NP; writing—original draft preparation, MP; writing—review and editing, MP and ND; supervision, ND. All authors have read and agreed to the published version of the manuscript.

Informed Consent Statement

All participants were informed in detail that their anonymity would be guaranteed, about the purpose of the study, and about how their data would be used.

Conflicts of interest

The authors declare no conflict of interest.

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