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Teaching geoinformatics: challenges and opportunities

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Abstract. In this paper, we discuss new challenges and opportunities in teaching geoinformatics on a conceptual level. We pose that spatial is not special anymore from a technological point of view, but at the same time teaching spatial thinking is more challenging than ever. We summarize our key positions and conclude with a call to action to rethink how we can ensure that our teaching of core geoinformation sciences and technologies remains a strong and supportive education pillar in our modern data-driven world.

Keywords. GIS, spatial thinking, training, education

1 Introduction

Geographic Information Systems (GIS) are increasingly being applied in academic research and teaching in a wide range of fields. A huge amount of geospatial data has become available from the thousands of satellite, airborne, and ground-based remote sensing systems, including data provided by "citizen science"(Butler, 2014; Chen and Wang, 2018). However, our ability to collect data has outpaced our ability to process and analyse it (Reichstein et al., 2019). Therefore, geospatial experts are in demand more than ever.

The impressive development of the earth observation sector, data and tools availability, becoming mainstream for "geo-" and the maturing of spatial data infrastructures have contributed immensely to the sector's success. Several initiatives have tried to address teaching and training for the widening geospatial domain over the last years. The most prominent to mention here is the EO4GEO project (http://eo-4geo.eu). Closely working with the European Union's Earth observation programme Copernicus, EO4GEO is claiming to service the complete skills development and capacity building strategy for Europe in the EO/GI field. The EO4GEO BoK, has been developed as part of the EO4GEO project (Hofer et al., 2020). EO4GEO perceives the space/geospatial sector as one in order to better support uptake of existing (Copernicus) data and services through training and education. Another important facet to consider in the European spatial data sector is the continuation and evolution of spatial data usage, interoperability and open access resulting from two decades of INSPIRE spatial data infrastructure implementation and open access policies in Europe. The SPIDER project aimed to raise awareness on holistic, multidisciplinary views on SDI and to encourage open SDI trends to be implemented in SDI teaching curricula.

Both projects collated and built an impressive amount of knowledge on skills, methods and teaching/training activities for their respective domains in the forms of knowledge trees, bodies of knowledge, with the intention that these terms form the basis of labelling knowledge that can be taught and consequently required by employers in job descriptions.

The latest initiative has been started by the European Umbrella Organisation for Geographic Information (EUROGI) and was named the Digital Earth Alliance (DEA). The idea behind DEA is to rebrand the classic, foundational geoinformatics/ GI domain in a new unique way that relates back to Al Gore's Digital Earth. DEA is not meant to build curriculum or teaching activities and content per se, but to provide a common inclusive naming beyond "geo-", for example in the career-building dialogue between companies and young soon-to-be expert graduates. In particular, in AI/ML for Earth observation research and industry, the term "geo" has been overused and can be ambiguous in academia, especially within the earth sciences/geosciences, and does not relate well to students of social sciences and human geography, transport and logistics, urban planning, that will want and need to work with GIS technology one way or another.

Undoubtedly, these initiatives have their merits. We acknowledge that there is a need to be able to talk about what we teach. In addition, the European Union has set itself the goal as part of the European Green Deal and the Digital Strategy of developing a global scale highly accurate digital model of the Earth to monitor and predict the interaction between natural phenomena and human activities (Destination Earth). To ensure this, the European Open Data Directive defines six high-value categories, two of these being geospatial data and remote sensing. This further increases the future demand for geospatial specialists and scientists and in turn places high responsibility on the geospatial educators. And there is a need for a discussion on how we teach and where to place emphasis on the foundational concepts.

In this position paper we aim to outline challenges, future opportunities and outlook for teaching geoinformatics at higher education levels.

2 Challenges

2.1 Methods vs tools

Historically, there has been a strong notion toward teaching GIS in terms of teaching how to use specific tools and software. GIS used to be "special" and mostly available only for those who had access to the tools. Nowadays, there is plenty of open-source desktop software (e.g. QGIS, SAGA) and programming languages (e.g., R and Python) that have geospatial analysis modules available. Tools as such should not be so much of the focus anymore. Furthermore, GIS does not need to be considered special anymore, because it is intertwined with many disciplines and is being applied by many different domain experts. This creates new challenges on how to teach GIS, because instead of teaching one specific tool, the educators need to focus on spatial thinking and methods and be able to teach broader concepts. Additional efforts are needed to better integrate GIS into the data science context, e.g. explaining raster as arrays, the mental model of neighbourhood when mostly doing tabular calculations etc. All of this comes down to training the students to think spatially. However, knowing spatial methods does not necessarily equate with spatial thinking. According to (Bednarz and Lee, 2011), manifestations of spatial thinking components are: map visualization and overlay, identification and classification of map symbols (point, line, area), generalized or abstract Boolean operations, map navigation or way-finding, and recognition of positive spatial correlation. However, to be able to implement these as pedagogical concepts, the student must have a certain amount of domain specific knowledge. For example, a computer science student may understand very well map algebra methods on a computational level, but he/she might not be able to successfully implement in an analytical workflow without having any knowledge about the phenomena he/she is modelling.

2.2 Critical (spatial) thinking

In addition to just training students to think spatially, we stress the importance of critical (spatial) thinking. This is more important than ever due to the immense amount of data but also because often enough, the data has serious quality issues. Even more so, with modern analysis tools that implement methods in an easy to use fashion, there is a temptation to use various methods on the data without critically evaluating the results or without thinking about whether the results even make sense in the spatial context and in the domain context. It becomes more challenging to train geospatial specialists because they will often be employed to work on global data products and services. This means that they will analyse data about regions where they have never been and don't know the local socio-economic conditions nor physical geography. This will make it hard for them to validate the validity of the results without local experts. Nevertheless, the educators must raise the awareness about the necessity to always check the validity and meaningfulness of the results.

2.3 Standards and metadata

Standards and metadata ensure the FAIR use of data. Proper use of standards and metadata demonstrates that you care about data and is a strong foundation for enabling data validation and, therefore also validation of our results and critical thinking. Metadata is often very clearly established in our heads while we prepare our datasets and it is challenging to teach the students always take time to add proper metadata to their data but also to check the metadata of the existing data. The realisation of the need for the metadata comes often only from the need for sharing and reusing.

2.4 Coordinate Reference Systems

Coordinate reference systems (CRS) are perhaps one the most challenging concepts for many students to grasp and master when learning to use GIS technology due to its abstract concept and technical complexity. The sheer array of different PCSs (map projections) and differentiating it from GCS (i.e. non-projected data) can be daunting to the introductory student or novice user. It is relatively simple to tach students to differentiate between geographic and projected coordinates, and to realize that geographic coordinates are almost always in WGS84 CRS. However, it is much more challenging to teach students to use correct projected CRS. Especially, if they work on larger regions or globally where their typical local CRS is not available. Then the choice of the CRS will depend on the purpose of the study and they need to consider whether they need to preserve the area, shape, distances or directions. It is important to consider CRSs as overarching geospatial skill that needs to be continuously dealt in all spatial analysis and data management.

2.5 Clean vs raw data

From the perspective of effective teaching methods, it is useful to provide well-prepared and clean data for the students to use in the assignments. However, it can be biased from the real world as in reality, the data is often not clean and e.g. has issues like invalid topology. Therefore, students should also be introduced to the "real data" during their studies to become familiar with steps on how to clean and validate the data. But crucially, students should not spend most of their time on data cleaning, otherwise, they will not be able to focus on learning and practicing fundamental spatial analysis methods. A good balance between raw and clean data usage is important.

3 Opportunities and outlook

The increasing interdisciplinarity and globalization is on one side a challenge, but it is also an immense opportunity in teaching GIS. The interdisciplinarity has already opened diverse fields where GIS can and should be applied and where the geospatial specialists are needed. This also enables the educators to train the students by using examples from different regions enabling global spatial thinking.

Data is increasingly driving the economy and remote sensing offers an incredible amount of new data that requires processing but also spatial analysis and modelling. Spatial modelling in particular is underexploited and undervalued. New opportunities are also opened up by integrating spatial aspects into machine learning based modelling e.g., spatial predictions. This in turn comes with the need to train students in literate programming and make their workflows reproducible (Nüst and Pebesma, 2021). This concept is more and more adopted by open science communities like Pangeo (https://pangeo.io) with technologies such as Jupyter notebooks and across platforms, such as the ESA DIAS or the Microsoft Planetary Computer. The next generations of geospatial specialists will be mostly processing and analysing spatial data in the cloud, because the traditional download model for data and analysis on the desktop computer will not scale and cannot keep up with the amount of data needed to provide meaningful large scale decision support.

We would also like to stress the importance of visualisation of the results as the main output of any spatial analysis. We all can agree that a well-prepared map is a very powerful communication tool and in GIS education it should be as important as spatial thinking.

Using problem-based learning in training geospatial specialists has been shown to be a good model to teach methods instead of tools (Drennon, 2005) and also train spatial thinking. Problem-based learning should be also applied as an effective method for teaching spatial thinking to non-geography students (Read, 2010) which is nowadays often the need. However, one final question remains: should education around spatial and critical thinking start with pathway 1) a domain science (Ecology, Geology) or generic spatial domain (BSc Geography) and then acquire more technical digital skills (Geoinformatics, Geospatial Data Science), or reversely pathway 2) by starting with computer literacy (BSc Computer or Information Sciences, generic Geoinformatics) and then focus on applying on a domain of interest?

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