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Future Education of Cartography and GIS: What Is Next?

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Abstract: Cartography and maps support the continuous rising of the awareness of the power of spatial data, which further lays a foundation for the popularity of various location based services and applications in society. Cartography and Geographic Information System education has been a core activity in the cartographic academic community for knowledge creation and transfer in higher education institutions. Maps in primary and high schools play a unique role across disciplines to build the spatial thinking capacities of young generations. Over years educators train students via lectures and lab works into which digital technologies are gradually incorporated. The COVID-19 pandemic has been fast forwarding our pace to employ digital technologies in online teaching and learning. Teachers are passively or proactively adapted to conduct their teaching online and redesign their lectures and assessments of students' performance. On another side, students are getting used to online learning even more quickly with various digital devices in an interactive and collective way. It creates opportunities for cartographic GIS educators to build a body of knowledge for cartography which can be used to build open source educational resources systematically. Further flexible curriculum can be designed and implemented for professional and continuous education and training at various levels. Future education of cartography and GIS can improve map literacy and make a sustainable education.

Key words: cartography and GIS; future education; online learning; spatial thinking; map literacy; sustainable

Citation: Tao WANG. Future Education of Cartography and GIS: What Is Next? [J]. Journal of Geodesy and Geoinformation Science, 2022, 5(3): 1-6. DOI:10.11947/j.JGGS.2022.0301.

1 Introduction

Cartography as a classic discipline has experienced opportunities and challenges over the last one hundred years, especially after information technologies were introduced into its technological sector. Map, at the same time, has been designed and produced in even more diverse forms. Public organizations and researchers continuously give new definitions of maps at different periods of history[1]. Basically these definitions are reflexes of corresponding social and technological contexts. In most of the definitions the core keywords consistently appear are representation and scale. As a scaled representation of the earth, map is used as an essential tool supporting most earth sciences[2] and a useful tool guiding anthropogenic activities. In analogue era, map had been mainly made by professional cartographers in governmental or public agencies. The general public can only get easy access to maps after computer assisted cartography and Geographic Information System (GIS), large scale geospatial databases and the internet are available. At the same time GIS has been introduced in and adapted to other disciplines and applications gradually in an accelerated speed, as map does continuously. During this course, map making and map use in the forms of geospatial visualization and geospatial analysis

Received date: 2022-07-25; accepted date: 2022-08-25
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are playing indispensable roles in traditional geosciences and smart cities[3]. Map is being used not only as a positioning reference, but also a platform to collect and align any data with location, even in personal social networking and daily life. Map users are being map makers and data providers simultaneously in many scenarios[4]. New technologies have exhibited the power and potential of cartography to more people in sharing economies. However, people's capabilities of spatial thinking, reasoning and understanding have not been improving dramatically.

Before cartography or map science emerged, few cartographers had conducted systematical summaries and reflections on theories, like Xiu Pei who proposed six principles of map making[5]. After cartography was recognized as an independent discipline, the contents of cartography education experienced changes and were growing as a system. A quick comparison of typical cartography and GIS textbooks published in the 1980s and those in the 2000s can tell readers many changes. Technologies have been fading away, migrating to other disciplines and emerging at different paces, for example, those related to map reproduction, computer programming language, software architectures and GeoAI[6]. Basic principles and methods in cartography remain stable albeit instructions to learners may change.

Information technologies have been introduced gradually into cartography teaching and learning, similar to what happened in other education fields. Cartography and GIS education has been continuously a research focus which evidences cartography's tradition of knowledge transfer to GIS. New frontiers of academic outputs have been adopted into educational resources together with new ways of teaching and changing pedagogies, all of which prepare our graduates for increasingly more opportunities. The last two years saw challenges and opportunities posed by the COVID-19 pandemic. It is time to look back and contemplate forward about future cartography and GIS education. In the following part, we first analysis challenges in the new normal era that we are facing. Then opportunities and transformations addressed by seven papers are introduced. This special issue puts together the latest thoughts and practices by cartography and GIS educators. The papers cover topics from theoretical framework of cartography education, new thoughts of Geoinformatics, to novel practices of teaching GIS. At the end, conclusions are drawn about future cartography and GIS education.

2 Challenges

Cartography education has been making efforts to train traditional cartographers with changing contents in the last one hundred years[2]. Cartographic theories and computer assisted mapping were introduced into curriculum gradually in the early periods of computer era. In last several decades, geospatial information technologies have been playing an increasingly more important role in smart cities and smart society at large. In this course, GIS data sources have been diversified and enriched as technologies in remote sensing and global navigation satellite systems, social media, and the internet of things advance rapidly. Artificial intelligence algorithms are changing spatio-temporal analysis in classical problems and widening geospatial applications. Geovisuliazation becomes a powerful tool in infographics for social narratives and embraces novel instruments in Virtual/Mixed/Augmented Reality. At this moment, it is crucial for educators in universities and other organizations to speculate about and share their experiences on how to effectively expose students and users to new knowledge. Educators are gradually incorporating knowledge frontiers generated in academic research, industries and neighboring disciplines into cartographic and GIS teaching. However, professional cartography training in higher education institutions is transforming at a slower pace comparatively. One possible reason is that

cartographic courses are compressed in universities to leave more space for GIS technologies, which are more appealing to job markets. Cartography programmes globally experience a similar situation as traditional geodesy[7].

Secondly, the general public has not been receiving enough knowledge to build reasonable spatial thinking habits. Although maps are more and more used in daily life by young generations and professionals in various ways, spatial thinking and reasoning capacities of the general public need more specific training in application contexts. Unawareness of basic knowledge when using maps may lead to serious consequences. Amateur map operators can be easily blamed for wrong map using purposelessly or purposefully in big or small crises like "military mistaken bombing"[8]. One related challenge is that map is not effectively used and explained in primary and high schools. Intrinsic properties of maps, like scale and projection, are not given appropriate attentions in geography, history and mathematics instructions. GIS, as a replacement of maps, has been introduced into basic education and offers many advantages. But little GIS has been specifically designed and implemented to support education of spatial thinking.

The third challenge is information technologies in cartography and GIS education adapting to young people. Conventionally, cartography has been mostly taught in classrooms with lectures and exercises to train students' map reading, making and application skills. Young generations grow in a digital environment and smart devices to them are paper and pen to older generations. However, very much like older generations do not build a comprehensive understanding of paper maps, young generations do not have a good grasp of digital maps albeit easier access to navigation and sport applications on their smart devices and digital wearables. One correlated challenge is brought to us by the COVID-19 pandemic: how to build a resilient and sustainable education system. UNESCO monitored that more than one billion students have experienced school closure[9]. Thanks to the fast development of information infrastructure in the last ten years, online teaching and distance learning promptly ensures the efficiency and effectiveness of education in many countries during the COVID-19 period. If we look back even longer, Educators have been working on online education no later than 2003 when SARS spread in many regions. However, online teaching and learning progress slowly in universities. Although a number of Massive Open Online Courses (MOOCs) offer digital learning resources, few considerations have been given on flexibility and adaptability to various education settings and backgrounds. On this regard, cartography and GIS education is in the similar situation. It is even more challenging when considering field and lab practices which are important parts of cartography and GIS programmes.

3 Opportunities

With the maturity of computer assisted cartography and further GIS and the wide availability of geospatial and statistical data, cartographers emancipate from laborious works of manual data collection and map drawing. Then the general public has the flexibilities to use and generate amateur maps with tools at no or low cost, which fit most application scenarios although not in a perfect manner. This situation offers cartographers opportunities to concentrate on analyzing data, designing maps, developing professional tools and creating more educational resources.

As indicated above, young generations are more familiar with maps through daily involvements of geospatial resources. Advanced knowledge of using geospatial data would give them more power to tackle real questions in many other areas. Then it is necessary to build a professional introduction for interdisciplinary education. Zhao et al.[10] present a new course, Geomatics Technology, for students in areas Mathematical and

Scientific Basic Science, Civil, Hydraulic and Marine Engineering at Tsinghua University. Geospatial data is used as a unique agent to connect interdisciplinary knowledge. Students are inspired to improve their practical ability and conduct innovative study and research with the support of a cloud based platform. Digital technologies in education can be employed to facilitate field and lab practices. Li et al.[11] designed a comprehensive platform specifically to facilitate teaching and learning of field and lab courses. Based on an analysis of the requirements of relevant courses, the platform was implemented to be compatible with various mobile and desktop computer clients. During the COVID-19 pandemic period, the authors evaluated students' performances and found very promising results. Among these, an education paradigm is transforming. Especially hybrid teaching and learning with an emphasis on balancing traditional contents and the latest progress shall be adopted. To address challenges, Feng et al.[12] conducted a systematical analysis of changes comparing with those remain unchanged on four dialectical aspects in GIS teaching. A core course, GIS Practice Design, is used as a case study to implement the design that balances the changes and unchanged in teaching.

The body of knowledge for cartography and GIS has been transforming continuously either internally or externally. Researchers and educators are conducting reflections on these changes and approaching different thoughts and views. Jiang[13] argues that the GeoInformatics is a science of living structure from the Third View of Space, which is an organic view of space. Tobler's law on a specific scale and scaling law across scales are used in a statistical manner to examine spatial patterns, and model spatial homogeneity and spatial heterogeneity. The livingness of a space can be determined using substructures and hierarchy. Differentiation and adaptation are used to transform a space into a living structure. The author points out that the new GeoInformataics requires the head/tail breaks as a clustering method and a new way of thinking of all spaces. This argument is particularly interesting as a new perspective to the building of the body of knowledge for cartography and GIS[14-15]. On the landscape of body of knowledge for cartography and GIS, map projection coupled with other classic principles remains essential to professional training. E-commerce and social networking platforms are depending on location and maps very much to offer effective services. However, most users, when using maps or involved in location-enabled smart applications, may not be fully aware of the planimetric distortions. Based categorical introduction of map projection and evaluation of distortions of typical projections, Lapaine[16] presents the procedures and results of distortion evaluation under approximate conformal, equal-area, and equidistant projections of an ellipsoid. This is essential for instructors and students to understand distortions of angle, area and distance when using popular online maps, most of which are based on sphere projections. This helps members of the public to build a professional map literacy based on spatial literacy.

Cartography and GIS together has been used as a platform and a way of solution to address the 2030 Agenda for Sustainable Development, which was adopted by member states of United Nations to build a shared future of peace and prosperity for people and the planet[17]. High-quality education is important to reduce inequities and build an inclusive educational community. Knowledge transfers among generations and among countries are essential both in the technology dimension like GeoAI and data, and in the policy dimension, like the coordinated global 2030 Agenda. Future learners are expected to bear capabilities of solving real world problems, which basically require learning and teaching process to be in problem based styles. Gartner[18] presents the background, considerations and design of the successful International MSc Cartography

Program, which is an "excellent master program" by the Erasmus+ agency of the European Union. Knowledge, skills and competencies are well integrated into a four semester training by four prestigious universities. This is particularly meaningful in the post COVID-19 new normal era and educators in cartography and GIS shall join efforts to achieve effective ways of resilient, sustainable and quality higher education.

Cartography and GIS educators have continuously pushed boundaries of theories and practices to in-depth research. At the same time new developments of neighboring disciplines, such as artificial intelligence and machine learning, are employed to handle classical cartographic questions and novel ideas. It is time now to enrich the cartography and GIS education resources with all these new findings and online open contents. Meng[2] presents the relationship among cartography and other geo-related scientific disciplines based on the history and background of science. The elaboration exhibits the emergence and uniqueness of cartography and the situation of cartographic education. The author's critical views about the transdisciplinary and interdisciplinary nature of cartography and the roles of cartographers are specifically inspiring not only to educators in universities but also to teachers in primary and high schools. Spatial cognition shall be developed as a basic capacity for young generations through clear understanding maps as a tool and a view of the world. And the expansion of knowledge frontiers coupled with the latest technology breakthroughs and related ethical issues shall be infused into the curriculum.

4 Conclusions

At this moment we are still witnessing the unprecedented impact by the COVID-19 pandemic. Educators and policy makers around the world have been working on solutions to cope with the crises and seek opportunities to improve quality education with new paradigms. Information technologies have been used intensively and effectively to mitigate the effects to young generations and build a resilience education. It is hard to imagine what it could be without effective and low cost offering of tools and resources from private and public sectors when schools had been experiencing closure in the early times of the pandemic. During fighting COVID-19, maps and GIS have been used intensively in contact tracing, social distancing, spread modelling and many other scenarios of infection prevention. Meanwhile, the general public gains deeper understanding of maps. Cartography and GIS educators can take this moment as an opportunity to get people to have a professional awareness to maps. Improvements of map literacy can further help build capabilities of spatial thinking.

For this purpose, data sharing for educational activities is crucial. Traditionally government agencies collect, make and archive unimaginable numbers of maps and statistical data. Specific agencies have developed advanced geospatial technologies[19]. All these are invaluable for teaching. With the movement of freedom of information, education community can acquire more such kind of data and technologies as teaching contents. Over the last twenty years, internet giants, especially those in the areas like e-commerce and online searching platform, are accumulating big geospatial data about their users which enable such companies to further develop algorithms and tools for big data analytics. We have long realized that sharing experiences of best practices and pedagogical insights can effectively improve cartography and geospatial information education. A sustainable education asks for a collaborative community joining education, government and private sectors together, in which all parties can benefit and find more opportunities. In this way a problem based learning environment can be built which is particularly crucial for young students to touch on new technologies and real questions. One particular reflection

is that communities have to work together in a more concerted way. Graduates will the more competent for opportunities and further accelerate the rapid development and innovation of the geospatial information industry.

In addition, the latest research outputs in other neighboring disciplines, such as geodesy, surveying, photogrammetry and remote sensing, can also be considered by cartography and GIS educators into classes. Cartographers had been actively incorporating new ideas like artificial intelligence and expert systems to solve existing and new questions[6, 20]. Body of knowledge for cartography and GIS can help to sort knowledge architecture and structures dependencies. Educators and learners can then customize education resources according to specific requirements in a reasonable order and design expected goals at a given level. Open textbooks and education resources can meet requirements at different levels.

All these will make a future education of cartography and GIS more sustainable and resilient.

Acknowledgements: The guest editors are grateful for the contributions by all authors, the suggestions from the reviewers and the professional support by the publisher. We also appreciate the support from members of the Commission on Education and Training of the International Cartographic Association for their participation. Without these, this special issue may not be possible.

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