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DEVELOPING GEOSPATIAL THINKING LEARNING LINES IN SECONDARY EDUCATION: THE GI LEARNER PROJECT.

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Abstract:

Geo-ICT is part of the digital economy identified by the European Commission as being vital for innovation, growth, jobs and European competitiveness. It is a rapidly growing business sector, but it is in many countries a shortage occupation sector. More attention to Geo-ICT in education, which relates to geospatial thinking, would help. The GI Learner project developed therefore a geospatial thinking learning line for secondary schools, so that integration of geospatial thinking can take place. The learning line concept used hereby different levels of complexity, referring to the taxonomy of Bloom, taking into account age and capabilities of students. For each of the competencies lesson materials related to the curriculum was produced, thus facilitating the implementation in education on short term. To measure the impact of the learning lines on spatial thinking a self-test was therefore developed, taking into account the level of complexity of each competence (A, B or C) for each age group. The GI Learner project website (http://www.gilearner.eu) provides access to as well the research publications as well as the developed teaching resources.

Keywords: *GIScience, geospatial literacy, learning line, education*

1. Introduction

The use of GI tools to support spatial thinking has become integral to everyday life. Through media agencies that use online interactive mapping and near ubiquitously available tools like GPS and car navigation systems, the general public has started to become aware of some of the potential of spatial data. Geo-ICT is part of the digital economy identified by the European Commission as being vital for innovation, growth, jobs and European competitiveness. As a rapidly growing business sector, there is a clear and growing demand for Geo-ICT know-how (Donert, 2005). At the same time the Geo-ICT sector is in many countries a shortage occupation sector. The Eurogeographics Association (http://eurogeographics.org/) confirmed that the GI sector is booming (e.g. employment rose to about 550,000 in 2014, despite the crisis). However there is a clear mismatch between workforce demand and supply. An inquiry in Flanders for example showed that on average every year only 1/3 of the available jobs is filled due to lack of students leaving high school or university without the necessary skills and knowledge.

Space and location make spatial thinking a distinct, basic and essential skill that can and should be learned in school education, alongside other skills like language, mathematics and science. The goal of GI-Learner is to integrate spatial literacy, spatial thinking and GIScience into schools. Bednarz & van der Schee (2006) made three recommendations for the successful introduction and integration of GIScience in schools. These were to:

i) address key internal issues related to GIS implementation: teacher training, availability of user friendly software, ICT equipment in schools.

ii) use a community of learners approach and

iii) institutionalize GIScience into curricula, making sure that it is aligned with significant general learning goals like graphicacy, critical thinking and citizenship skills.

In terms of the first two recommendations considerable progress has already been made, for example there have been more training opportunities for teachers as the EduGIS Academy (http://www.edugis.pl/en/), iGuess (http://www.iguess.eu), I-Use (http://www.i-use.eu) and SPACIT (http://www.spatialcitizenship.org) projects, schools nowadays generally have better ICT equipment, pupils are asked to bring their own devices, data is more freely available and Web-based platforms have reduced costs. The digital-earth.eu network launched 'Centres of Excellence' in 15 European countries (http://www.digital-earth-edu.net) . The Geo For All imitative has developed a network of Open Source Geospatial Labs around the world and has also focused its attention on school education (http://geoforall.org/). These initiatives have helped build a community of practitioners, in Europe and beyond, by collecting and disseminating good practice examples and organizing sessions with teachers. However, there are still needs for much more training, additional learning and teaching materials, good practice examples and a comprehensive and well-structured compilation of digital-earth tools. The institutionalization of geo-technology and geo-media into curricula still remains a goal in almost all countries. It has by and large not been achieved, despite the development of:

i) benchmarks (Herodot 2009; Lindner-Fally & Zwartjes 2012), intended to give a rationale and recommendations on the implementation to teacher trainers, teachers and headmasters, but also to policy and decision makers

ii) competence models (Schulz E et al., 2012, 2013, 2015, Gryl et al. 2013),

iii) teacher guidance (Zwartjes, 2014) whereby teachers can select suitable tools to use, based on curricula, abilities of their students and their own capabilities and

iv) innovative projects like iGuess, SPACIT, EduGIS Academy, I-Use etc.

The GI-Learner project responded to this by the development of a GIScience learning line for secondary schools, so that integration of geospatial thinking can take place. This implied translating spatial and other competences, taking into account age and capabilities of students, into real learning objectives that will increase spatial thinking education activities and help produce the workforce we need now and for the future and geospatially literate citizens. GI-Learner was a project supported by Key Action 2 of the Erasmus Plus education program. It was a three-year project, with seven partners from five European countries (Figure 1).

Figure 1: The GI Learner consortium

GI-Learner aimed to help teachers – and on the longer term governments – implement learning lines for geospatial thinking in secondary schools, using GIScience. In order to do this, the project:

1) summarized the most important literature on learning lines and spatial thinking

2) defined geospatial thinking competencies
3) created learning lines & translating them into learning objectives, teaching and learning materials for the whole curriculum (K7 to K12)
4) developed a self-evaluation tool to analyse the impact of the learning lines on geospatial thinking and

2. DIMENSIONS MODES AND FRAMEWORKS OF (GEO)SPATIAL THINKING

Geospatial thinking is a learning outcome mainly based on ways of thinking and reasoning related to pattern recognition, spatial description, visualization, spatial concept use and the spatial use of tools. It concerns the critical application of spatial information to deal with real-world problems. It is not a single ability, it comprises a collection of different skills, it is the ability to study and make sense of the characteristics and the interconnected processes of nature and human impact in time and at appropriate scale. Traditionally spatial thinking is linked to spatial visualization, orientation, spatial perception and mental rotation (Figure 2).

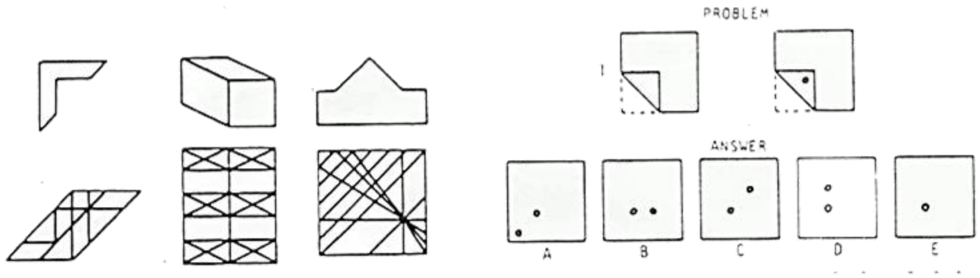

Figure 2. National Research Council, 2006, Learning to think spatially: GIS as a Support System in the K-12 Curriculum, Washington DC, National Academy Press

But geospatial thinking is more. It is a distinct form of thinking, which helps people to visualize relationships between and among spatial phenomena (Stoltman & De Chano, 2003). It strengthens students' abilities to conduct scientific inquiry, engage in problem solving and think spatially. Goodchild (2006) argues that spatial thinking is one of the fundamental forms of intelligence needed to function in modern society, it is a basic and essential skill whose development should be part of everyone's education, like learning a language, numeracy and mathematics. Geospatial thinking can be seen as « the ability to deal with a mental model of the Earth and the ability to operate using this model » (Otero & De Lazaro, 2017), the model being a constructive combination of three mutually reinforcing components: the nature of space, the methods of representing spatial information, and the processes of spatial reasoning (Lee & Bednarz, 2009).

Geospatial thinking be defined as a collection of cognitive skills comprised of knowing concepts of space, using tools of representation and reasoning processes (Figure 3). It is exactly the links among these three that gives spatial thinking its power of versatility and applicability (NRC, NAP, 2006; Jarvis, 2011).

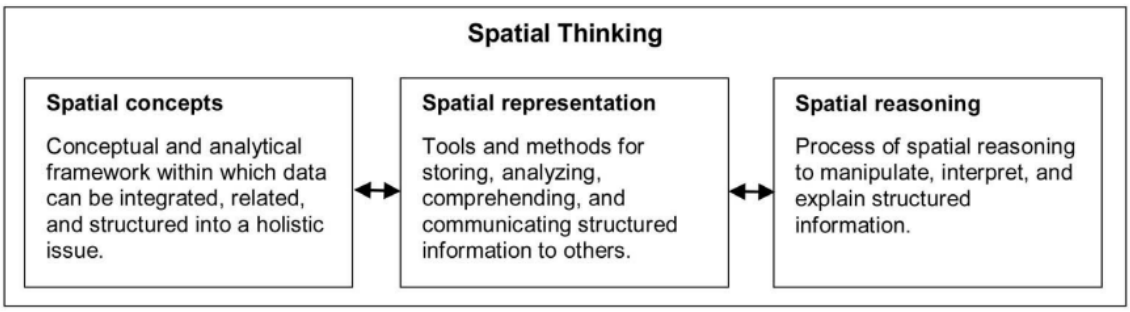

Figure 3. Spatial Thinking dimensions and related terms (Michel & Hof, 2013)

This means that geospatial thinking is not a single ability but comprised of a collection of different skills, students need to know these building blocks of spatial thinking (Bednarz & Lee,2011). There have been many attempts to analyse, organise, classify and define them. The remainder of this section examines some of the key literature. The Committee on Support for Thinking Spatially (2006) suggested spatial thinking involves breaking the process down into three component tasks: extracting spatial structures, performing spatial transformations, and drawing functional inferences. Representations are used to help us remember, understand, reason, and communicate about the properties of and relations between objects represented in space.

Many interpretations of spatial thinking have sought to establish hierarchical classifications. Kim & Bednarz (2013) examined spatial habits of mind. These are the broadest learning outcomes, which are mainly based on ways of thinking. They identified five spatial sub-dimensions: pattern recognition, spatial description, visualization, spatial concept use, and spatial tool use (Table 2) and described basic and extension modes.

Table 2. Five spatial habits of mind (adapted from Kim & Bednarz, 2013)

Pattern Recognition	students should be taught and encouraged to foster their spatial habits to recognize patterns in their everyday life	extension: recognize, describe, and predict spatial patterns
Spatial Description	Students can use spatial vocabulary proficiently	extension: a more advanced spatial lexicon and more frequent use of spatial vocabulary
Visualization	Students increase understanding through the aid of graphical representations	extension: enhance comprehension by converting the information into visual representations, understand the benefit and power of graphic representations
Spatial Concept Use	Students use or apply spatial concepts to understand and perform various tasks	extension: employ spatial concepts to understand surroundings
Spatial Tool Use	Students use spatial representations and tools to support spatial thinking exposure to tools helps understand space and develop spatial cognition	extension: spatial thinkers using spatial tools to solve problems

Newcombe and Shipley (2015) identified five classes of spatial skills on which research was done to classify spatial abilities. They identified an intrinsic-static skill (disembedding), two intrinsic-dynamic skills (spatial visualization and mental rotation), a extrinsic-static skill (spatial perception) and a extrinsic-dynamic skill (perspective taking). Cook et al. (2014) add a strategic domain to spatial thinking, applying it to the need for planning or developing programs designed to achieve future goals. They say developing a strategy enables the design of approaches that can help meet future challenges. This specifies preparation and anticipation to reach an ideal but possible state.

Jo & Bednarz (2009) developed a taxonomy to evaluate different components of spatial thinking in the curriculum, textbooks, lesson plans, and other instructional materials. Jo et al. (2010) use this to examine questioning in spatial thinking as part of everyday teaching practice applied to the pedagogical strategy of questioning, in both texts and as part of classroom activities. The taxonomy uses three components of spatial thinking: (1) concepts of space, (2) using tools of representation, and (3) processes of reasoning as primary categories. The subcategories differentiate varying levels of abstraction or difficulty. They make the case that a taxonomy of spatial thinking is a useful tool for designing and selecting questions that integrate the three components of spatial thinking and for determining the degree of complexity of a question in regards to its use of spatial concepts and the cognitive processes required. Scholz et al. (2014) used this system to identify the level and type of spatial thinking found in textbook questions (Table 3) and suggested a simplified taxonomy for evaluating materials integrating all three components.

Table 3. Three components of spatial thinking in questions (adapted from Scholz et al. 2014)

Component 1: Concepts of Space Nonspatial: No spatial component in the question. Spatial Primitives: the lowest level concept of space, involves the concepts of location, place-specific identity, and/or magnitude.
Simple-Spatial: A higher level concept of space, based on concepts and distributions, including distance, direction, connection and linkage, movement, transition, boundary, region, shape, reference frame, arrangement, adjacency, and enclosure.
Complex-Spatial: The highest level concept of space, based on high-order derived concepts, including distribution, pattern, dispersion and clustering, density, diffusion, dominance, hierarchy and network, spatial association, overlay, layer, gradient, profile, relief, scale, map projection, and buffer.
Component 2: Tools of Representation These relate to the use of maps, graphics and other representations to answer a question.
Use: The question involves a tool of representation to answer the question
Non-use: The question is not considered a spatial-thinking question.
Component 3: Processes of Reasoning The processes of reasoning component evaluates the cognitive level of the question.
Input: The lowest level - receiving of information and includes name, define, list, identify, recognize, recite, recall, observe, describe, select, complete, count, and match.
Processing: A higher level of reasoning, analyzing information, includes: explaining, analyzing, stating causality, comparing, contrasting, distinguishing, classifying, categorizing, organizing, summarizing, synthesizing, inferring, analogies, exemplifying, experimenting, and sequence.
Output: The highest level of processes of reasoning, uses the analysis of information received to evaluate, judge, predict, forecast, hypothesize, speculate, plan, create, design, invent, imagine, generalize, build a model, or apply a principle.

Gersmehl & Gersmehl (2006; 2007; 2011) reviewed neuroscience research observing how areas of the brain are related to the kinds of "thinking" that appear to be done. They suggested long-lasting learning of geographic information is more likely to occur when lessons are explicitly designed so that students perform spatial tasks. They proposed eight modes of spatial thinking (Table 4). They confirmed that students would greatly benefit if spatial thinking skills were more prominently placed in the school curriculum and concluded that several brain regions appear to be devoted to doing specific kinds of thinking about locations and spatial relationships.

Table 4. Modes of Spatial Thinking (adapted from Gersmehl and Gersmehl, 2011)

Location — Where is this place? a. Conditions (Site) - What is at this place? b. Connections (Situation) - How is this place linked to other places?
Eight aspects of Spatial Thinking (an example of a concrete activity) 1. **Spatial comparison** – similarities and differences between places
2. **Spatial influence** (Aura) – the effect of a lace on the surrounding areas
3. **Spatial groups** (Region) –regions of similar places
4. **Spatial transition** – changes taking place
5. **Spatial hierarchy** – where and how does a place fit in
6. **Spatial analogies** – places with similar situations
7. **Spatial patterns** – how features are arranged
8. **Spatial associations** (correlations) – possible causal relationships
Spatio-temporal thinking - How do spatial features and conditions change over time?

This section has not been an attempt to comprehensively review spatial thinking research, but to examine how its evolution has been rooted in many different domains, as widespread as neuroscience, psychology and geography. From this it is clear that spatial thinking involves highly complex cognitive activities of which some are related to the evolution of the brain. Out of this literature review (Zwartjes et.al., 2017) – and with the feedback received during many conferences and specialists meetings – 10 geospatial thinking competences have been selected. **All 10 competencies are required to develop geospatial thinking in GI Science.**

3. LEARNING PROGRESSION LINES

To be useful in education the competences needed to be included into a learning line.
Lindner - Fally & Zwartjes (2012) defined a learning line as an educational term for the construction of knowledge and skills throughout the whole curriculum. It should reflect a growing level of complexity, ranging from easy (more basic skills and knowledge) to difficult. Each block builds upon the already acquired knowledge and skills (Figure 4).

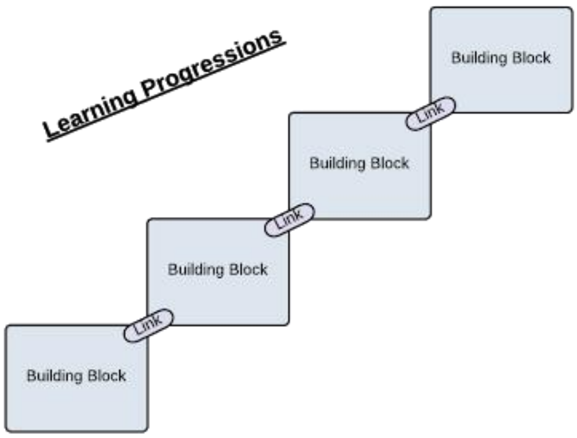

Figure 4. Concept of a learning progression line

Bloemen & Naaijkens (2014) describe a ‘learning line’ as an overall framework for education and training, with a distinct sequence of steps from beginners to experts. Their learning line was i) analytical; i.e. it distinguishes in detail the skills, knowledge and attitudes on several levels that may be expected and ii) competence-based; the learning line distinguishes a set of competences that together build the overall competence in the field. Perdue et al. (2013) proposed a spatial thinking framework and hypothesized that certain spatial thinking skills are higher order than others and build upon previous, less complex skills (Figure 4). So, in the example shown, regional identification is conceptualized as a high level skill achieved through the accumulation of proximity, boundary, clustering, and classification skills (Figure 5).

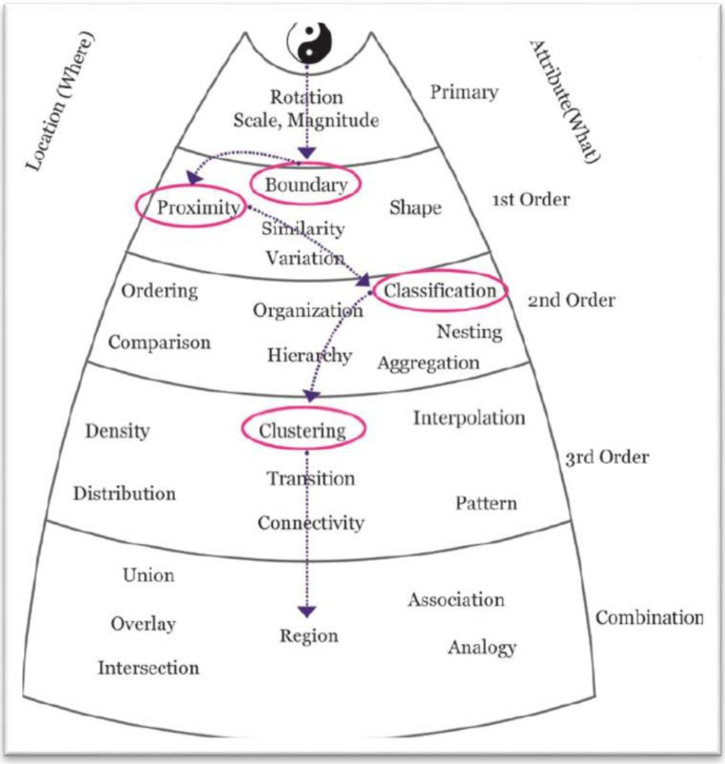

Figure 5. Spatial thinking framework (Perdue, 2013)

Based on this review, the 10 GI-Learner geospatial thinking competences are each translated into a progression from easy (A) to more elaborated (C) (Figure 6). Each has been illustrated with an example. The numbering of these 10 competencies does not reflect their level of difficulty nor their level of importance.

1	**Critically read, interpret cartographic and other visualisations in different media**	**interpretation**
	A: Be able to read maps and other visualisations	Example: use legend, symbology ...
	B: Be able to interpret maps and other visualisations	Example: use scale, orientation; understand meaning, spatial pattern and context of a map
	C: Be critically aware of sources of information and their reliability	Example: critically evaluate maps identifying attributes, representations (e.g. inappropriate use of symbology, or stereotyping) and metadata of the maps
2	**Be aware of geographic information and its representation through GI and GIS.**	**learning about**
	A: Recognize geographical (location-based) and non-geographical information	Example: describe GPS, GIS, Internet interfaces; be able to identify geo-referenced information
	B: Demonstrate that geographical information can be represented in some ways	Example: employ some different representations of information (maps, charts, tables, satellite images...)
	C: Be critically aware that geographic information can be represented in many different ways	Example: be able to evaluate and apply a variety of GI data representations
3	**Visually communicate geographic information**	**produce**
	A: Transmit basic geographic information	Example: produce a mental map, be aware of your own position
	B: Communicate with geographic information in suitable forms	Example: basic map production for a target audience - using old and new media, Share results with target group
	C: Be able to use GI to exchange in dialogue with others	Example: discuss outcomes like survey results/maps online or in class, referring to a problem in own environment
4	**Describe and use examples of GI applications in daily life and in society**	**applying**
	A: Be aware of GI applications	Example: know about GPS-related/locational (social networking) applications including Google Earth; produce a listing of known GI applications or find them on the internet/cloud
	B: Use some examples of (daily life) GI applications	Example: problem-solving oriented with GI application like navigating; use an app to read the weather, environmental quality, travel planner
	C: Evaluate how and why GI applications are useful for society	Example: assess the functionality and use for society of a GI application (emergency services, police, precision agriculture, environmental planning, civil engineering, transport, research) and present the results

5	**Use (freely available) GI interfaces**	**use**
	A: Perform simple geographical tasks with the help of a GI interface	Example: Find your house in a digital earth browser; finding a certain location; measuring the distance between two points by different means; use applications for mobile phones (ex. GPS) to locate a place
	B: Use more than one GI interface and its features	Example: collect data and compare to set the best route from school to home and back; get a topographical map for a walk
	C: Effectively solve problems using a wide variety of GI interfaces	Example: Find and use data from various data portals (SDI) to look for the best facilities of a specific region, or for the 'best' place to live using parameters like infrastructure, noise, open spaces, ...
6	**Carry out own (primary) data capture**	**produce / gathering**
	A: Collect simple data	Example: gather data during fieldwork (coordinates, pictures, comments...) e.g. sound data to analyse impacts of traffic; map attractive places for children in your city
	B: Compare different qualitative and quantitative data and select an appropriate data gathering approach, tool etc.	Example: when investigating environmental factors choose what data is needed
	C: Solve issues concerning data gathering and select the most suitable alternative approaches to data capture	Example: design a methodology which explains the data collection for land use change, like how to collect data from different sources and classify them appropriately
7	**Be able to identify and evaluate (secondary) data**	**use / evaluate**
	A: Locate and obtain data from source maps (different visualisations)	Example: Find and download data on migration and be able to use it
	B: Acknowledge that there is different quality in data, not everything is useful	Example: Identify multiple data sources for example of population or pollution and be able to assess their level (scale), detail, frequency, accuracy and other considerations; analyse different sources and decide which is the most useful
	C: Fully assess value / usefulness / quality of data	Example: Use data on climate change from ESA, IPCC compared to Facebook graphs
8	**Examine interrelationships**	**analyse**
	A: Recognise that items may, or may not, be related (connected) in different ways to one another	Example: recognize simple relationships between things, e.g. heat and sunshine, or city size and traffic jams // inverse relationships // some things are not related
	B: Demonstrate interrelationships between a variety of factors	Example: changes in environment, influence, connections and hierarchy of ecosystems
	C: Valuate different relationships and judge causes and effects	Example: Evolution of ecosystems over time is complex and is related to many variables; problem-oriented exploration of interrelationships like: where do my jeans or my mobile phone come from
9	**Extract new insight from analysis**	**produce**
	A: Read what the analysis says	Example: understand there are different types of climate
	B: Combine elements from the analysis to make sense of the outcomes	Example: realise that climate is changing
	C: Assess the analysis in depth, create new meaning and make links to the bigger picture	Example: responding and suggest solutions on climate change
10	**Reflect and act with knowledge**	**action: decision making / applying in real world**
	A: Recognise the decisions that had to be made	Example: Use geodata to assess which new road system should the local authority build
	B: Judge implications for individuals and society	Example: conclude there will be winners and losers for each road proposal
	C: Design future actions to stakeholders - including themselves	Example: develop a campaign to persuade decision makers concerning traffic planning; make a blog or a website with collected and visualized data; write a documented article in a magazine using GI information

Figure 6. The 10 GI-Learner geospatial thinking competences with (A) to (C) progression.

Competency	K7-8	K9	K10	K11	K12
1	A	B	C		C
2	A	B	C		C
3	A		B		C
4	A	B	C		C
5	A	B	C		C
6	A		B		C
7	A		B		C
8		A	B		C
9			A	B	C
10	A		B		C

Figure 7. Level of learning across the secondary school curriculum K7-K12

In order to create a learning line, the GI Learner competence levels (A, B and C) have been summarized across the K7-K12 curriculum (Figure 7), a model that has been developed through feedback from a number of events across Europe. For each year different exercises have been made - linked to the curriculum and mapped to the competencies and level of difficulty for that each group. All these materials can be found on the website www.gilearner.eu → Course. A teacher can replace an existing lesson topic with one of the lessons provided. If this is done for each year (with at least 2 lessons) the implementation of the learning line will be fruitful.

4. INTEGRATING GIS AS A TOOL FOR GEOSPATIAL CRITICAL THINKING

Because of its capabilities GIS is inherently an excellent vehicle in expressing the five themes of geography, as defined by The Joint Committee On Geographic Education (1984): location, place, relationships with places, movement and region. Geospatial technologies can be used to ask or answer different sorts of spatial question, which can be related to many different study areas. It helps foster geographic skills, knowledge, and understanding by developing the spatial thinking capabilities of students. Also when manipulating a map students can learn a lot about the way maps function, thus better understanding the importance of correct communicating with maps (Barnikel & Ploetz, 2015).

The prevalence of GIS technology is thus a solution to the need to develop spatial skills and being able to reason spatially. It is this multiple functionality that makes GIS an excellent component to learn according the TPCK framework as described by Mishra and Koehler (cited by Favier et al, 2012): « the knowledge a teacher should have about how to use technology in instruction in such a way that students develop knowledge and skills in a certain domain ». The TPCK framework is added with the GIS component in his GIS-TPCK framework approach (Figure 8).

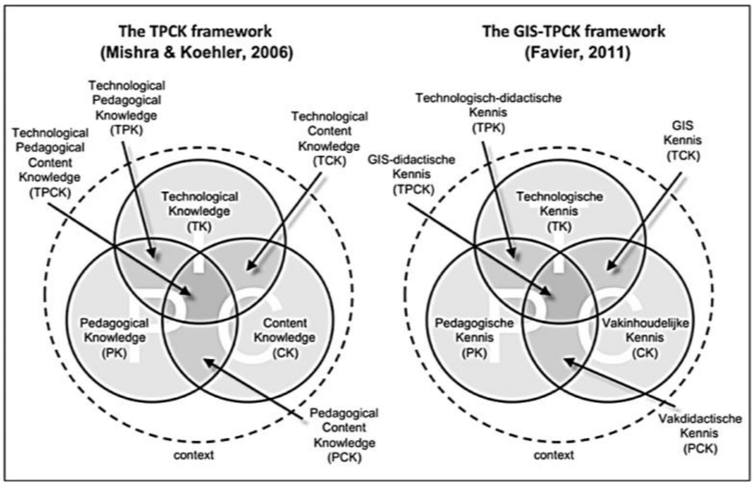

Figure 8: The general TPCK model (left) and the GIS-TPCK framework (Favier et al., 2012)

Favier (2013) describes five ways on how GIS can be integrated in secondary education (Figure 7). Teaching and learning about GIS (number 1 and 3 in the figure) focuses more on the theoretical aspects of GIS (knowledge of GIS, structure of the technology), where the three other ways use the technology to develop and use spatial thinking skills.

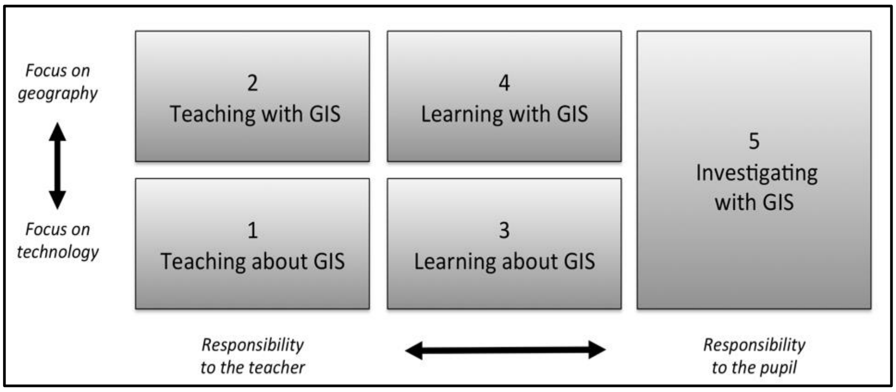

Figure 9. Five ways of integrating GIS in geography education (Favier, 2013)

Research shows that most 'successful' and easiest integration of GIS is done in 'Investigating with GIS', where students are asked to do a real geographic enquiry. Liu and Zhu (2008) explain this by linking GIS to constructivism. Geography enquiry draws on constructivism, emphasizing problem-solving and inquiry-based learning instead of instructional sequences for learning content skills. And

GIS provides useful tools for constructing a computer-based constructivist-learning environment for geography education. The project mostly used the webGIS platform ArcGIS Online (Esri) as this offers many advantages for schools:

- No software to install
- Accessible via as well pc's, laptops or tablets
- Accessible in the classroom and also on fieldwork using mobile devices
- Providing for the derived 10 competences enough possibilities, including spatial analysis tools and access to standardized and interoperable spatial data infrastructure (SDI).
- Also Esri is providing free access for all schools to the platform.

5. IMPACT OF THE APPROACH / STUDENT COMMENTS

The project involved students from five different European countries. Their role was double: on the one hand providing feedback and provide amendments on the first versions of the developed learning materials; on the other hand they were needed to measure the impact of the learning lines on geospatial thinking. There were initially 311 students (Tabel 5), and it was fully completed by 120 of them (2018). One of the main limitations in the GI Learner project has been the continuity of the students during the three years. There are many reasons that haven't allowed to have the exact same students from the beginning to the end of the project. Some of those students are no longer at their original school, as the school roll fluid, and there are pupils who transfer in and out. Also to map the impact over the whole K7-K12 curriculum thus following the same pupil the project should have lasted 6 years.

Table 5. Students involved on the project with valid tests results

Level	Average age	Female	Male	Total	Female (%)	Male (%)
K7	12.54	27	42	69	39.13	60.87
K9	14.01	27	32	59	45.76	54.24
K10	15.58	67	67	134	50.00	50.00
K12	17.2	34	15	49	69.39	30.61
Total	-	155	156	311	49.84	50.16

The assessment of progress from the beginning to the end of the project (summative evaluation) has been carried out through self-evaluation tests, carried out at the beginning and end of the project (test for K7, K9-10 and K12) which have made it possible to verify what pupils have learned. The students self-evaluated using the Likert scale, which has been used for its simplicity. The test consists of several parts, related to the selected learning outcomes /competencies which were developed for use in the project. The tests were completed at the start of the project (0-value) and at the end of every year and based on the comments and opinions of the pupils involved.
The general results can be seen in the graph (Figure 8).
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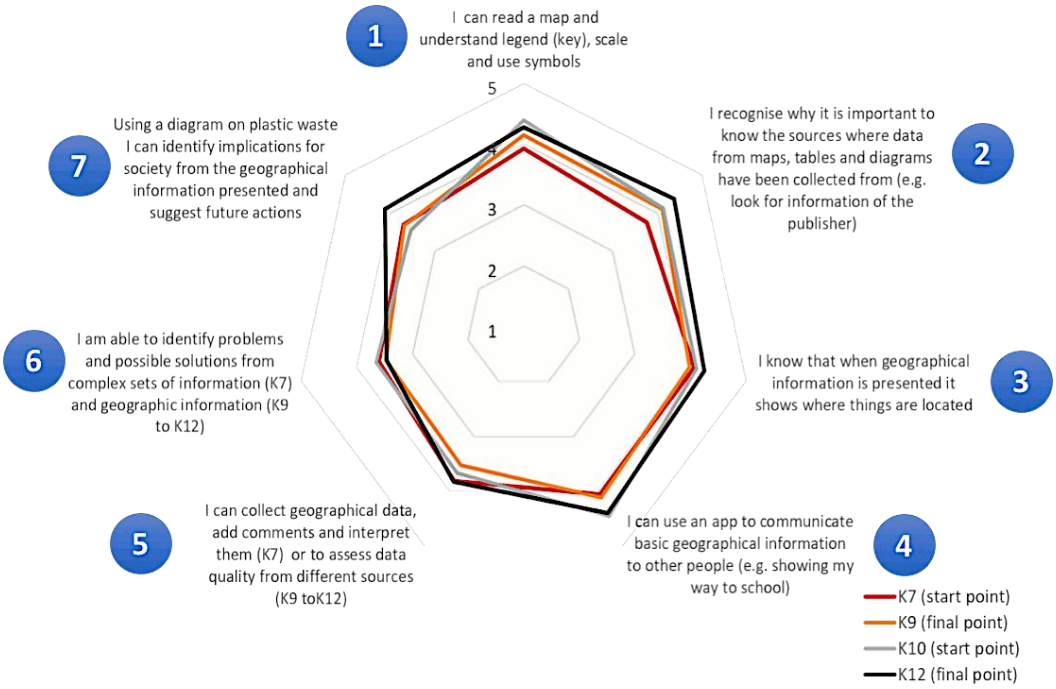

Figure 10. Improvement of several tasks/competencies along the project.

Regarding reading and interpreting maps and images (Q1) there is a clear improvement from K7 to K 12. K10 has better self-assessment than K12, a result of more cautiousness in the self-evaluation. The learning of the students helps them to know better the limits of their own knowledge. The next two questions (Q2 & 3) have shown an undoubtedly improvement. Students have learned that geographic information shows not only where things are located, but why, perhaps this is the reason of the slow down on improvement in the question about geographical information.

Regarding gathering, communicating and using quality geographical information (GI), there are two clear levels, the K7-K9 and the K10-K12, with an imperceptible improvement in the task (Q4). Most students feel able to use an app, maps and images and show the results to other people, for example, indicating their way to school or the institute. However, when we add some nuance about the quality of these data, self-assessment is reduced, as in the answers to Q5 (K9 toK12). Students have seen the complexity of the world and the huge quantity of available data (Big geodata), as in the current world, the raw material begins to be the data. Regarding Q6 there were low scores. In general, students are more confident in the use of the closest data than in the use of data far from their living place. But in Q7 their scores increased. This question is perhaps the most important of all, since it requires all the skills and competences of the designed learning line. The students provide year by year a greater appreciation of nuances, in relation to the contamination by plastics in the ocean, which was the proposed theme for application, being a major contemporary issue (De Lazaro & Zwartjes, 2018).

6. CONCLUSIONS

The GI Learner project had as aim to support teachers with the implement of a learning progression lines for geospatial thinking in secondary schools, using GI tools. The project provided the necessary scientific background as it started with an elaborated literature review out of which ten geospatial learning competences have been selected. By translating these into a learning line with the necessary curriculum related material the implementation is possible. For the teachers these recommendations can be made:

1. Improve their skills on visualizing geographical information on maps.
2. Use GI Science Methodology for selected topics, e.g. as suggested in GI-Learner materials.
3. Find topics in your curriculum that fit to GI-Learner contents and take advantage of ready-to use materials.

REFERENCES

Bednarz, S. W., Van der Schee, J. 2006. Europe and the United States: the implementation of geographic information systems in secondary education in two contexts, Technology, Pedagogy and Education. 15 (2), 191-205

Bednarz, R., Lee, J. 2011. The components of spatial thinking: empirical evidence. Procedia Social and Behavioral Sciences 21, 103–107.

Bloemen, H., Naaijkens, A. 2014. January. Designing a (Continuous) Learning Line for Literary Translation. In Second international conference on research into the didactics of translation: book of abstracts (pp. 36-36). PACTE group, https://lirias.kuleuven.be/handle/123456789/489288

Barnikel, F., Ploetz, R. 2015. The acquisition of spatial competence – fast and easy multidisciplinary learning with an online GIS. European Journal of Geography Volume 6, Number 2:6-14.

Committee on Support for Thinking Spatially 2006. Learning to Think Spatially, Washington, DC: National Academies Press. https://www.nap.edu/catalog/11019/learning-to-think-spatially

Cook, C.N., Inayatullah, S., Burgman, M.A., Sutherland, W.J. & Wintle, B.A., 2014. Strategic foresight: how planning for the unpredictable can improve environmental decision-making. Trends in Ecology & Evolution, 29(9), 531-541.

De lazaro y torres, M.L., Zwartjes, L. (coord.) 2018. Geospatial thinking test analysis. GI Learner project, www.gilearner.eu.

Donert, K., 2015. Digital Earth–Digital World: Strategies for Geospatial Technologies in Twenty-First Century Education. In: Solari, O.M., Demirci, A. and van der Schee, J., Geospatial Technologies and Geography Education in a Changing World, 195-204. Springer Japan.

Favier, T., Van der schee, J. (2012). Op zoek naar een kennisbasis voor lesgeven met GIS. Aardrijkskundeonderwijs onderzocht, Landelijk Expertisecentrum Mens- en Maatschappijvakken – Centrum voor Educatieve Geografie, p. 135-146.

Favier, T. (2013). Geo-informationtechnologie in het voortgezet aardrijkskundeonderwijs: Een brochure voor docenten, Vrije Universiteit Amsterdam, 80 p.

Gersmehl, P.J., Gersmehl, C.A., 2006. Wanted: A Concise List of Neurologically Defensible and Assessable Spatial-Thinking Skills. Research in Geography Education 8: 5-38.

Gersmehl, P.J., Gersmehl, C.A., 2007. Spatial thinking by young children: Neurologic evidence for early development and “educability”. Journal of Geography, 106(5), 181-191.

Gersmehl, P.J., Gersmehl, C.A., 2011. Spatial Thinking: Where Pedagogy Meets Neurocience. Problems of Education in the 21st Century, 27: 48-66.

Goodchild, M. 2006. The Fourth R? Rethinking GIS Education, ArcNews Fall 2006.

Goodchild, M.F., Janelle, D.G., 2010. Toward critical spatial thinking in the social sciences and humanities. GeoJournal, 75(1), 3-13.

Gryl, I., Jekel, T., Donert, K. 2010. GI & Spatial Citizenship. In Jekel, T., Koller, A., Donert, K. & R. Vogler, (eds.) Learning with Geoinformation V, 2-11, Berlin, Wichmann Verlag.

Gryl, I., Schulze, U., Kanwischer, D., 2013. Spatial Citizenship: the concept of competence. GI_Forum 2013: Creating the GISociety – Conference Proceedings, 282-293, http://hw.oeaw.ac.at/0xc1aa500e_0x002e6e6c.pdf

Herodot 2009. Benchmarks in Geography, HERODOT Network for Geography in Higher Education http://www.herodot.net/geography-benchmark.html

Jarvis, C.H., 2011. Spatial literacy and the postgraduate GIS curriculum. Procedia-Social and Behavioral Sciences, 21, 294-299.

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

Jo, I., Bednarz, S., Metoyer, S., 2010. Selecting and designing questions to facilitate spatial thinking. The Geography Teacher, 7(2), 49-55.

Kerski, J. 2008. Developing Spatial Thinking Skills in Education and Society. ArcWatch 2008, ESRI. http://www.esri.com/news/arcwatch/0108/spatial-thinking.html

Kim, M., Bednarz, R. 2013. Development of critical spatial thinking through GIS learning. Journal of Geography in Higher Education 37(3): 350-366.

Kolb, D. A. (1984). Experiential Learning: Experience As the Source of Learning and Development. Engelwood Cliffs, New Jersey: Prentice-Hall.

Koutsopoulos, C. K., Kotsanis, Y. C. 2014. School on Cloud: Towards a paradigm shift. Themes in Science and Technology Education, 7(1), 47-62, http://earthlab.uoi.gr/theste/index.php/theste/article/view/147/96

Lee, J., Bednarz, R. 2009. Effect of GIS Learning on Spatial Thinking, Journal of Geography in Higher Education, 33(2), 183-198

Lindner-FallY, M., Zwartjes, L., 2012. Learning and teaching with Digital Earth–Teacher training and education in Europe. In: Jekel, T., Car, A., Strobl, J. & Griesebner, G. (eds.), GI_Forum 2012: Geovisualization, Society and Learning, 272-282, http://gispoint.de/fileadmin/user_upload/paper_gis_open/537521027.pdf

Liu, S., Zhu, X. (2008). Designing a Structured and Interactive Learning Environment Based on GIS for Secondary Geography Education, Journal of Geography 107: 12–19.

Michel, E., Hof, A., 2013, Promoting Spatial Thinking and Learning with Mobile Field Trips and eGeo-Riddles, Jekel, T., Car, A., Strobl, J., Griesebner, G. (eds.), GI_Forum 2013: Creating the GISociety, 378-387. Berlin, Wichmann Verlag

National Academy Of Sciences. 2006. Learning to Think Spatially-GIS Across the K-12 Curriculum. Washington, D.C.: National Academy of Sciences.

Newcombe, N.S., Shipley, T.F., 2015. Thinking about spatial thinking: New typology, new assessments. In: Gero, J.S. (ed.), Studying visual and spatial reasoning for design creativity, 179-192. Springer Netherlands.

NRC, 2006. Learning to think spatially: GIS as a support system in the K-12 curriculum. National Academies Press.

Otero, A. J., De lazaro Y Torres, M.L. 2017. Spatial data infrastructures and geography learning. European Journal of Geography Volume 8, Number 3:19-29.

Perdue, N. and Lobben, A., 2013. The Challenges of Testing Spatial Thinking Skills with Participants who are Blind or Partially Sighted. Sharing knowledge, In: Reyes Nuñez J. J.. Sharing knowledge. Joint ICA Symposium, http://lazarus.elte.hu/ccc/2013icc/skproceedings.pdf#page=112

Scholz, M.A., Huynh, N.T., Brysch, C.P., Scholz, R.W., 2014. An evaluation of university world geography textbook questions for components of spatial thinking. Journal of Geography, 113(5), 208-219.

Schulze, U., Gryl, I., Kanwischer, D. 2012. A Competence Model for Spatial Citizenship education, SPACIT Project, http://www.spatialcitizenship.org/media/WP2_report_D2_1-final_.pdf

Schulze, U., Kanwischer, D., Reudenbach, C., 2013. Essential competences for GIS learning in higher education: A synthesis of international curricular documents in the GIS&T domain. Journal of Geography in Higher Education, 37(2), 257-275.

Schulze, U., Gryl, I., Kanwischer, D. 2014. Spatial Citizenship: Creating a Curriculum for Teacher Education, 230-241: In: Vogler R., Car. A., Strobl J. & Griesebner G. (eds.), Geospatial Innovation for Society, Berlin, Wichmann

Schultz, U., Gryl, I., Kanwischer, D., 2015. Spatial Citizenship education and digital geomedia: composing competences for teacher education and training. Journal of Geography in Higher Education, 39(3), 369-385.

Shin, E.E., Milson, A.J., Smith, T.J., 2015. Future Teachers’ Spatial Thinking Skills and Attitudes. Journal of Geography, November, 1-8.

Stoltman, J., De Chano, L. 2003. Continuity and change in geography education: Learning and teaching. In R. Gerber (ed.), International handbook on geographical education, 115–137. Dordrecht: Kluwer

Tsou, M.H., Yanow, K. 2010 Enhancing General Education with Geographic Information Science and Spatial Literacy, URISA Journal, 22 (2), 45-55

Zwartjes, L., 2014. The need for a learning line for spatial thinking using GIS in education, In de Miguel González, R. & Donert K. (eds.), Innovative Learning Geography in Europe: New Challenge for the 21st Century, 39-62, Cambridge, Cambridge Scholars Publishing

Zwartjes, L., De Lazaro Y Torres, M.L., Donert, K., Buzo Sanchez, I., De Miguel Gonzalez, R., Wołoszyńska-Wiśniewska, E. 2017. Literature review on spatial thinking. GI Learner project, www.gilearner.eu.