Lifelong Learning Programme

GI-N2K – Geographic Information Need to Know

LLP – Erasmus Academic Network
N° 540409-LLP-1-2013-1-BE-ERASMUS-ENW

Integrated analysis of the demand for and supply of geospatial education and training

Results of the GI-N2K Surveys

Towards a more demand-driven geospatial workforce education/training system

GI-N2K – Geographic Information Need to Know

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Relevant Work Package(s) / Task(s):

WP 1 Analysis of demand and supply (Task 1.3)

Short Description:

This report describes the situation in 2014 with regard to the demand for and the supply of education and training in the domain of geographic information ("GI"). It is the outcome of an analysis of the results of two simultaneous internet surveys, directed at two target groups in 25 European countries. The first target group, the demand side, consisted of organisations and companies with a need for geographic information competences. At the supply side the survey was directed at organisations that offer teaching in this field. The analysis focused on three aspects: the awareness and use of the GIS&T BoK, the GI knowledge domain reference document; the possible gap between needed competences and teaching on offer; and the incompleteness of the GIS&T BoK. The conclusions are as follows. Awareness and use of the GIS&T BoK are limited at the supply side and even more limited at the demand side. With regard to a possible teaching gap: indications were found but no conclusive evidence of its existence. The incompleteness of the GIS&T BoK was substantiated by the respondents providing dozens of subjects not included in the first edition. These results are to be used in subsequent work packages of the GI-N2K project, heading for an improved version of the GIS&T BoK in 2016.

Keywords:

Geospatial education and training, demand and supply, teaching gaps, GIS&T BoK awareness & use, content gap

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Executive summary

A new version is needed of the Body of Knowledge for the domain of Geographic Information (GIS&T BoK). It would be an important tool to help achieve a more demand driven education and training system for the GI-workforce in Europe. The current version of the GIS&T BoK is a paper document published in 2006, whereas the new version should be dynamic and up-to-date, easy to use, in line with the constantly evolving technologies. It should reflect recent developments and needs of the public, private and academic geospatial sector in Europe.

Project

A project was commissioned by the European Union to a consortium of 31 partners from 25 countries, its objective being an improved version of the GIS&T BoK, including tools to use and maintain it. The project was named "Geographic information – Need to Know" (GI-N2K). It runs from October 2013 to October 2016. Its first work package was to assess the present situation completed in August 2014.

This report describes the current awareness and use of the GIS&T BoK, as well as the demand for and the supply of education and training in the GI domain. Shortcomings of the GIS&T BoK are a third subject. It is the outcome of an analysis of the results of two internet surveys, held simultaneously in early 2014, directed at two target groups in 25 European countries.

Surveys

The Demand side target group consists of organisations and companies with a need for geographic information competences: private companies, public administration, non-governmental organisations and academic institutions. The survey resulted in 435 useful responses, 77% of which were provided by non-teaching organisations. In addition, 21 interviews were held with key representatives in the GI communities of 7 countries.

At the Supply side the survey was directed at organisations that offer teaching in the GI field. Of the 234 useful responses 90% originated from employees of educational institutes.

Analysis

The analysis of the survey outcomes focussed on three aspects:

- **Awareness and use of the GIS&T BoK**. The relevance of this aspect is that a more demand-driven teaching supply requires the Demand and Supply sides to use the same terminology. And the first requirement for use is awareness;
- **A teaching gap**. The need for more demand driven teaching presupposes that there is a gap between the Demand side need for GI competences and the GI teaching on offer.
- **A GIS&T BoK content gap**. A domain reference document should be up-to-date, covering the newest developments in the width of the domain. Missing subjects will make it harder to have the GIS&T BoK accepted among users and educators. Such acceptance is an important condition for achieving a more demand driven teaching offer.

Awareness and use of GIS&T BoK

From the Demand and Supply survey results, it appeared that awareness of the GIS&T BoK among the survey respondents is less than 50% (Supply side) to 30% (Demand side). The use of the GIS&T BoK is about half that at both sides. At the Supply side the awareness rate is a little better than Masik concluded from her survey in 2010. A number of respondents, aware of the GIS&T BoK, reported not to use it. Their motives varied. At the Demand side, the GIS&T BoK is seen as impractical and too academic. At the Supply side more than a quarter of the 44 aware non-users

indicated to have neither need nor wish to introduce the GIS&T BoK in the way they work. Another quarter (11 respondents) reported organisational obstacles. Less than half of the respondents at the Supply side mentioned shortcomings in content and usability of the GIS&T BoK as reasons for not using the GIS&T BoK.

The teaching gap

The comparison of the demand for GI competences with the Supply of GI teaching resulted in

- A possible teaching gap with regard to “Web” competences;
- A clear teaching gap with regard to “Mobile” competences;
- A possible teaching gap with regard to “Programming” competences;
- A possible need for more teaching in the Knowledge Areas of Organisational and Institutional Aspects, Design Aspects, Analysis Methods and Data Manipulation.

The uncertainty in the results was caused by the low use rate of the GIS&T BoK to describe Demand and Supply. Also, the Supply Survey questions were not intended to produce a complete list of GI courses per teaching organisation. Apart from that, there is a practical dimension. Existing teaching offers that would fit a specific competence need may not fit in the agenda or in the budget of an interested person. So, in reality the gap would be more serious than would appear from a subject based comparison. These aspects make it difficult to assess the teaching gap.

The GI BoK content gap

After publication of the GIS&T BoK in 2006, quite a number of developments took place in the GI domain. A number of them will become more important than they are now. The subject computer programming subject, kept out of the current the GIS&T BoK, already represents an often sought competence. The Demand side and Supply side surveys produced about 50 terms in total of subjects that are missing in the GIS&T BoK. Remarkably, the Demand side list is twice as long as the Supply side list. They only have three terms in common.

Which of these terms should be included in the GIS&T BoK requires further analysis of their meaning. Other aspects to be taken into account are:

- Geographical extent of the relevance of a term: the relevance could be limited to Europe, as in the case of INSPIRE.
- Terms could originate from other knowledge domains. In the future version the question should not be if those terms should be included or excluded, but how to connect to them.

This work shall be taken up in second work package of GI-N2K.

Perspective

In Europe the GIS&T BoK has not yet become a well-known and accepted reference for the GI-domain, in spite of its potential. Lack of maintenance and insufficient user friendliness are not helping. The intended improvements and its projected use for a more demand driven GI teaching might well make the difference.

1 Introduction

1.1 Introducing the GI-N2K project

As an aspect of its ambitions for the future, the European Commission aims for a better match (Vasilliou 2014) between the needs of employers for competent employees and the teaching on offer that should produce those competences.

One of the knowledge fields to which this objective applies is the use of geographic information, "GI" for short.

The project "Geographic Information: Need to Know" (GI-N2K) was commissioned to a consortium of 31 organisations from 25 countries in Europe, led by the university of Leuven in Belgium. The project, with a duration of three years, started in October 2013.

Objective of the project is to improve the Geographic Information Science and Technology Body of Knowledge (DiBiase et al. 2006), a description of the knowledge field, hereafter referred to as "GIS&T BoK". Appendix 1 provides an overview of the two highest levels of the domain description: 10 Knowledge Areas and their constituent Units.

The motive for improvement is the assumption that the improved tool will better support matchmaking between employer demands (the market) and teaching supply (training and education) in the GI field. To achieve that, the content of the GIS&T BoK will be included in a software tool with facilities for curriculum design and for job description.

The central position of the GIS&T BoK in this project is based on its potential to connect teaching with jobs by means of specification and codification of knowledge parts selected from this Body of Knowledge. If both teachers and employers would use the same vocabulary, i.e. GIS&T BoK, then the GI capabilities required for a job would be better comparable with the contents of GI-teaching, which should enable a better match between Demand and Supply.

1.2 Problem statement

What, then, is the problem with the GIS&T BoK that it should be improved? In order to be useful as a reference for the GI-domain and as a common vocabulary for both the Demand side and the Supply side, the GIS&T BoK should fulfil some requirements. With respect to its coverage of aspects of the GI field and developments therein, the GIS&T BoK should

- be as up-to-date as possible and as complete as possible
- have a place for regional communal standards (e.g. as in the INSPIRE directive)
- have good usability (e.g. allowing queries)
- be flexible, i.e. allowing changes and updates
- be well known and accessible

The current edition of the GIS&T BoK, which is a book printed on paper, has some shortcomings with respect to these requirements:

- The GIS&T BoK has not been updated to follow developments in the field after 2006;
- The GIS&T BoK is incomplete. Important areas of the field are not well represented. Reinhardt proposed extra Knowledge Areas like Spatial Data Infrastructures and Application Programming (Reinhardt, 2011);
- The GIS&T BoK has an inflexible knowledge item hierarchy, fixated in a paper document; Ahearn et al. (2013) outlines an ontology-based web-version the GIS&T BoK. The proposed improvements are indicators of the shortcomings of the first version;

- The paper document does not allow any electronic approach of its contents. The release of the GIS&T BoK in PDF format in 2012 as a free download was an improvement because that enabled word searches. It also simplified obtaining the document. However, more is needed. Painho et al. proposed a software prototype to support curriculum development (Painho et al. 2008);
- Awareness of the existence of the GIS&T BoK among the potential users in Europe is limited, as reported by Masik (2010) about awareness among European universities. About awareness in Europe among professional GI users nothing is known.

From the above it was concluded that the central issues are:

- Awareness and use of the GIS&T BoK;
- The relationship between the need for GI competences and the GI teaching on offer;
- What is missing in the contents of the GIS&T BoK.

The GI-N2K project aims to address the above mentioned shortcomings. The work is organised in a number of packages.

1.3 GI-N2K work packages

The project consists of eight work packages (WP). Four of those (WP 1-4) are devoted to the GIS&T BoK and its improvement. WP1 produces an assessment of the present situation with regard to the above mentioned central issues. WP2 focusses on revision of the GIS&T BoK content. WP3 is about rebuilding the GIS&T BoK as a dynamic environment, the result of which will be disseminated, tested and validated in WP4.

The remaining work packages contain activities around Quality Assurance (WP5), Dissemination (WP6), Exploitation & Sustainability (WP7) and Management of the project (WP8).

This document reports about the results of WP1.

1.4 Components of work package 1

The WP1 results include:

- An overview of awareness of the GIS&T BoK and its use among respondents of the surveys in at least the 25 European countries that participate in the project;
- A comparison of employer's demands with the supply of GI teaching;
- An overview of subjects to supplement the GIS&T BoK with.

It is based on reports on the outcomes of surveys about the Demand side (Wallentin et al. 2014) and the Supply side (Rip et al. 2014), that were held early in 2014 as part of this work package. These reports are summarised in the next sections.

1.5 Survey reports

The contents of the two survey reports mentioned in the previous section are summarized below.

1.5.1 The Demand side

More than 1000 responses were received from countries throughout Europe. For the analysis only the subset of fully completed questionnaires (n=435) was used. Its response is shown in Figure 1.

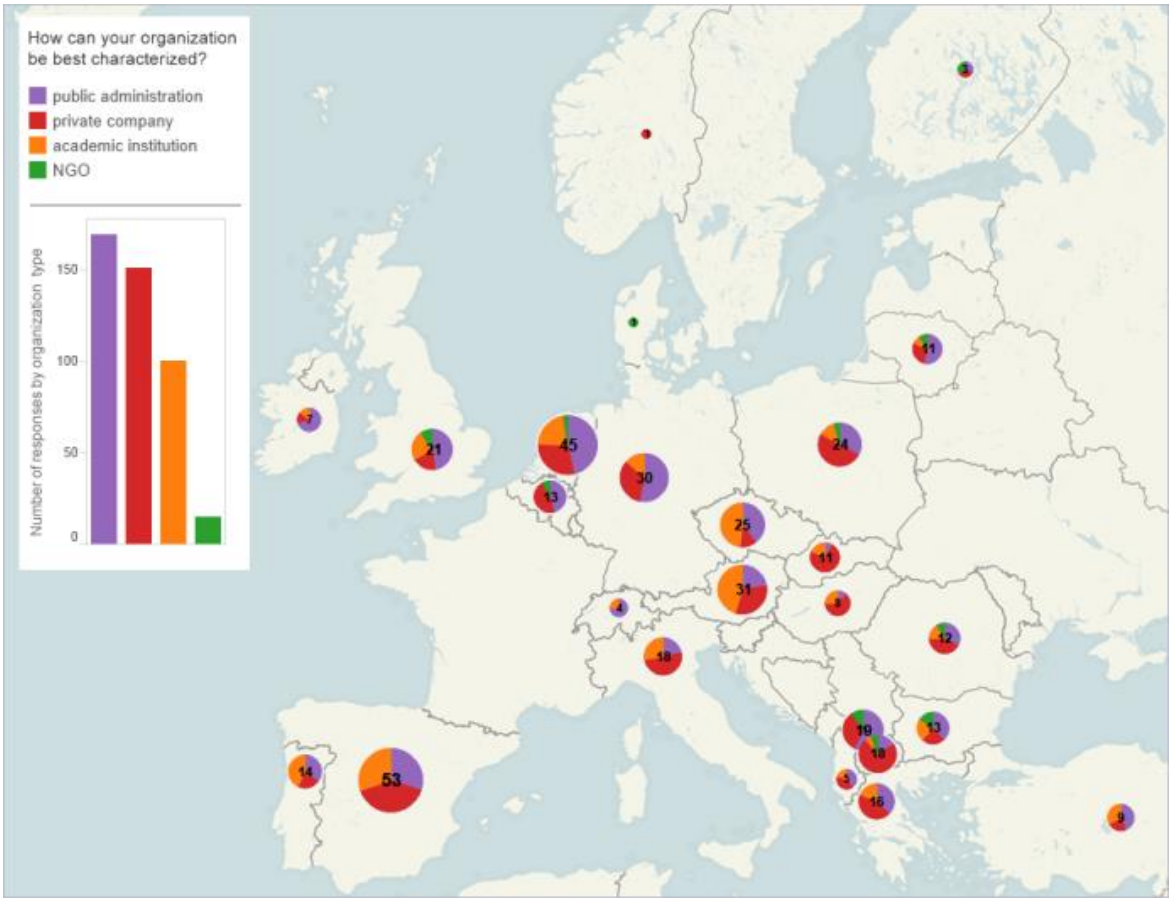


Figure 1 Number, origin and respondent type of fully completed Demand questionnaires

Shift of focus

The survey results indicate an accentuated shift in focus from the present emphasis on map making and local database handling towards online and mobile technologies based on spatial data infrastructure with a massive amount of data to be integrated. Application development is expected to play an increasing role in customising individual solutions. The survey results showed a strong interest among GI users in obtaining the respective competences.

Relevance of the GIS&T BoK Knowledge Areas

The GI user evaluations of the relevance of the current GIS&T BoK content for their professional work are varied. Knowledge Areas *Geospatial Data* and *Cartography and Visualization* were considered most relevant, whereas *Geocomputation* methods had the lowest rating. The Knowledge Area *GIS&T and Society* had the highest respondent numbers in the "somehow relevant" category, an indication that GI is still primarily seen as a technical discipline.

Missing subjects in the GIS&T BoK

The gap analysis points at topics that are not fully covered in the current GIS&T BoK. This includes Programme development, WebGIS, SDI, data acquisition and other 'hot' topics such as big data, augmented reality or CityGML. Also a number of 'learning aims' was identified, referring to competences that respondents would like to obtain or enhance.

Complementary interviews

Twenty one interviews were held to complement the survey findings. They confirmed the above results and embedded the findings in a broader context:

Awareness of the GIS&T BoK among Demand side respondents appears very limited. It is only used for teaching development. This shows that teaching organisations also have a Demand side: they are using GI and they need competent staff. Some Demand side interviewees recognised a certain potential for the GIS&T BoK other than teaching.

With regard to content-related gaps between workforce demands and GI education, the discussions largely evolved around the integration of 'geo' with 'IT', where a general lack of IT-related competences of the workforce was stated.

1.5.2 The Supply side

Response

Out of a total of 264 responses, there were 234 valid ones from 28 European countries to the Supply survey (Fig.2). The countries with the highest response numbers were Spain and Poland.

Of the 234 respondents from 171 organisations (146 of them being universities), 90% was affiliated to an educational institute, 5% to a public authority, 3% to a private company and 2% (4 persons) to a Non-Governmental Organisation. The roles of the respondents were as follows: 77% teaching staff, 13% study programme manager, 4% study programme board and 3% study consultant. The remaining 3% reported to be in an 'Other role'.

Each of the 234 valid response specified 1 -3 existing courses (on average: 1.8 course) and 1-3 intended courses (average: 0.6). This resulted in 427 specified existing courses and 134 specified intended courses.

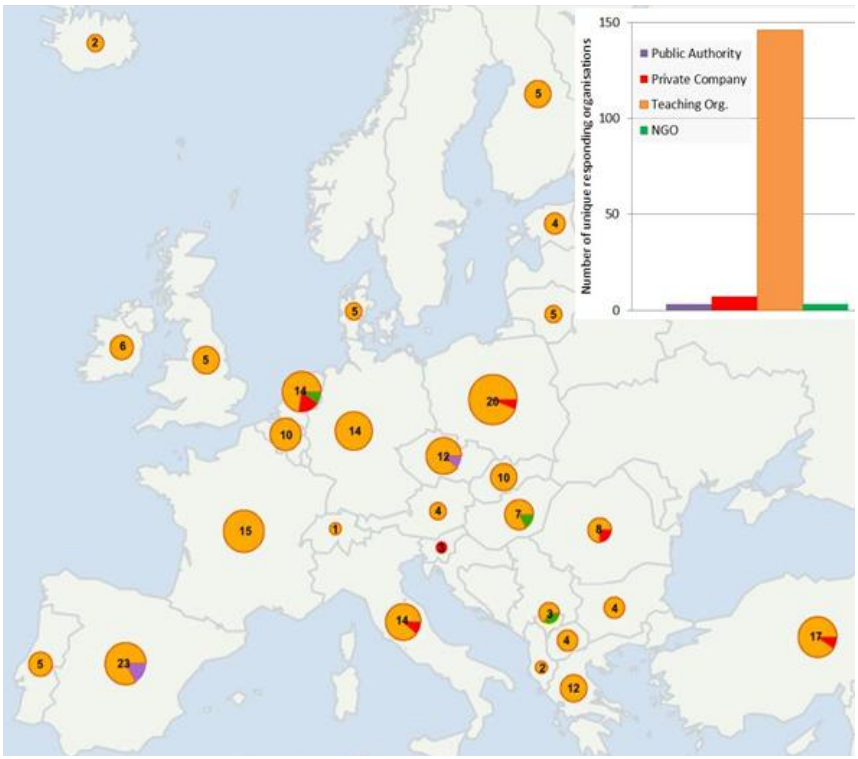


Figure 2 Number, origin and type of responding organisation to the Supply survey

Teaching level

To specify the teaching level, the European Qualification Framework (EQF) levels were used. A specification of the Framework levels is provided in the official Recommendation of the European Parliament (European Parliament et al., 2008). In short, EQF provides a number of country independent qualification levels. Diploma's and other certificates from the education and training system in a European country could be linked to the appropriate EQF level. That would make the merits of the diploma recognisable in European countries with another education system.

In the Supply survey only the EQF levels 4 to 8 were used because they represent tertiary education. These levels are: EQF4: vocational, EQF5-6: professional, EQF7: academic and EQF8: doctorate.

Of the 427 specified existing courses, the majority (48%) is on the EQF level 7 (BSc/MSc), whereas 43% is taught at EQF level 5-6 (professional Bachelor/Master).

Of the 134 specified intended courses, the majority (68%) is on EQF level 7, whereas 21% of the intended courses will be taught on EQF level 5-6.

Teaching content

With regard to teaching content, the Knowledge Areas most referred to for specifying existing GI-teaching are: Analysis Methods, Geospatial Data and Cartography and Visualization.

With regard to the content of intended teaching in the next two years, the most popular Knowledge Areas are Data Modeling, Analysis Methods and GIS&T and Society. This might indicate a shift in teaching content emphasis.

GIS&T BoK awareness and use

A precondition for using the GIS&T BoK is being aware of it. More than half of the respondents reported to be not aware of the GIS&T BoK. Almost a fifth is aware of the existence of the GIS&T BoK, but is not using it. Motives for not using the GIS&T BoK were provided by 44 respondents. The 39 useful ones were categorised as follows:

Neither need nor wish to use the GIS&T BoK: 13x, 8 by teaching staff, 5 by study programme manager

- Organisational reasons: 11x, 9 by teaching staff, 2 by study programme manager
- GIS&T BoK content shortcomings: 8x, all by teaching staff
- Awareness too recent: 5x, 3 by teaching staff, 2 by study programme manager
- GIS&T BoK usability problems: 2x, 1 by study programme manager, 1 by 'other' role

Missing knowledge items

A number of subjects emerged from the survey that are missing in the first version of the GIS&T BoK. These are the subjects that are felt missing when developing teaching material or describing teaching content. The majority of the subjects could be categorized under the themes Web services, Data acquisition technology and Modeling. The subjects are candidates to supplement the next version of the GIS&T BoK.

1.6 Structure of this report

A knowledge domain reference can only be relevant when it is widely known and widely used. Then it can play a role in comparing the demand for teaching with its supply. If most of the GI community is aware of it, then it would make sense to use the GIS&T BoK to describe Demand, Supply and their difference: omission and commission, or gaps and overlap. However, being aware of a reference does not automatically lead to using the reference.

The basic assumption of the GI-N2K project is that the GI-competence needs at the demand side are not completely covered by the teaching on offer at the supply side. Therefore, the difference will be referred to as the GI-demand teaching gap.

Adequately describing demand and supply over the years using the GIS&T BoK as a reference requires that GIS&T BoK is kept as complete as possible. If the reference is not kept up to date, it becomes incomplete. This incompleteness will be referred to as the GIS&T BoK content gap.

In line with this reasoning these aspects will be dealt with in the next chapters:

- Chapter 2: GIS&T BoK awareness and use
- Chapter 3: The GI-demand teaching gap
- Chapter 4: The GIS&T BoK content gap

2 GIS&T BoK awareness and use

As the domain of Geographic Information Science and Systems has matured over the last decades, its educational foundation has also evolved. In the USA the University Consortium for Geographic Information Science (UCGIS) developed the GIS&T BoK. This UCGIS initiative was the first comprehensive attempt to provide a domain inventory in a *strictly hierarchical list* of knowledge areas, units, topics and related learning objectives. The intention of the GIS&T BoK initiative was to provide a comprehensive and structured basis for curriculum development. It aimed at allowing the design of adaptable curricula that enable individualised pathways through its 1,660 educational objectives (DiBiase et al., 2007). Further uses were expected to closely link to the geospatial industry, including programme accreditation, professional certification and the design of job descriptions.

The GIS&T BoK has been a point of reference for several authors since its publication in 2006 in the sense that they made proposals for improving the GIS&T BoK. Examples of this were the BoK e-Tool application (Painho & Curvelo 2008) and the extra Knowledge Areas proposed by Reinhardt (Reinhardt 2011). Linking the GIS&T BoK Knowledge Areas to the study load of a course or curriculum, expressed in ECTS (European Credits Transfer System), called "EduMapping", was proposed in (Rip & Lammeren, 2010) and further illustrated in (Rip & Verbree, 2012).

Ahearn et al. (2013) described a plan for a fundamental overhaul of all aspects of the GIS&T BoK. Central issue is the transfer of the GIS&T BoK into a digital environment, with an emphasis on user interaction and connections between knowledge items.

This GI-N2K project was inspired by these publications.

2.1 Demand side interview outcomes

Only 6 of the 21 interview partners were aware of the GIS&T BoK. Only three of them make active use of it (Fig.3). These three work in academia and used the GIS&T BoK in the context of curriculum development.

Some further potential uses were identified by stakeholders outside academia, if '*it was more practical oriented*'. Several representatives from the private sector perceive the GIS&T BoK as '*strongly academic*' and '*way too theoretical*', where private companies '*rather need an easy-to-use and more straightforward tool*'. A suggestion from the academic sector was to use the GIS&T BoK for student self-assessment. A stakeholder from Germany, who represented the public sector, suggested using the updated GIS&T BoK as a foundation for the new competence-oriented salary system in the German public administration.

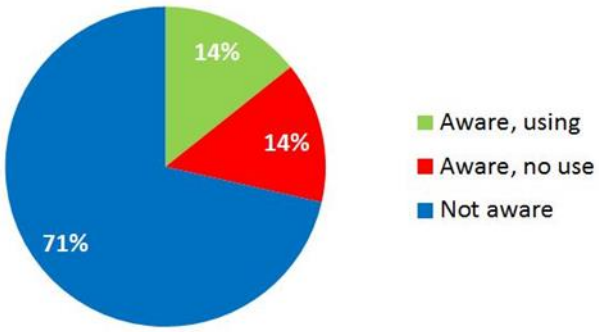


Figure 3 Awareness and use of the GIS&T BoK among interview partners at the Demand side (N=21)

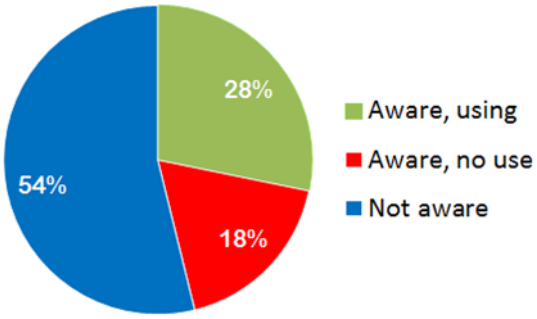


Figure 4 Awareness and use of the GIS&T BoK at the supply side (N=233)

2.2 Supply side

Results of the Supply survey show, that 46% of the 233 respondents is aware of the GIS&T BoK. The percentage of actual users is 28%. Almost a fifth of the respondents (42) is aware of the availability of the GIS&T BoK, but is not using it (Fig. 4). This group is largest among the respondents from Germany (10 out of 14 respondents), the Netherlands (6 out of 14 respondents) and Czech Republic (4 aware non-users out of 12 respondents).

When aware but non-using respondents were asked why they are not using GIS&T BoK, 44 answered. The 39 useful responses were categorised as follows:

- Neither need nor wish to use the GIS&T BoK: 13x, 8 by teaching staff, 5 by study programme manager
- Organisational reasons: 11x, 9 by teaching staff, 2 by study programme manager
- The GIS&T BoK content shortcomings: 8x, all by teaching staff
- Awareness too recent: 5x, 3 by teaching staff, 2 by study programme manager
- The GIS&T BoK usability problems: 2x, 1 by study programme manager, 1 by 'other' role

Only 8 of them were unhappy with the content of the GIS&T BoK. Only 2 indicated GIS&T BoK usability shortcomings. However, 13 answers were in the category of 'No need, no wish' to use the GIS&T BoK, and 11 indicated organisational obstacles. A further 5 had no time to start using it. So, less than half of the answers referred to content and usability of GIS&T BoK as a reason for not using it.

Masik (2010) reported a Not-aware percentage of 60% and a GIS&T BoK use percentage of 22%. Her survey was directed at European universities. The difference with her outcomes might indicate a slight growth trend in GIS&T BoK awareness and use in academic GI circles.

2.3 Conclusions

- The GIS&T BoK is considered useful. This is shown by the fact that – at the Supply side – the users outnumber the aware non-users. At the Demand side, the few remarks in interviews about potential uses also point in that direction. At the other hand, however, the responses from the aware non-users at the Supply-side point at a number of perceived shortcomings. Those responses also made clear that the introduction of an external reference document doesn't always suit teaching staff or teaching programme managers, as the aware non-users at the Supply side commented on *their lack of need for GIS&T BoK* and on *organisational problems* to apply the document.

- The remarks of the Demand-side interviewees about the GIS&T BoK *being too academic and/or theoretical* are in line with the higher use percentage among teaching staff in the Supply survey, of which the majority of respondents is employed at a university.
- The remark of a Demand side interview partner from a private company that the GIS&T BoK *should be more easy to use, more straight forward* refers to its usability. At the Supply side there was little comment on that aspect.

From the responses and comments it is clear that awareness of the existence of the GIS&T BoK is limited. Actual use of the GIS&T BoK is even more limited. This finding leads to two general conclusions.

- *The GIS&T BoK has no role in Europe*.
- *The GIS&T BoK is not sufficiently attractive*.

2.3.1 GIS&T BoK has no role in Europe

Apart from the findings from the Demand and Supply surveys, the conclusion can be further illustrated by the following.

In the United States, the GIS&T BoK has at least two roles with respect to GI competences. It is one of the standards used as a basis for voluntary certification by the GIS Certification Institute (http://www.gisci.org) as a geospatial professional, a GISP (Jackson 2013). In 2011, there were more than 4700 GISPs, mainly in North America (Ibid.).

The second role of the GIS&T BoK is as a complement to the Geospatial Technology Competency Model (GTCM). This is a comprehensive competence model for Geospatial Technology, developed for the United States Department of Labor in 2010 (DiBiase et al. 2010). Jackson (2013) describes the relationship between the GIS&T BoK and GTCM as: "The Geospatial BoK is a comprehensive listing of formal educational objectives related to geospatial information science; GTCM is more generalized and focuses on those competencies and tasks that a geospatial professional may encounter over the span of a career".

The GIS&T BoK has been developed by UCGIS, the University Consortium for Geographic Information Science, a consortium of American universities. In Europe, a similar organisation is AGILE, the Association of Geographic Information Laboratories for Europe. AGILE has 99 members, 83 of them of an educational nature. The low level of awareness and practical relevance of the GIS&T BoK among the members of AGILE is reflected in the organisation's web page where members can describe their GI Education field(s) in a spider diagram with the GIS&T BoK Knowledge Areas. Only six of the 83 teaching members have used this facility, which came into existence in the summer of 2012.

Another illustration of the lack of status of the GIS&T BoK among organisations in Europe was presented at an AGILE pre-conference workshop in France in 2012 called "Views on the Body of Knowledge". As the result of a tiny survey, it appeared that the respondents of organisations EuroSDR (European Spatial Data Research), EuroGeographics (representing the European National Mapping, Cadastral and Land Registry Authorities) and ISPRS (International Society for Photogrammetry and Remote Sensing) said not to be aware of the GIS&T BoK (Crompvoets 2012). However, in another presentation in that same workshop ICA, the International Cartographic Association, did show to be aware of the GIS&T BoK (Kraak, 2012).

In May 2014 a workshop was held in the Netherlands as part of the GeoSkills+ project, a European Commission funded project under DG Education and Culture in the Leonardo da Vinci programme. The project focusses on the mismatch between Europe's geospatial vocational education and training and the geospatial labour market. At that occasion, the President-Elect of the education commission of FIG (International Federation of Land Surveyors) announced that in 2015 FIG will try to improve the educational chain, from the vocational up to the academic level (Rip 2014). There will be a role for the Surveying Body of Knowledge. Although related, this is not the same as the GIS&T BoK (Greenfeld, 2012).

In summary: geo-related organisations in Europe appear to be unaware of the existence of the GIS&T BoK. Hence its use is not a requirement for anything. It has no role. Its potential as a knowledge domain reference seems to have been largely unnoticed. This is remarkable for a region with so many different languages, education systems and

teaching organisations, a common spatial information infrastructure like INSPIRE and an ongoing process to harmonize education systems, i.e. the Bologna process.

2.3.2 GIS&T BoK Attractiveness

If the first version of the GIS&T BoK is not sufficiently attractive, then the next version should be improved. To make the GIS&T BoK more attractive should mean that a next version of the GIS&T BoK offers tools and facilities that better serve the needs of the users than they do now. The improvements should make it worthwhile to overcome the reluctance against acceptance of a new tool that pretends to be better than the present tools, to tackle organisational obstacles and to spend time to familiarize with a new domain reference system and its user interface. Whereas the primary objective of the GIS&T BoK initially was to support curriculum development, the intended improvements should also cater for non-teaching users and employers. Use cases are a way to focus on functionality and interface requirements to embody the improvements necessary in the next version of the GIS&T BoK. In a Work package 1 workshop, held in Spain in June 2014, it was decided to brainstorm in a breakout group about possible use cases, for the benefit of the subsequent work packages. Apart from being based on personal expertise of the participants, a preceding presentation of the prototype software developed for the American BoK2 concept (Ahearn et al. 2013) will also have contributed. The resulting ideas are organised according to perspectives of parties that might benefit from the improved tool.

The perspectives are those of:

- A private company or any other employer of persons with GI competences
- An educational institute or any other organisation offering the teaching of GI subjects
- A Government, as in: the organisation(s) in a country guarding the quality of publicly offered GI-teaching (accreditation organisations), or assessing a person's GI capabilities independent of accredited teaching
- A student, as in: any learner engaged in a GI course, -programme or curriculum
- The scientific field

For each perspective a number of possible use cases was suggested without the intention of being exhaustive. They are listed in Table 1.

Table 1 Suggested use case for the application of the GIS&T BoK

Company perspective

- Job description: which GI-competences are required?
- Job candidates evaluation: determination of difference between GI competences of a job candidate and job requirements;
- Organisation description: where the GI-competences of this organisation are (or should be);
- Staff description: create profile(s) of existing GI competences;
- Assessing the evolution of staff GI competences.

Government perspective

- Accreditation of an organisation's GI teaching programme, based on a description using GIS&T BoK concepts and terminology;
- Certification of a person's GI capabilities by using GIS&T BoK's learning outcomes as a measure for GI competence extent (array of subjects) and depth (cognitive level). Example: the GISP certification by GISCI in the USA http://www.gisci.org/).

Educational institute perspective

- Teaching development: which GIS&T BoK subjects will be taught, aiming at which learning outcomes?
- Description of the offered teaching: a characterisation using concepts and terminology of GIS&T BoK;
- Presentation and visualisation of GI-teaching content;
- Comparison of teaching: using GIS&T BoK concepts and terminology to determine differences between teaching offers;
- Assess transferability and mobility of staff: comparing a staff member's GI competence profile against the GI competence needs in another organisation, maybe in another country.

Student perspective

- Assess own GI-competences;
- Comparison of curricula.

Scientific field perspective

- Describe contents of documents in terms of the GIS&T BoK;
- Promote the GI knowledge field.

A final aspect of improving attractiveness is the GIS&T BoK's completeness. The point of the GIS&T BoK being incomplete and out-of-date has received substance implicitly by the collections of subjects. This will be dealt with in chapter 4 of this report. At the Demand side this came about by asking respondents for subjects they wanted to learn about and what they expected to be important in the future. At the Supply side this was based on what respondents missed to describe their existing teaching and their intended courses.

These subjects should be included in a next version of the GIS&T BoK to prepare it for GI practice in the future. This inclusion would make the GIS&T BoK more complete and by that increase its attraction for potential users.

3 The Teaching gap in terms of the GIS&T BoK

3.1 Definition

The teaching gap is provisionally defined here as the difference between the need for obtaining GI-competences as expressed in the GI using community in an area and the GI-teaching on offer in that area.

3.2 Competences and Knowledge Areas

In the Demand survey, respondents were asked about competences: which competences will become important?, which competences would you like to obtain?. In this chapter, the competences mentioned by the respondents are attributed to a GIS&T BoK Knowledge Area, directly or through one of its components.

'Competence' usually is an umbrella term for demonstrating requisite knowledge and skills as well as appropriate behaviour in a work context (Winterton et al. 2006, p.12). In the GIS&T BoK the Knowledge Areas form the top layer of a three level hierarchy of knowledge items: Knowledge Area – Unit – Topic. At the bottom layer each Topic, representing a single concept, methodology or technique, is defined by a representative group of educational objectives. The objectives are formulated as action verbs, emphasizing student competences at the various cognitive levels: Remember, Understand, Apply, Analyze, Evaluate and Create (Dibiase et al. 2006, p.41).

The aspect of behaviour in a work context was included in the questions and responses of the Demand survey, because respondents were asked about competences for their work situation. Therefore, it is acceptable to attribute competences to a Knowledge Area.

The competence needs at the Demand side were formulated as free text and emerge from the Demand Survey report as a list of 20 keywords, each with a word frequency percentage. A selection of 16 of the keywords in this list was used to compose a word cloud (Fig. 5). The word clouds include the most frequent terms mentioned in the free-text responses of the workforce demand survey, regarding current and future workforce needs as well as individual learning objectives. The terms in the right hand side word cloud represent the competence needs (Wallentin et al. 2014).

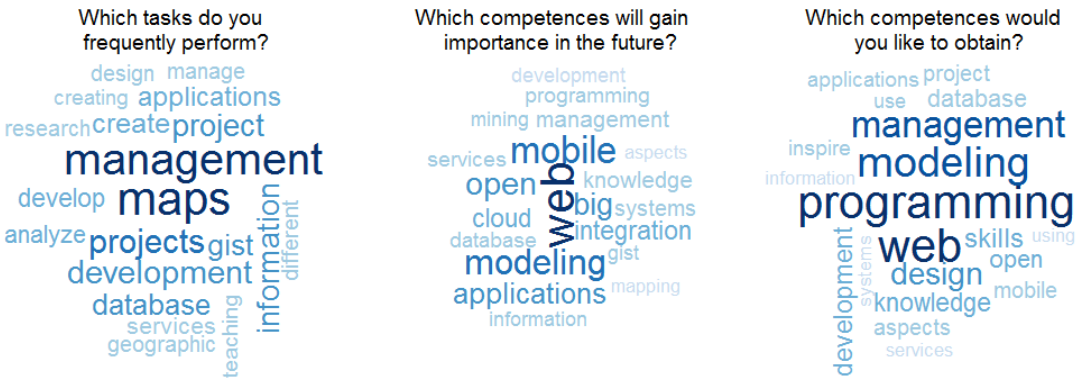
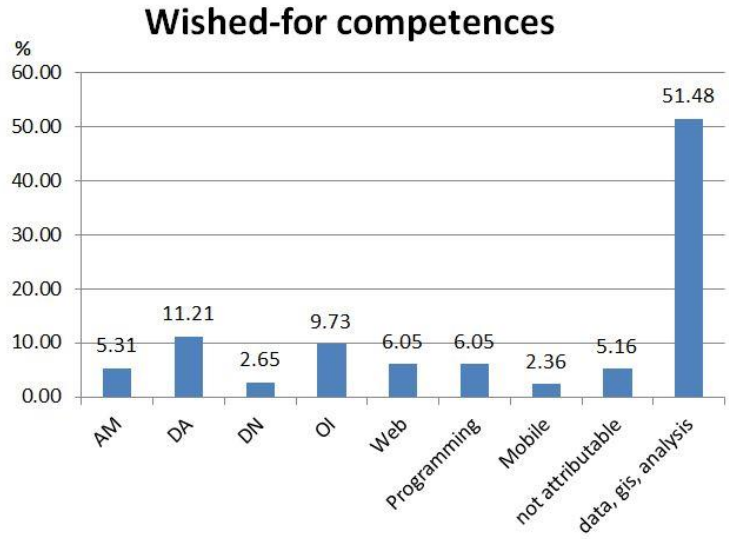


Figure 5 Word clouds with the most frequent terms mentioned in the Demand survey regarding current workforce needs, future workforce needs and individual learning objectives.

From the word cloud term set of competence needs, 9 keywords, together representing 28.9% of all keywords, could be attributed to one of the GIS&T BoK Knowledge Areas. The three competences not present in the GIS&T BoK, "Web", "Programming" and "Mobile", counted for 14.5% (Fig. 6). The remaining five keywords in the word cloud were not sufficiently specific to represent a competence. The attribution was based on the highest occurrence of the

keyword in the GIS&T BoK Unit and/or Topic names. An overview per keyword is in Appendix 3. The words 'data', 'gis' and 'analysis' occurred in the original list of competences the respondent wished to obtain. They are considered core concepts of the domain and for that reason left out of the word cloud.
The keywords in the word cloud are now linked with the GIS&T BoK Knowledge Areas and three separate competence areas outside the present GIS&T BoK are identified. Next, these competence needs can be compared to what the Supply side has on offer. If there are no courses, or just a few, that deal with the needed competence, this difference is a teaching gap. The comparison is in the following sections.



GIS&T BoK abbreviations: *AM - Analysis Methods; DA - Design Aspects; DN - Data Manipulation OI - Organizational & Institutional Aspects*

Figure 6 Number of keywords attributed to areas of competence

3.3 The *Web* competence

In the Supply survey responses 12 existing courses (from respondents in 6 countries) have the term 'web' in their free text descriptions. There were 5 descriptions of intended courses containing the term from 4 other countries. Various combinations occur, like "webgis", "web services", "webmapping", "web tools", "sensor web" and others. In total, 17 courses from 10 different countries were reported. As this amounts to, on average, less than one course per participating country, there seems to be a teaching gap with regard to web competences.

3.4 The *Mobile* competence

Comparison of the attribution result for this keyword with the Supply survey result shows a clear teaching gap. In the Supply survey responses only two universities mentioned their intention to develop teaching with descriptions containing this keyword: "Development of location based mobile applications" (EQF4, 15 ECTS) and "We would like to focus on mobile GIS" (EQF7, 4 ECTS). There is no indication that "Mobile" is a prominent subject in existing teaching, but of course the subject could be dealt with in courses under another name, or in courses that did not surface in the Supply Survey. If that were the case, the gap would be less serious.

3.5 The *Programming* competence

Another teaching gap might be present in this competence area. In the Supply Survey responses, programming as part of the teaching (existing and intended) is mentioned several times:

Existing:

- Geographic Information Systems and Geotelematics, including: programming (EQF7, 30 ECTS) (Spain);
- MSc in GIS and Remote Sensing (EQF7, 30 ECTS), with optional programming (Ireland);

Intended:

- Programming in GIS (EQF5-6, 3ECTS) (Turkey);
- Automation in GIS, programming in Python, vector and raster manipulation and modelling (EQF7, 6 ECTS) (Belgium);

As this subject was mentioned only four times from among 171 respondent organisations, of which two times as "intended", this might indicate a teaching gap.

Another indicator of the existence of a teaching gap was obtained from the 21 interviews that were held to complement the Demand survey: during the interviews "discussions largely evolved around the integration of 'geo' with 'IT', where a general lack of IT-related competences was stated." (Wallentin et al. 2014).

However, as the Supply Survey did only ask for 1-3 existing and/or 1-3 intended courses that best represent the expertise of an organisation in the GI field, there might be a lot more teaching about programming than came to the surface through the Supply Survey. This means that with regard to programming there is no conclusive evidence for a teaching gap.

3.6 Keywords attributed to Knowledge Areas

The keywords attributed to the GIS&T BoK Knowledge Areas represent the actual need for GI competences. These needs probably have a foundation in the respondents of already present GI competences. This foundation is represented by the outcome of the Demand Survey Knowledge Area Relevance Rating. The averages of the recorded values per Knowledge Area were visualised as a spider diagram (Fig.7) to make the rating comparable with what the Supply side has to offer.

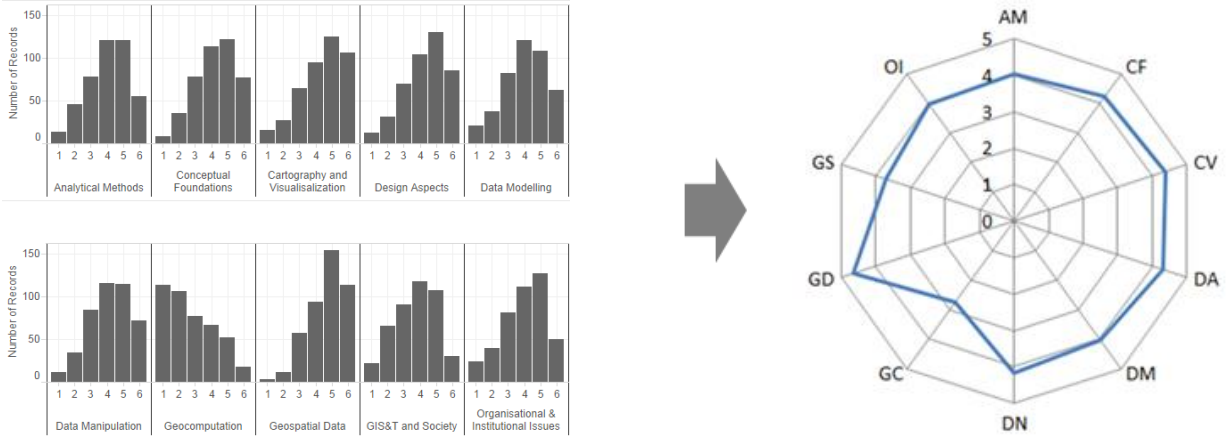


Figure 7 The ratings by European GI professionals of the overall relevance of individual GIS&T BoK Knowledge Areas on a scale of 1-6 translated to a spider diagram (After Wallentin et al., 2014).

The keyword percentages representing competence needs could be seen as pulling forces, as amplifiers for the relevance rating of the Knowledge Areas they were attributed to (Fig.7).

The spider diagram of the KA Relevance rating, overlaid with the pulling forces (Fig. 8), visually compared with the shape in the spider diagram of the Existing + Intended teaching supply (Fig.9) shows two rather different patterns.

The demand for competences in Knowledge Areas, as indicated in Figure 8, seems to be quite different from the supply of competences represented in Figure 9. This difference is interpreted as a teaching gap. It indicates that much teaching is on offer about CV (Cartography and Visualization), DM (Data Modeling) and GD (Geospatial Data). There seems to be an urgent need for more teaching on offer about OI (Organizational and Institutional Aspects), DA (Design Aspects), DN (Data Manipulation) and even about AM (Analysis Methods).

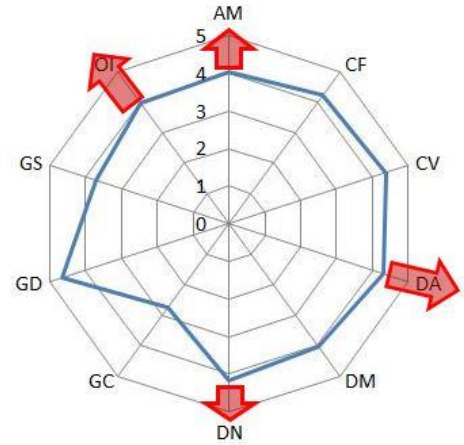


Figure 8 The average Knowledge Area relevance rating, combined with pulling forces of wished-for competences

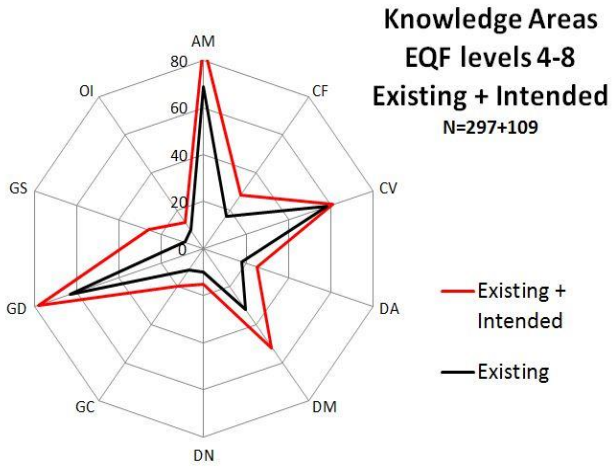


Figure 9 Study load in ECTS credits of existing and intended teaching

3.7 Conclusions about differences between Demand and Supply of GI teaching

The results of this analysis points into the direction of a considerable gap between the present need for GI competences and the GI teaching that is on offer, or will be in the next few years. It seems that, compared with the present situation, the need is felt for more teaching about the subjects “Programming” and “Mobile”. In addition to that, respondents would like to obtain competences in the Knowledge Areas of Design Aspects, Organisational and

Institutional Aspects, Analysis Methods and Data Manipulation. At the Supply side the majority of existing teaching on offer belongs to Analysis Methods, Geographical Data, Cartography and Visualisation and Data Modeling. Plans for new courses in the near future will change that offer only to a limited degree.

At one hand, the seriousness of this gap should be taken with a grain of salt. The responses to the two surveys matched less well than hoped for. This could be attributed to the necessity to keep the number of survey questions as low as possible, in combination with the need to have the GIS&T BoK terms used by an audience the majority of which is not using it. This means that the potential of the GIS&T BoK as a common vocabulary for both the Demand and the Supply side is hardly exploited. It also means that teaching gap assessment is tentative.

At the other hand, however, the teaching gap might in practice be worse than indicated here, due to organisational aspects. Looking at the complete set of results for more than 25 European countries, the difference between Demand and Supply might be larger, because of the following obstacles:

- Language: There might be a teaching language mismatch. A course taught only in Danish would not help a potential learner from Turkey unless he or she speaks Danish.
- Packaging: Also a mismatch of the teaching level or course size is possible. A person needing a 1 ECTS practical course on EQF4 level would not be served well by a 5 ECTS course on EQF7 level.
- Scheduling: A course could be scheduled unfavourably compared to the user's needs or possibilities.
- Location: If a course is offered at more than daily commuting distance and without remote access facilities, participation would also require temporary accommodation.
- Financial: participation fees might be prohibitive.

All this means that the teaching gap is not only about the right course content being on offer. Also organisational aspects need to be taken into account when comparing the Demand for GI competence teaching with the Supply thereof.

4 The GIS&T BoK content gap

4.1 Definition

With respect to the GIS&T BoK, a content gap is provisionally defined here as the difference between the collection of terms present in the GIS&T BoK with another collection of terms originating from the GI-field.

In the context of this project two of such collections were distilled from the Demand Survey and the Supply Survey.

4.2 The Demand side collection

From the Demand side, the GIS&T BoK content gap becomes concrete by the list of terms (based on section 4.6, table 11 in the Demand side report) in the free-text responses which do not occur in the GIS&T BoK, shown in Table 2. These terms were used to indicate the present tasks of the respondents, the competences that become relevant in the future and their personal learning aims.

Table 2 Demand side keywords not in the GIS&T BoK (adapted from Wallentin et al. 2014)

Data archive	Semantic web	Big data
Frontend	Harmonization	Radar Remote Sensing, SAR
API	Geoportal	(Sidelooking Airborne Radar)
Geojson	ISO standards 19107, 19109	Geomarketing
Python	OSM (Open Street Map)	2D
Plugin	UAV (Unmanned Aerial Vehicle)	Semantics
Javascript	Drone	OBIA (Object Based Image Analysis)
Object oriented programming	GNSS (Global Navigation Satellite	4D
Java	System)	BIM (Building Information Model)
Web application	Mass data	Data archive
Geoprocessing	Open data	Augmented reality
Html5	Crowd sourcing	Indoor GML / City GML 4D
Smartphone, mobile	VGI (Voluntary Geographic	
GPRS (General Packet Radio Service)	Information)	
RESTful		

4.3 The Supply side collection

Because of developments in the GI field after the publication of the GIS&T BoK, it was expected that specifications for courses in which these new developments are the subject could not be made using the GIS&T BoK Knowledge Areas or Units. In the survey, respondents were asked to use their own description if they encountered this problem.

This option was used for 166 out of 367 existing courses, and for 48 out of 134 intended courses.

It was expected that in these free text comments subjects could be found which are not in the first edition of the GIS&T BoK, but already included in existing or intended GI teaching. This proved to be the case.

Subjects, presently outside the GIS&T BoK, that were mentioned in the remarks about existing and intended teaching offers are listed.

Table 3 Supply side keywords not in GIS&T BoK

Web platforms	Mobile GIS
System architecture	Point cloud analysis
OGC services (Open GIS Consortium)	Programming in Python
Web processing services	UML (Unified Modelling Language)
SDI service components	XML (Extensible Markup Language)
UAV	Qualitative GIS
LiDAR (Light Detection and Ranging)	Open source software

Together, the above tables represent a footprint of the content gap between the GIS&T BoK and the present and future activities in the GI-domain. Therefore, the terms in both lists are all candidates to be included in the next version of the GIS&T BoK. In Appendix 2 they are listed on one page.

4.4 How to include the terms in the GIS&T BoK?

Which of the candidate terms should be included in the next version of the GIS&T BoK? This requires further analysis beyond the scope of this work package. Reasons for that are:

- There might be overlapping meanings, hidden by different terms. Remarkable is, that the two sets of terms have, at face value, only three terms in common: Inspire, Python and UAV. Without further analysis it is hard to say if this is another symptom of the teaching gap. The question is: Do Supply side respondents see other things than the Demand side respondents? Or are both groups using different words for the same subjects?
- The terms are on various conceptual levels. Some terms are concrete and specific (e.g. ”UML”, “UAV” or “OSM”), where others indicate broad categories (e.g. “Crowd sourcing”, “Harmonization” or “SDI”). An analysis of meaning might show that one term is a container concept for other terms. For instance, “geoprocessing” could contain “point cloud analysis”.
- Some terms refer to other knowledge domains than GI. Examples are terms referring to computer programming like “UML” or “Javascript”, which is considered a prerequisite skill in the GIS&T BoK, not part of it. Also terms like “BIM (building information model)” or “semantics” will be a subject in common with other knowledge domains. In these cases, the challenge will be to connect to the right term in other domain references.

These aspects could be accommodated within an ontology based digital version of the domain reference such as proposed by Ahearn (Ahearn et al, 2013).

5 Conclusions

The essence of the GI-N2K project could be formulated as:

For the geographic information knowledge domain a reference document on paper exists, the GIS&T BoK. However, this document is not good enough to help supply GI using organisations in Europe with sufficient employees with the right competences. The main problems are that the GIS&T BoK is not generally known and it is incomplete because it is not kept up-to-date. In addition, there is a lack of tools to maintain and use the GIS&T BoK in an easy and efficient manner. The GI-N2K project is going to change that by providing an improved version of the GIS&T BoK, web-based and up to date, including tools for use and for maintenance, and disseminate it.

This document reports about the assessment of the present situation, to provide a foundation for following work packages. The assessment focused on three aspects:

- Awareness and use of the GIS&T BoK amongst the expert community
- The teaching gap: the gap between Demand and Supply of competences
- The content gap: the incompleteness of the GIS&T BoK

The results of this assessment generally confirm the premise of the GI-N2K project and also add some interesting details.

5.1 Overview of conclusions

5.1.1 Awareness and use of GIS&T BoK

From the Demand and Supply survey results, it appeared that awareness of the GIS&T BoK among the survey respondents is less than 50% (Supply side) to 30% (Demand side). The use of the GIS&T BoK is about half that at both sides. The awareness rate is a little better than Masik (Masik 2010) found.

An interesting group are the respondents that are aware of the GIS&T BoK and reported not to use it. Their motives varied. At the Demand side, the GIS&T BoK is seen as impractical and too academic. At the Supply side more than a quarter of the 44 aware non-users indicated to have neither need nor wish to introduce the GIS&T BoK in the way they work. Four of the respondents in this group indicated to use their own notes or other sources. Three others responded to feel no need to use GIS&T BoK. Another quarter (11 respondents) reported organisational obstacles. This is a collection of various reasons to indicate that GIS&T BoK is not easily fitted into the present way of GI teaching. So, at the Supply side shortcomings in content and usability of GIS&T BoK are not the strongest reasons for not using the GIS&T BoK.

A strategic conclusion is that the GIS&T BoK is -in Europe- under-exposed, resulting in limited awareness. As a tool it is not sufficiently attractive to get aware non-users interested (the no need, no wish group) or to overcome their organisational objections.

Presumably this situation prevented that –in Europe- the GIS&T BoK was given a role as a reference document by professional organisations or teaching quality assurance organisations. This absence of any role does not stimulate awareness.

5.1.2 The gap between Demand and Supply of competences: the teaching gap

The comparison of the demand for GI competences with the Supply of GI teaching resulted in:

- A clear teaching gap with regard to “Mobile” competences;
- A possible teaching gap with regard to “Programming” competences;

- A possible need for more teaching in the Knowledge Areas of Organisational and Institutional Aspects, Design Aspects, Analysis Methods and Data Manipulation.

At one hand this outcome might in reality be less serious than concluded here because the GIS&T BoK does not yet function very well as a common vocabulary for the Demand and Supply sides. This means that course names or descriptions might not disclose course content in terms of the GIS&T BoK, whereas job descriptions and competence needs are not formulated using the GIS&T BoK terminology. Also, the Supply Survey questions were not intended to produce a complete list of GI courses per teaching organisation.

At the other hand the gaps might be more serious, because making use of teaching on offer also depends on the quality of the match between a number of organisational issues of a particular course and the agenda of the individual learner.

These aspects make it difficult to assess the teaching gap.

5.1.3 The incompleteness of the GIS&T BoK

The Demand side and the Supply side produced about 50 terms in total that are missing in the GIS&T BoK. Remarkably, the Demand side list is twice as long as the Supply side list. They only have three terms in common.

Which of these terms should be added to the GIS&T BoK requires further analysis of their meaning and their semantic relationship. Other aspects to be taken into account:

- Geographical extent of the relevance of a term: the relevance could be limited to Europe, as in the case of INSPIRE.
- Terms could be referring to concepts that have their roots in other knowledge domains or Bodies of Knowledge, such as the Surveying Body of Knowledge (Greenfeld 2012) or the Project Management Body of Knowledge (PMI 2004).

5.2 Final remarks

It is hoped that the GI-N2K project will be able to elevate the GIS&T BoK out of the chicken-and-egg situation it is in at the moment. If a more attractive version (with regard to content, tools and user interface) can be constructed, it might stimulate awareness in Europe on both the Demand and the Supply side. Then it might start to function as a common vocabulary and perhaps as an official GI domain reference.

In order to achieve a more attractive version of the GIS&T BoK, we have the following suggestions.

- For WP2 [revision of the GIS&T BoK content]: study the option to operationalise most used terms referring to existing and intending Geo-information competences in wider sense than only a vocabulary: make a Context of Use Analysis, as described on the Usability Body of Knowledge website. The 50 terms resulting from the surveys could be the starting point.
- WP2 should also give attention to the most recent trends in research. The Demand and Supply sides may miss the latest scientific outcomes (e.g. terms related to concepts, methods, techniques and application domains).
- WP3 is about rebuilding the GIS&T BoK as a dynamic web environment. For this work package we suggest to include concepts of the semantic web to create a dynamic self-updating terminology base.
- Besides, the look and feel of the interface should be developed in accordance with results of user requirements tests.
- The final result, to be disseminated, tested and validated in WP4, should be done with at least 4 different respondent groups (GIS&T BoK unaware supply siders, aware supply siders, unaware demanders and aware demanders).

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Winterton, J., Delamare - Le Deist, F., Stringfellow, E., 2006: Typology of knowledge, skills and competences: clarification of the concept and prototype. Cedefop Reference series; 64. Luxembourg: Office for Official Publications of the European Communities, 2006
http://www.cedefop.europa.eu/EN/Files/3048_en.pdf [accessed 07.07.2014]

Consulted websites:

AGILE membership webpage: http://www.agile-online.org/index.php/community/members

EuroGeographics website: http://www.eurogeographics.org

EuroSDR website: http://www.eurosdr.net

ICA website: http://icaci.org

INSPIRE website: http://inspire.ec.europa.eu

ISPRS website: http://www.isprs.org

Geoskills+ website: http://www.geoskillsplus.eu

GI-N2K project website: http://www.gi-n2k.eu

Usability Body of Knowledge website: http://www.usabilitybok.org

Annex 1 Overview of the GIS&T BoK Knowledge Areas and Units

This table shows the meaning of the codes used to indicate teaching content. To further illustrate the content of the Units, a number of sub-Units is shown for each Unit.

Table 4 Overview of the GIS&T BoK Knowledge Areas and their Units. (Source: DiBiase et al., 2006)

Knowledge Area	Unit	Sub-units
AM Analytical Methods	AM-1 Academic and analytical origins	Academic foundations, Analytical approaches.
	AM-2 Query operations and query languages	Set theory, Structured Query Language (SQL) and attribute queries, Spatial queries.
	AM-3 Geometric measures	Distances and lengths, Direction, Shape, Area, Proxim-ity and distance decay, Adjacency and connectivity.
	AM-4 Basic analytical operations	Buffers, Overlay, Neighborhoods, Map algebra.
	AM-5 Basic analytical methods	Point pattern analysis, Kernels and density estimation, Spatial cluster analysis, Spatial interaction, Analyzing multidimensional attributes, Cartographic modeling, Multi-criteria evaluation. Spatial process models.
	AM-6 Analysis of surfaces	Calculating surface derivatives, Interpolation of surfaces, Surface features, Intervisibility, Friction surfaces.
	AM-7 Spatial statistics	Graphical methods, Stochastic processes, The spatial weights matrix, Global measures of spatial association, Local measures of spatial association, Outliers, Bayesian methods.
	AM-8 Geostatistics	Spatial sampling for statistical analysis, Principles of semi-variogram construction, Semi-variogram modeling, Principles of kriging, Kriging variants.
	AM-9 Spatial regression and econometrics	Principles of spatial econometrics, Spatial auto-regressive models, Spatial filtering, Spatial expansion and Geographically Weighted Regression (GWR).
	AM-10 Data mining	Problems of large spatial databases, Data mining approaches, Knowledge discovery, Pattern recognition and matching.
	AM-11 Network analysis	Networks defined, Graph theoretic (descriptive) mea-sures of networks, Least-cost (shortest) path, Flow modeling, The Classic Transportation Problem, Other classic network problems, Accessibility modeling.
	AM-12 Optimization and location-allocation modeling	Operations research modeling and location modeling principles, Linear programming, Integer programming, Location-allocation modeling and p-median problems.
CF Conceptual Foundations	CF-1 Philosophical foundations	Metaphysics and ontology, Epistemology, Philosophical perspectives.
	CF-2	Perception and cognition of geographic phenomena, From

	Cognitive and social foundations	concepts to data, Geography as a foundation for GIS, Place and landscape, Common-sense geographies, Cultural influences, Political influences.
	CF-3 Domains of geo-graphic information	Space, Time, Relationships between space and time, Properties.
	CF-4 Elements of geo-graphic information	Discrete entities, Events and processes, Fields in space and time, Integrated models.
	CF-5 Relationships	Categories, Mereology: structural relationships, Genealogical relationships: lineage, inheritance,Topological relationships,Metrical relationships: distance and direction, Spatial distribution, Region, Spatial integration.
	CF-6 Imperfections in geo-graphic information	Vagueness, Mathematical models of vagueness: Fuzzy sets and rough sets, Error-based uncertainty, Mathematical models of uncertainty: Probability and statistics.

CV Cartography and Visualization	CV-1 History and trends	History of cartography, Technological transformations.
	CV-2 Data considerations	Source materials for mapping, Data abstraction: classification, selection, and generalization, Projections as a map design issue.
	CV-3 Principles of map design	Map design fundamentals, Basic concepts of symbolization, Color for cartography and visualization, Typography for cartography and visualization.
	CV-4 Graphic representation techniques	Basic thematic mapping methods, Multivariate displays, Dynamic and interactive displays, Representing terrain, Web mapping and visualizations, Virtual and immersive environments, Spatialization, Visualization of temporal geographic data, Visualization of uncertainty.
	CV-5 Map production	Computational issues in cartography and visualization, Map production.
	CV-6 Map use and evaluation	The power of maps, Map reading, Map interpretation, Map analysis, Evaluation and testing, Impact of uncertainty.

DA Design Aspects	DA-1 The scope of GI S&T system design	Using models to represent information and processes, Components of models: data, structures, procedures, The scope of GI S&T applications, The scope of GI S&T design, The process of GI S&T design.
	DA-2 Project definition	Problem definition, Planning for design, Application/user assessment, Requirements analysis, Social, political, and cultural issues.
	DA-3 Resource planning	Feasibility analysis, Software systems, Data costs, Labor and management, Capital: facilities and equipment, Funding.
	DA-4 Database design	Modeling tools, Conceptual model, Logical models, Physical models.
	DA-5 Analysis design	Recognizing analytical components, Identifying and designing analytical procedures, Coupling scientific models with GIS, Formalizing a procedure design.
	DA-6 Application design	Workflow analysis and design, User interfaces, Devel-opment environments for geospatial applications, Computer-Aided Software Engineering (CASE) tools.

	DA-7 System implementation	Implementation planning, Implementation tasks, System testing, System deployment.

DM **Data Modeling**	DM-1 Basic storage and retrieval structures	Basic data structures, Data retrieval strategies.
	DM-2 Database management systems	Coevolution of DBMS and GIS, Relational DBMS, Object-oriented DBMS, Extensions of the relational model.
	DM-3 Tessellation data models	Grid representations, The raster model, Grid compression methods, The hexagonal model, The Triangulated Irregular Network (TIN) model, Resolution, Hierarchical data models.
	DM-4 Vector and object data models	Geometric primitives, The spaghetti model, The topological model, Classic vector data models, The network model, Linear referencing, Object-based spatial databases.
	DM-5 Modeling 3D, temporal, and uncertain phenomena	Spatio-temporal GIS, Modeling uncertainty, Modeling three-dimensional (3D) entities.

DN **Data Manipulation**	DN-1 Representation transformation	Impacts of transformations, Data model and format conversion, Interpolation, Vector-to-raster and raster-to-vector conversions, Raster resampling, Coordinate transformations.
	DN-2 Generalization and aggregation	Scale and generalization, Approaches to point, line, and area generalization, Classification and transformation of attribute measurement levels, Aggregation of spatial entities.
	DN-3 Transaction management of geospatial data	Database change, Modeling database change, Reconciling database change, Managing versioned geospatial databases.

GC **Geocomputation**	GC-1 Emergence of geocomputation	Origins, Trends.
	GC-2 Computational aspects and neurocomputing	High performance computing, Computational intelligence, Non-linearity relationships and non-Gaussian distributions, Pattern recognition, Geospatial data classification, Multi-layer feed-forward neutral networks, Space-scale algorithms, Rule learning, Neural network schemes.
	GC-3 Cellular Automata (CA) models	CA Model Structure, CA Transition Rule, CA simulation and calibration, Integration of CA and other geocomputation methods, Typical CA applications.
	GC-4 Heuristics	Greedy heuristics, Interchange heuristics, Interchange with probability, Simulated annealing, Lagrangian relaxation.
	GC-5 Genetic algorithms (GA)	GA and global solutions, Genetic algorithms and artificial genomes.
	GC-6 Agent-based models	Structure of agent-based models, Specification of agent-based models, Adaptive agents, Microsimulation and Calibration of Agent Activities, Encoding agent-based models.
	GC-7 Simulation modeling	Simulation modeling
	GC-8	Definitions within a conceptual model of uncertainty, Error.

	Uncertainty	Problems of scale and zoning, Propagation of error in geospatial modeling, Theory of error propagation, Problems of currency, source and scale.
	GC-9 Fuzzy sets	Fuzzy logic, Fuzzy measures, Fuzzy aggregation operators, Standardization, Weighting schemes.

GD **Geospatial Data**	GD-1 Earth geometry	History of understanding Earth's shape, Approximating the Earth's shape with geoids, Approximating the geoid with spheres and ellipsoids.
	GD-2 Land partitioning systems	Unsystematic methods, Systematic methods.
	GD-3 Georeferencing systems	Geographic coordinate system, Plane coordinate systems, Tessellated referencing systems, Linear referencing systems.
	GD-4 Datums	Horizontal datums, Vertical datums.
	GD-5 Map projections	Map projection properties, Map projection classes, Map projection parameters, Georegistration.
	GD-6 Data quality	Geometric accuracy, Thematic accuracy, Resolution, Precision, Primary and secondary sources.
	GD-7 Land surveying and GPS	Survey theory and electro-optical methods, Land records, Global Positioning System.
	GD-8 Digitizing	Tablet digitizing, On-screen digitizing, Scanning and automated vectorization techniques.
	GD-9 Field data collection	Sample size selection, Spatial sample types, Sample intervals, Field data technologies.
	GD-10 Aerial imaging and photogrammetry	Nature of aerial image data, Platforms and sensors, Aerial image interpretation, Stereoscopy and orthoimagery, Vector data extraction, Mission planning.
	GD-11 Satellite and shipboard remote sensing	Nature of multispectral image data, Platforms and sensors, Algorithms and processing, Ground verification and accuracy assessment, Applications and settings.
	GD-12 Metadata, standards, and infrastructures	Metadata, Content standards, Data warehouse, Exchange specifications, Transport protocols, Spatial Data Infrastructures.

GS **GI S&T and Society**	GS-1 Legal aspects	The legal regime, Contract law, Liability, Privacy.
	GS-2 Economic aspects	Economics and the role of information, Valuing and measuring benefits, Models of benefits, Agency, organizational, and individual perspectives, Measuring costs.
	GS-3 Use of geospatial information in public sector	Uses of geospatial information in government, Public participation in governing, Public participation GIS.
	GS-4 Geospatial information as property	Property regimes, Mechanisms of control of geospatial information, Enforcing control.
	GS-5 Dissemination of geospatial information	Incentives and barriers to sharing geospatial information, Data sharing among public and private agencies, organizations, and individuals, Legal mechanisms for sharing geospatial information, Balancing security and open access to geospatial information.
	GS-6	Ethics and geospatial information, Codes of ethics for

	Ethical aspects of geospatial information and technology	geospatial professionals.
	GS- Critical GIS	Epistemological critiques, Ethical critiques, Feminist critiques, Social critiques,

OI Organizational and Institutional	OI-1 Origins of GI S&T	Public sector origins, Private sector origins, Academic origins, Learning from experience, Future trends.
	OI-2 Managing the GI system operations and infrastructure	Managing the GI system operations and infrastructure, Ongoing GI system revision, Budgeting for GI system management, Database administration, System management.
	OI-3 Organizational structures and procedures	Organizational models for GI system management, Organizational models for coordinating GI systems and/or program participants and stakeholders, Integrating GI S&T with management information systems (MIS).
	OI-4 GI S&T workforce themes	GI S&T staff development, GI S&T positions and qualifications, GI S&T training and education, Incorporating GI S&T into existing job classifications.
	OI-5 Institutional and inter-institutional aspects	Spatial data infrastructures, Adoption of standards, Technology transfer, Spatial data sharing among organizations, Openness, Balancing data access, security, and privacy, Implications of distributed GI S&T, Inter-organizational and vendor GI systems (software, hardware and systems).
	OI-6 Coordinating organizations (national and international)	Federal agencies and national and international organizations and programs, State and regional coordinating bodies, Professional organizations, Publications, The geospatial community, The geospatial industry.

Annex 2 Supplementary subjects for the GIS&T BoK

in Demands list	in both lists	in Supply list
2D	inspire	analytical models
4D	python	gps
API	uav	3d city models
augmented reality		lidar
big data		mobile gis
BIM (building inf. model)		modeling theory
crowd sourcing		OGC services
data archive		open source software
drone		point cloud analysis
frontend		qualitative gis
geojson		SDI service components
geomarketing		simulation modeling
geoportal		system architecture
geoprocessing		UML
GPRS		web mapping
harmonization		web platforms
html5		web processing services
indoor GML / City GML 4D		XML
ISO standards 19107, 19109		
java		
javascript		
mass data		
OBIA (object based image		
object oriented programming		
open data		
OSM		
plugin		
python		
Radar Remote Sensing, SAR		
RESTful		
semantic web		
semantics		
smartphone, mobile		
VGI (voluntary geographic		
web application		

Annex 3 Overview of the attribution of keywords to the GIS&T BoK Knowledge Areas

All terms in word cloud "Which competences would you like to obtain?" (Wallentin et al. 2014, fig. 2). Importance is reflected by % of keywords.	**GIS&T BoK Unit or Topic <u>names</u> containing the term.**	**Best fitting GIS&T BoK Knowledge Area** Assignment to a Knowledge Area is based on the number of times the term occurs in names of Topics or Units. No attribution when term is too generic.
Web **6.05%**	CV4-5	**Considered as separate competence**
Programming **6.05%**	AM12-2, AM12-3	Programming skills are a prerequisite (DiBiase et al. 2006, p.43), not a part of the GIS&T BoK. **Considered as separate competence**
Spatial **5.9%**		'Spatial' is an adjective, occurring hundreds of times in the GIS&T BoK. Not attributed.
Modeling **5.31%**	AM5-6, AM8-3, AM9-3, AM11-4, AM11-7, AM12-1, AM12-4,	Attributed to AM
Management **4.72%**	Management DA3-4, OI2-3, OI2-5, OI3-1, OI3-3 Managing DN3-4, OI2-1,	Attributed to OI
Design **3.69%**	Map design: CV2-3, CV3-1 System design DA1-4, DA1-5, DA2-2, DA5-4, DA6-1	Attributed to DA
Skills **3.1%**		The term 'Skills' is not specific for any Knowledge Area in the GI-domain. The term refers to a person's capability of proficient use of, for instance, tools and methods. Not attributed.
Knowledge **2.95%**		The term 'Knowledge' is not specific for any Knowledge Area in the GI-domain. Not attributed.
Development **2.95%**	DA6-3, OI4-1	System development or staff development? System seems more appropriate in this context. Attributed to DA
Open **2.8%**	GS5-4, OI5-5	Attributed to OI
Database **2.65%**	DA4, DM2, DN3-1, DN3-2, DN3-3, DN3-4, OI2-4	DA4: Unit "Database Design", DM2: "Database Management Systems" DN3: "Transaction management of geospatial data" OI2-4: "Database administration" Attributed to DN
Project **2.36%**	DA2	DA2: Unit "Project definition" Attributed to DA

Mobile 2.36%		The term does not occur in the GIS&T BoK hierarchy. **Considered as separate competence**
Aspects 2.36%		Many subjects have "Aspects" inside and outside the GI domain. Not attributed.
INSPIRE 2.21%	GD12-6, OI2-1	Term probably refers to European phenomenon in category of spatial data infrastructure Attributed to OI
Applications 2.21%	DA1-3, DA-6, GC3-5, GD11-5	Attributed to DA
Use 2.06%	CV6 Map Use GS3 Use of geospatial information	The term 'Use' is, as a verb, too generic to refer to a specific competence. Not attributed.
Terms not included in word cloud: **Data: 18.73%** **Gis: 12.98%** **Analysis: 7.67%**		Left out of word cloud as being domain core concepts
Together 100%: all terms with a frequency count >2% of the responses		