The need for a learning line on spatial thinking using GIS in education

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ABSTRACT

Spatial thinking/literacy in education should be a fixed value in addition to other such as linguistic and mathematical thinking. It is part of the everyday life. As research showed one of the best tools to introduce spatial thinking in education is geography. It offers all the tools for the three components of geography: skills, subject matter and perspectives.

But nevertheless the introduction and use of GIS in education is not a success. Researchers have described many reasons, among others the lack of education standards on the use of GIS in the curriculum.

Therefore the Digital Earth project creates a benchmark with learning outcomes through the educational primary and secondary curriculum. To make it practical a learning line – including an increasing level of complexity – in using GIS should be developed.

Key words:
GIS, spatial thinking, spatial literacy, education, learning outcomes, skills, competences, learning line

1 SPATIAL THINKING & SPATIAL LITERACY IN GEOGRAPHY EDUCATION

Today education is overwhelmed with all kinds of literacy: language literacy, mathematics literacy, computer literacy, technological literacy, science literacy, critical literacy, social literacy, relational literacy and many more. So what is so special about the need of spatial literacy?

Spatial literacy is defined as a set of abilities related to working and reasoning in a spatial world, like the ability to communicate in the form of a map, understand and recognize the world as viewed from above, recognize and interpret patterns, know that geography is more than just a list of places on the earth's surface, see the value of geography as a basis for organizing and discovering information, and comprehend such basic concepts as scale and spatial resolution (Goodchild, 2006).

The National Research Council formulates in their standard work ‘Learning to think spatially’ (Down et al., 2006): a spatially literate person has following characteristics:

- He has the habit of mind of thinking spatially – he knows where, when, how and why to think spatially,
- He can practice spatial thinking in an informal way – he has deep and broad knowledge of spatial concepts (such as distance, direction, scale, and arrangement and representation (maps, 3D-models, graphs...),
- He can adopt critical stance to spatial thinking and evaluate quality of spatial data, he can use spatial data to construct, articulate.

Spatial thinking is integral to everyday life. With the use of online mapping tools, GPS and car navigation the general public has become aware the possibilities of spatial data. And it is the concept of space that makes spatial thinking a distinct form of thinking. It is a basic and essential skill that can and should be learned, besides other skills like language, mathematics and science.

According to the National Research Council (Down et al. 2006) thinking spatially entails knowing about

- Spatial concepts – Different ways of calculating distance, coordinate system and the nature of spaces in two and three dimensions. It includes also relative location, concepts of adjacency, intersections and regions.
- Spatial representation – The relationship among views: orthogonal versus perspective maps, the effect of projections, the principles of graphical design (semiology, Figure 2).
- Spatial reasoning – Different ways of thinking about shortest distances, the ability to extrapolate and interpolate, estimate the slope of a hill from a map of contour lines...

For Michel & Hof (2013, Figure 1) it is exactly the links among these three that give spatial thinking its power of versatility and applicability.
Kerski (2008) summarizes spatial thinking as the ability to study the characteristics and the interconnected processes of nature and human impact in time and at appropriate scale. In fact this is real geography: to be able to think critically about the earth, the activities of people and the interaction between the two. Thinking spatially is more than knowing where things are located, it’s about asking geographic questions: why there, how originated and what if...

Bednarz and Lee (2011) conclude in their spatial thinking ability test (STAT) that spatial thinking is not a single ability but comprised of a collection of different skills, whereby following spatial thinking components emerge: map visualization and overlay, identification and classification of map symbols (point, line, area), use of Boolean operations, map navigation and recognition of spatial correlation.

Geographic skills provide necessary tools and techniques to think spatially. They enable to observe patterns, associations, and spatial order. “Geographic representations ... are essential because they assist in visualizing spatial arrangements and patterns” (National geography Standard, 2012).

The US Department of Labor developed in 2010 a Geospatial Technology Competency Model (Figure 3), “developed by researching and analysing publicly available resources, existing skill standards, competency-based curricula and certifications to provide an employer-driven framework of the skills needed for success in geospatial technology” (United States Department of Labor, 2010).

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**Figure 1**: The concept of spatial thinking (Michel & Hof, 2013)

**Figure 2**: An incorrect use of semiology can give strange results (source: http://wiki.ead.pucv.cl/index.php/Archivo:02_ejemplo_cartografia_penademuerte_chernoff.jpg)

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The concept of spatial thinking is introduced, followed by an example of an incorrect use of semiology. The text elaborates on the components of spatial thinking, emphasizing the necessity of geographic skills for spatial reasoning. The role of the US Department of Labor in developing a competency model is also discussed.
Competency models offer job seekers or students an opportunity to learn what it takes to enter a particular field. For this competency model at the level of ‘Academic Competencies’ geography is mentioned as “Understanding the science of place and space. Knowing how to ask and discover where things are located on the surface of the earth, why they are located where they are, how places differ from one another, and how people interact with the environment.” (United States Department of Labor, 2010). If we look inside the specifications on level of skills and perspectives two concepts are conspicuously present: GIS and spatial thinking (Figure 4).
GIS plays also an important role in acquiring Geographic Information Literacy. Sharing geographic literacy (knowledge about geography) with information literacy (information search strategies, critical evaluation of sources) leads to Geographic Information Literacy (Figure 5): the possession of concepts, abilities, and habits of mind (emotional dispositions) that allow an individual to understand and use geographic information properly and to participate more fully in the public debate about geography-related issues (Miller and Keller, 2005).

![Figure 4: Academic competencies of geography inside the Geospatial Technology Competency Model](http://www.careeronestop.org/competencymodel/)

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![Figure 5: Contextual diagram for geographic information literacy](http://www.careeronestop.org/competencymodel/)

**Figure 5:** Contextual diagram for geographic information literacy (Miller and Keller, 2005)
2 LINKING SPATIAL THINKING TO THE USE OF GIS

When referring to GIS mostly is meant ‘Geographic Information System’: a set of computer technologies that allows visualizing and manipulating geodata in an easy visual method. But GIS can also be called ‘Geographic Information Science’ (Goodschild, 1992), thus also involving a way of methods and ways of looking at the world (Milson, 2012), whereby GIS is used to obtain spatial thinking skills. Freeman (1997) stated ‘changes in technology pervade the pedagogy and methodology of geography’ so with the possibilities offered to use GIS nowadays (free software, available datasets, computers with internet common) we can no longer ignore the use of it in education. Koutsopoulos (2010) mentions two approaches for using GIS in education:

- We can use the powers of GIS to teach geography for it can help us understand our world through both the natural and the man-made manifestations which are the essence of geography
- In teaching with GIS a positive effect can be created on the development of spatial thinking and reasoning.

Thompson (1991) states that GIS is an ‘educational delivery system for improving the student’s knowledge of the world in which she or he lives.’ GIS is able to answer all the questions that knowledge, understanding and application in geography education requires (Koutsopoulos, 2010). Thus “GIS can be defined as the study of the fundamental issues of geographic information, and is often motivated by the need to improve geographic information technologies” (Goodchild, 2011).

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.

Koutsopoulos (2010) developed a conceptual framework for using GIS. For his idea he uses the Geographic Education Standards Project (GESP, 1994), stating that geography is composed of three components: skills, subject matter and perspectives whereby all three are necessary to be ‘geographically informed’ and thus should be examined (Figure 6).

Geographic skills are a series of tools and techniques, including asking geographic questions, acquire and organize spatial information. The purpose is mainly focused on the level of knowing (“where is it?”), although some questions will lead to the process of understanding (“why is it there?”) or even applying (“what if …?”). The subject matter is divided - according to GESP - into six “essential elements”. Most of these refer to the process of understanding.

A geographic perspective is a lens through which geographers look at the world. It involves the ways that knowledge and understanding can be used to solve geographic problems (process of applying). The specific aspect of geography – linking human and physical systems in a spatial lens – provides everything to solve spatial problems by active participation.

Geographic skills, subject matter and perspective correspond to the processes of knowing, understanding and applying: by “learning the concepts and vocabulary of geography (knowing) students may begin to think about what they mean (understanding) and apply to real problems (applying)” (NAEP Geography Consensus project, 2010).

Knowing is in spatial terms expressed by the questions ‘What is it?’ and ‘Where is it?’, in GIS this means processing spatial data. Understanding is expressed by questions such as: ‘Why is it there?’; ‘What has changed?’, ‘What is the pattern?’, ‘What is the interaction?’, in GIS this is spatial analysis. Applying is expressed by the question ‘What if …?’ to solve spatial problems, in GIS this means planning.
Koutsopoulos (2010) linked the 3 GIS processes with the questions and the five themes of geography – created by the Joint Committee on Geographic Education (1984): location, place, relationship with places, movement, and region (Figure 7). His framework shows very clearly the impact and importance of GIS in answering the questions on the level of the three processes. He results that “GIS can serve as an unique educational tool in which the manipulation, analysis and presentation of spatial data can support the teaching of geography” (Koutsopoulos, 2010).
More specific typical spatial thinking skills are enhanced using GIS. By involving student activities using GIS “students not only learn by hearing and seeing, they also have the ability and opportunity to personally apply the knowledge using higher-order skills such as problem solving and synthesis” (Sanders, 2002) In order to foster such skills teachers and students may need to work in new ways such as through enquiry based methods and problem-based learning.

The approach developed by Koutsopoulos follows one of the four GIS schools described by Kemp (1992, quoted in Sui, 1995, Figure 8): GIS as an enabling Technology for Science, arguing that GIS is not an goal in itself but a means to use spatial thinking skills.
Figure 8: Four schools of thought about the relationship between geography & GIS (Kemp. et al, mentioned by Sui, 1995)

Two of the four schools describe the ideal vision for secondary education:
- The first schools stating that Geography is uniquely suited as the home discipline of GIS. It simply automates the tasks geographers have been doing for several thousands of years, and aims at a full integration of GIS into all aspects of geography curriculum.
- The third school seeing GIS as the tool to support scientific inquiry as ultimate goal in a variety of disciplines, thus GIS as enabling tool for science.

Both put the emphasis of the course content on application – GIS as a tool, whereas the two other schools are focusing on the technical aspects of GIS.

3 INTEGRATING SPATIAL THINKING – USING GIS – IN EDUCATION

The introduction of GIS in education has been argued by three complementary rationales that correspond to GIS’s strengths:
1) The educative rationale: GI Science and GIS support the teaching and learning of geography.
2) The place-based rationale: GIS is the ideal tool to use to study geographical problems at a range of scales.
3) The workplace rationale: GIS is an essential tool for knowledge workers in the twenty-first century.

Van Leeuwen and Scholten (2009) see an added value of using GIS based on 5 senses:
• Sense of reality: using realistic data – e.g. of the own environment – makes abstract spatial theories become real
• Sense of urgency: by using realistic data and thematic items students get interested.
• Sense of experience of having influence: using GIS students get the opportunity to visualize a todays and tomorrows landscape, influenced by (their) own decisions
• Sense of fun: people learn more easily when they are enjoying what they are doing and using GIS is fun when the tools are easy, interesting data is available and the case study is exiting.
• Sense of location: by using GIS in combination with GPS routes, tracking and tracing games or doing field work gives an extra dimension, location (x,y,z coordinates) becomes an exciting thing to explore.

These arguments have not appealed to large numbers of teachers however. According the research of Bednarz and van der Schee (2006) the main reasons are:
• In teacher training (pre-service and in-service) GIS is not a core item.
• Non-geographers, leading to teachers with limited pedagogical content knowledge, resulting in fewer teachers recognizing the potential opportunities GIS offers to teach geography content and skills, teach more and more geography.
• The curriculum doesn’t include or impede adoption to include GIS.
• The availability of free data and easy-to-use software.
• The attitude of teachers. It seems difficult to persuade teachers to use new technologies, certainly if they are highly technical demanding and if teachers are not fully convinced of the effectiveness and added value.

They made 3 recommendations,
1) Address the key internal issues related to GIS implementation: teacher training, availability of user friendly software, ICT equipment in schools
This was a matter of developing easier to use software with data access. As Goodchild (2011) concludes in his analysis of GIS software programs: “the GIS user interface remains complex, hard to learn and use, and lacking in any consistent conceptual or theoretical framework.”

A lot of progress is made. There are free GIS viewers (no need to install software) or open source full GIS software programs available. Schools are nowadays well equipped with computers and a high speed (mobile) Internet. As a result of the INSPIRE directive more and more governments are offering datasets (for free) or provide open access to database servers. In different countries specific educational GIS-frameworks have been developed, like EduGIS in the Netherlands (van der Schee, J. et al., 2006), the Pairform@nce Project in France (Genevois, 2011) or PaikkaOppi in Finland. These learning environments offer a simplified viewer – mostly inside a browser – with content that fits into the existing national curriculum.

The 2011 digital-earth.eu network survey on teacher training (Lindner-Fally and Zwartjes, 2012) concluded that only 45% of the participants have geoinformation/GIS included in teacher education/training in their countries, 55% of teachers have to be provided with teacher education/training courses and information on available offers (Figure 9).

The impact of a continued teacher training is important. After attending a teacher training in digital geomedia the teachers focus their work on the learned technologies, the more and longer trainings the attended the more and higher the level of integration (Bartocheck and Carlos, 2013).

2) Use a community of learners approach.
A community of learners means bringing together within a school or school region all involved and crucial stakeholders in the educational process. Together they reflect and act upon best practices. Although this is a much praised and effective method, reality shows that certainly in secondary education this is not always working.

The Digital-Earth.eu network has launched in many countries ‘Centre of Excellence’. These centres will help building up the community of geomedia learners, e.g. by collecting and disseminating good practice examples, organizing informal sessions with teachers.

3) Institutionalizing GIS into curricula, making sure that it is aligned with significant general learning goals like graphicity, critical thinking and citizenship skills.
This is also mentioned by The National Academy of science (Downs et al. 2006) who stated as one of the primordially recommendations the development of spatial thinking standards and curriculum material.
Favier (2013) describes five ways on how GIS can be integrated in secondary education (Figure 10). Teaching and learning about GIS 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 10:** 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.

Without questioning the importance of this we must nevertheless try to generate a more continuous integration of GIS in education, using all five ways. The Irish pilot project ‘GIS into schools’ is a good attempt to create and test curriculum materials for teaching GIS principles and practice (Tschirner and O’Brien, 2006). They indicate – just like Koutsopoulos (2010) and Favier (2013) - to achieve an overall integration of GIS that students first need to learn about GIS (theory and practice) and then apply this knowledge to learn with GIS. The Irish example used several geography curriculum based topics and is thus not really integrated over the different years of the curriculum.

### 4 CREATING GIS LEARNING OUTCOMES THROUGH EDUCATION

The digital-earth.eu project examines the use of geographic media in schools and teacher education. Geo-media is the visualization of information from different media sources and is concerned with digital content and its processing based on place, position and location. Many geographic media are widely used for navigation and routing purposes. The digital-earth.eu network seeks to provide broad access to resources, promoting innovation and best practice in the implementation of geo-media as a digital learning environment for school learning and teaching. The goal is to raise the profile of learning with digital earth tools and resources. The network encourages the sharing of innovative practices and rewards organizations and individuals displaying ‘excellence’.

Special Interest Groups (SIGs) work on following topics
1. Resources, technologies and geoinformation
2. Learning and teaching with geo-media and geoinformation
3. Teacher Education and Training in geo-media
4. Curriculum aspects and geodata.

Developing spatial literacy assumes the availability of digital earth tools, which allow students to interact with geoinformation, to answer questions and critically reflect using a geographic approach. They can also clearly communicate the results to a broader audience.

The Special Interest Group 3 of the Digital-Eath.eu network (Woloszynska et al. 2013) see the importance of introducing GIS (use of geo-media) for three competences (Figure 11):
Personal competences
Developing spatial literacy assumes interaction with geoinformation. A geographic approach is necessary to answer questions critically and constructively. Therefore, teachers must understand basic geographic concepts and be able to support students’ learning needs. Employability is enhanced by geo-media skills.

Social competences
Education for active citizenship equips people with the content knowledge, skills and understanding to play an effective role in society. They become interested in controversial issues and engaged in discussion, debate and decision-making. Therefore, education for spatial citizenship plays an important role for the learning process. To enable teachers to bridge the technological gap between students and themselves, they need to use geo-media in the classroom to allow learners to explore real world issues and encourage lifelong learning strategies.

Professional competences
Geo-media brings the real world into the classroom. Constructive and active learning practices like problem solving, project-based learning, fieldwork strategies and enquiry approaches are favoured and will help them to face future challenges.

Therefore, teachers must understand basic geographic concepts and be able to support students’ learning needs. Taking in account the different levels of age and education, teachers must be enabled to apply different methods and tools in the respective learning environments.

To help a benchmark has been created¹, indicating the competencies needed to reach spatial literacy.

Competencies:

- Spatial thinking:
  - To know concepts of spatial thinking
  - Be able to use tools of spatial representation,
  - To apply processes of reasoning (Where is it? Why is it there? What if it was somewhere else? Making informed decisions and defend personal points of view)

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¹ This benchmark statement has been produced as a result of the digital-earth.eu COMENIUS network SIG 3 (Teacher education and teacher training) meeting in Brugge, Belgium in October 2011

[www.digital-earth.eu](http://www.digital-earth.eu)
Pedagogic and didactical skills for the use of digital earth tools in school
• Ability to use spatial skills in real world problem-solving context
• Understanding complex and changing interrelationships
• Awareness and understanding for the digital earth concept
• Ability to use digital earth tools (also technological skills)
• Lifelong learning competencies: ability to find training opportunities, time management, planning competency, communication competencies
• Being able to identify and evaluate resources
• Social learning:
  o Being able to work with others – teamwork
  o Use professional social networks (virtual and face-to-face)

In order to prepare teachers to effectively implement digital earth in their practice, teacher training and teacher education needs to appropriately prepare teachers for different levels of education.

**Primary school teachers** need to be able to enable students (year 1-6) to

• Open digital maps and virtual globes on a computer
• Indicate the different parts of digital maps/virtual globes (navigation bar, menu, scale, map window, Figure 12)
• Interpret symbols on digital maps
• Work with digital maps and 3D representations of the world:
  o Find significant locations (their home, school or town) on a virtual globe
  o Pan, zoom, orientate
  o Make measurements
  o Use the layers to focus on specific features
  o Update maps
• Be aware of generalization levels applied in different zoom levels (e.g. road density)
• Access information efficiently and effectively, evaluate information critically and competently (see maps as manipulated representations created by people/organizations with a certain purpose, e.g. classification methods, color schemes, map contents)
• Use digital maps and virtual globes for a variety of different purposes

![Figure 12: Primary school pupils should be able to work with digital globes and simple GIS-software](image-url)

**Secondary school (year 7-12)**
In addition to the learning outcomes of primary school, secondary school teachers need to enable their students to

• Know the digital earth concept and its tools
• Understand the basic purpose and application of digital earth to real world problems
• Be able to gather and evaluate information
• Use advanced digital earth tools for learning (starting with Web-GIS, GIS viewers to GIS software)
• Manipulate maps
  o Display information on maps
  o Create own maps
  o Communicate cartographic information

• Understand the construction of digital maps as a representation of the real world
  o The power of maps (reliability of data, classification and color schemes)
  o Topology: points, lines, polygons
  o Layers
  o Database

• Know about the professional use of GIS and other digital earth tools
• Gather information from data resources or through fieldwork activities (use GPS devices, mobile applications)
• Use digital earth tools for investigation/research
  o Interpret content
  o Identify and ask significant questions that clarify various points of view and lead to sustainable solutions
  o Frame, analyse and synthesize information in order to solve problems and answer questions

5 CREATING A LEARNING LINE IN GIS

Taking in account the age and level of complexity the best option is to work with a learning line in education, thus covering at least the six years from age 12 to 18, but even better starting in primary education.

A learning line is defined here as the educational term that refers to the construction of knowledge and skills throughout the whole curriculum. This learning line reflects an increasing level of complexity, ranging from easy (more basic skills and knowledge) to difficult.

As an example the Flemish geography curriculum (LEERPLANCOMMISSIE AARDRIJKSKUNDE (2010) defines these learning lines in the secondary geography curriculum:

<table>
<thead>
<tr>
<th>5 learning lines:</th>
<th>Fieldwork</th>
<th>Working with images</th>
<th>Working with maps</th>
<th>Working with statistical material</th>
<th>Creation of knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Perception – knowledge of facts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>Analysis – selection of relevant geographic information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3</td>
<td>Structure – look for complex connections and relationships</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Level 4</td>
<td>Apply – thinking problem solving</td>
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</tr>
</tbody>
</table>

Some existing examples:

Learning line maps
  • Level 1: Recognize and name the elements of the legend on the map. Distract the scale.
  • Level 2: Retrieve from the map those geographic elements that are relevant within a research context.
  • Level 3: Classify and relate elements on the geographic map.
  • Level 4: Interpret a map.

Learning line images
  • Level 1: Describe the image
  • Level 2: Retrieve from the image those geographic elements that are relevant within a research context
  • Level 3: Examine the correlation between the different elements by using various techniques (map studies, surveys, statistics ...).
  • Level 4: Make up a synthesis of the image

When applying the learning line concept to the learning outcomes (described in the previous section) we get this result:

Level 1: Perception - being able to work with digital maps and virtual globes:
• Open digital maps and virtual globes on a computer
• Indicate the different parts of digital maps/virtual globes (navigation bar, menu, scale, map window)
• Interpret symbols on digital maps
• Understand the construction of digital maps as a representation of the real world (topology, layers, database)

Level 2: Analysis – selection of the relevant geographic information
• Work with digital maps and virtual globes: find locations, pan, zoom, orientate, make measurements
• Access information efficiently and effectively, evaluate information critically and competently
• Be able to gather and evaluate information from data resources or through fieldwork activities
• Interpret content

Level 3: Structure – look for complex connections and relationships
• Use digital maps and virtual globes for a variety of different purposes
• Identify and ask significant questions that clarify various points of view and lead to sustainable solutions
• Manipulate maps by creating own maps
• Communicate cartographic information

Level 4: Apply – thinking problem solving
• Be aware of generalization levels applied in different zoom levels (e.g. road density)
• Understand the basic purpose and application of digital earth to real world problems
• Use advanced digital earth tools for learning (starting with Web-GIS, GIS viewers to GIS software)
• Frame, analyse and synthesize information in order to solve problems and answer questions

For introduction in the different grades of schools the level would depend on the age. Level 1 should be reached in primary education; level 2 can already be reached in primary – depending of the class group - but must be reached in lower secondary education. Level 3 can be reached in lower secondary – again depending of the class group, but must be reached together with level 4 in upper secondary education.

Another method is the cataloguing of the needed competencies into competencies areas as the basis for a learning line (Woloszynska et al. 2013), whereby teachers need to be able to choose suitable tools to use based on the abilities of their students, their own capabilities and their curriculum.

<table>
<thead>
<tr>
<th>Competence Areas</th>
<th>Primary 6 – 10 y</th>
<th>Lower Secondary 11 – 14 y (In addition to 6-10 y)</th>
<th>Upper Secondary 15 – 18 y (In addition to 11-14 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>understanding / analysing digital geomedia</td>
<td>reading, orientating, combining, interpreting, measuring, comparing, querying</td>
<td>geo processing network analysis spatial analysis</td>
<td></td>
</tr>
<tr>
<td>producing and communicating digital geomedia</td>
<td>collaborative activities, mapping, visualising, sharing, discussing update geo-media, maps, infographics, charts, presentations collect and represent information add information to maps and other geo-media thematic mapping ... at different levels of scale and complexity over the years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>critical use / awareness of digital geomedia in everyday life</td>
<td>awareness of generalization, different zoom levels, perspectives, intentions, manipulated representations, volunteered geographical information (vgi) reflect on content and representation, information rights and ethics identification of digital media in everyday life geomedia as part of decision making</td>
<td></td>
<td></td>
</tr>
<tr>
<td>geographical technology: hardware &amp; tools</td>
<td>GPS, digital maps, virtual globes web mapping</td>
<td>3D representations of the world (DEM) satellite images open geodata online, desktop and mobile GIS</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS

Spatial thinking in education should be a fixed value in addition to other such as linguistic and mathematical thinking. Because of its capabilities GIS – Geographic Information System – is inherently an excellent vehicle to obtain the essential spatial thinking skills. The framework developed by Koutsopoulos shows very clearly the impact and importance of GIS in answering the questions on the level knowing, understanding and applying. GIS can serve as a unique educational tool in which the manipulation, analysis and presentation of spatial data can support the teaching of geography.

The introduction of GIS in secondary education is not easy. Most reasons why previous attempts didn’t succeed are overruled by recent developments. But the main reason to persuade teachers is the implementation in the curriculum. The benchmark created by the Digital Earth project SIG 3 is a first step. When adding the concept of learning lines we can construct the content depending of the pupil age. With input from others this might lead to a real curriculum reform.

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