Journal of Geographical Systems (2021) 23:599–625
https://doi.org/10.1007/s10109-020-00339-x

ORIGINAL ARTICLE

Open geospatial tools for humanitarian data creation, analysis, and learning through the global lens of YouthMappers

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Received: 1 December 2019 / Accepted: 29 October 2020 / Published online: 22 November 2020

Abstract

OpenStreetMap (OSM), often thought of as a technological tool or platform, can be envisioned as a community of communities and informed by a broad understanding of geographical systems. In this article, we explore the community of university students known as YouthMappers, who utilize OSM and related tools for humanitarian data creation, analysis and learning. Students approach OSM simultaneously as aspiring members of the workforce in a global digital economy and as emerging world citizens of a global society. Established in 2014, YouthMappers is a campus-based consortium of more than 200 chapters in approximately 50 countries that networks and supports engagement in humanitarian data with practitioners, government agencies, and other actors. Open geospatial data are contributed to authentic campaigns through OpenStreetMap and an ecosystem of open source and proprietary tools. A 2019 survey of YouthMappers and an analysis of YouthMappers data contributions allow us to explore the following questions: Who are using open geospatial tools, and in what context? Which open geospatial tools are being used and where? How proficient are they as users? How confident do they feel? How prepared does this make them for the future? How do these patterns vary across the global digital divide? Results show evidence of mapping both locally and globally. They also reveal a gendered confidence gap, and tool use patterns hint at a gendered division of geospatial labor in some global contexts. Internships are key to unlocking job opportunities, and are prevalent among YouthMappers members. Findings also reveal that with growing self-reported proficiency, a commitment to the ethic of being a good global citizen increases, underscoring the potential promise for open geospatial tools to support not only workforce capacity, but also meaningful connections to learning about geography, place, people, and the world.

Keywords OpenStreetMap · Humanitarian mapping · Geospatial workforce · Digital divide · Gender · Global south

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JEL Classification I2 · O0 · J49

1 Introduction: Open tools for an open community

OpenStreetMap (OSM) is generally thought of as technological product. In practice, however, it is much more than the end result of users contributing through its tools. OSM defines itself as "a free, editable map of the whole world that is being built by volunteers largely from scratch and released with an open-content license" (OpenStreetMap Wiki contributors 2017), but the technology essentially serves as a data platform where as many as 5 million users contribute, edit, download and assess this shared public good. This leads some observers to describe OSM as an "online project, a perspective that refocuses attention on the efforts of creating the map over the map or database itself" (Brovelli et al 2019: 599). Other scholars notice that these actors who are a part of this project more frequently speak of OSM as a *community*, bringing into view the many sets of actors who create it. In line with thinking about the constellation of elements that make up a geographical system, we agree with this latter perspective, and add that it may be best thought of "as a community of communities" (Solís 2017) or a "complex socio-techno ecosystem that operates as a multi-scalar network" (Vespignani 2009).

In the interest of analyzing this system, we reflect in this article on a unique contributor community of university students who are mapping for humanitarian purposes. This global student community operates under the banner of YouthMappers, and engages in this ecosystem as a force of about 5000 or so users who comprise a network of campus-based groups. Despite their common identity as students, the wide participation of YouthMappers in building OSM through a variety of tools, across more than 200 institutions of higher education operating in more than 50 countries on all continents offer a unique opportunity to reflect on the use of OSM-as-platform, related tools and their performances as mappers. We explore this student-to-tool connection with the system, using both a contributor-centric analysis of dashboard metrics on their contributions and a survey of the respondents with respect to their perspectives as they prepare to enter the job market as members of a global society.

2 Background: The lens of YouthMappers

YouthMappers is a global consortium of university-based, student-led, and faculty-mentored local chapters, currently with members from 200 + university campuses in 50 countries around the world (www.youthmappers.org). The co-founding organizers, youth leaders, and supporters from the humanitarian community, chiefly USAID, help to organize global connected campaigns and encourage local mapping campaigns that directly address community-identified development

needs. Open geospatial data are contributed to and used from the open platform OpenStreetMap, and an ecosystem of open source and proprietary tools help to structure data creation and numerous applied activities of members.

YouthMappers was founded by faculty from Texas Tech University, The George Washington University, and West Virginia University, with support from the US Agency for International Development's GeoCenter, and now administered at Arizona State University. The consortium encourages students to expand experiences that lead to workforce capacity building, such as through internships and research fellowships. Moreover, a key aim is to go well beyond just building maps, to "build mappers" as members of a global society. The remote campaigns, leadership fellowships, regional ambassadors program, support for conference attendance, and blogs that promote exchange and solidarity among student peers across continents all serve to create bridges through technology. Jointly identifying common global targets such as the UN Sustainable Development Goals (Solís et al. 2018a, b; Solís et al. 2020), helps to consolidate a common vision for open geospatial tools at the service of community needs. Nevertheless, the flexibility of the consortium-chapter model allows each group of students to determine which tools to apply, which applications to develop, and how to conduct their own activities such as mapathons in unique ways that serve localized perspectives on what is valuable. Perhaps unsurprisingly, outcomes are as "diverse and richly contextual to the specific character of the campus and its students, as much as they share some approaches, tools, and the humanitarian open data vision" (Coetzee et al. 2018).

Embedded within the complex and highly varied landscape of higher education globally, populated with institutions that have wildly diverse standards, pedagogies, traditions, reputations, and assessments, the challenge of understanding the impact of open geospatial tools in this context becomes clear. Previous research on the network has explored questions of participation for learning standards and competencies, as well as attitudes and perceptions. Within the US tertiary education system, digital humanitarian mapping of YouthMappers has been linked down to the very tasks and activities both to the National Geography Standards (Heffron and Downs 2012) and the Geospatial Technology Competency Model (GTCM) (DiBiase et al. 2010) via (Solís et al. 2017). This underscores the potential for formalization of authentic use of such tools for broad learning goals. Yet in the global context, Hite et al. (2018) revealed stark differences between mappers in the US and from other countries in the network by examining the blogs of YouthMappers. For students in the Global South, an overwhelming tendency toward thinking on the collective level rather than the individual level has been found, a tendency that persists across genders and nationalities, and that can be considered evidence of students utilizing the experience to forge group or collective identities, especially since the mapping contributes to authentic programming (Hite et al. 2018). Indeed, Solís and DeLucia (2019) found that students who know the purpose and understand the end use of digital humanitarian mapping are more satisfied and show greater awareness of the benefits of technology, promoting reflection on affective aspects of learning about substantive content (e.g., disasters or needs in other parts of the world). When asked to respond

to statements before and after mapping, informed mappers significantly change their ideas about the importance of being a global citizen and giving back after building the map (Solís and DeLucia 2019). This study adds to this literature by exploring the tools that participants use to contribute, both in light of those contributions and in light of their roles as students.

3 Students preparing for the workforce

Over the last few decades, the geospatial workforce has grown globally across all sectors, and the field is expected to have a compound annual growth rate (CAGR) of 19% from 2017 to 2023 (Jackson 2013). Humanitarian mapping efforts are one-way for young people to gain valuable experience in both technical and practical aspects of the geospatial industry and to take advantage of such opportunities by learning the tools of the geospatial trade. Employability has emerged as a central concern for universities and students (Jackson 2013; Sin and Neave 2016). Today's global economy has evolved to become 'knowledge-driven' and increasingly competitive. University and college education more and more emphasize employment after graduation, and there is increasing pressure on educational institutions on developing the employability of students. Yet, research highlights that inadequate skills among graduates remain a constant problem for joining the modern workforce (Cumming 2010). With the importance of employability skills being a question for students in all degree tracks, students themselves have started to scrutinize the roles, and jobs that are available for them ahead (Dowling and Ruming, 2013). The calls for looking into student's employability skills have opened the opportunity for researchers to understand workforce preparation of students in higher education institutions. As the landscape of the global economy changes, there is a growing recognition that transforming learning in higher education institutions into employment-oriented preparation is often not straightforward (Fallows and Steven 2000). Ever-evolving technologies, shifting industries and the changing nature of jobs add to the complexity of employability and workforce development efforts (Fallows and Steven 2000). Employers today prefer graduates who are multi-skilled, not just trained for a specific job, and these changes occur rapidly, certainly on average more rapidly than university degree programs can keep up with adaptation (Arrowsmith et al. 2011).

The study of geospatial systems includes many skill-based competencies and in the present era of data, Geographic Information Systems (GIS) has emerged as one important skill for career advancement—and not just for geographers. GIS has grown to become an integral part of many degree programs. Including in fields like economics (Overman 2010), public policy and management (Miller et al. 2007), planning (Holdstock 2016), public health (Craglia and Maheswaran 2016), and many others. In fact, these skills are increasingly recommended additions and increasingly as recommended addition for credentialing, and there is evidence that shows GIS certificate programs can become more popular than the actual degree track (Kawabata et al. 2010). Students from different majors who may not wish to earn certificates may still choose to learn the importance of GIS literacy as an important factor for decision making. Furthermore, there is growing recognition

among students that non-technical skills are equally important as technical ones for professional success (Medlin et al. 2001; Knobbs and Grayson 2012). 'Teamwork' is one of the most important competencies consistently mentioned across all employability frameworks (Tymon 2013). Many of the soft skills present in mapping through YouthMappers are considered important by professionals in geographic career fields (Solem et al. 2008) as well others like engineering (Itani and Srour 2015) and business (Robles 2012). Songer (2010) find that web-based GIS increases student's self-efficacy and content knowledge in general. Furthermore, open GIS is seen as a potentially essential component for robust research, whereby the principles of openness, transparency, and sharing underscore practices of critical spatial data science (Brunsdon and Comber 2020). These are just some of the many reasons why higher educational institutions are actively pursuing to integrate GIS-based coursework to improve skills of an interdisciplinary body of students (Sinton 2009). What is less well understood is how the extra-curricular activities students undertake during their time at higher educational institution impacts their workforce development and employability (Lau et al. 2014; Arranz et al. 2017), as well as the extent to which the participation helps students in their career preparedness (Stuart et al. 2011). While students prepare for careers through tertiary education, how might their association with extracurricular activities such as YouthMappers help them acquire proficiency, experience, and confidence in using geospatial tools, as well as learning related "on the job" skills that are associated with humanitarian mapping?

4 Students emerging as global citizens

As noted above, the end goal of landing a job looms increasingly large in the minds of students and universities alike. At the same time, the impetus for higher education to prepare a broadly educated citizenry continues unabated. In the geospatial field, humanitarian mapping is making important contributions not only to introduce tools and skills, but also for opening possibilities to connect to others and contribute to solving real world issues such as for disaster prevention and relief (Solís and Rajagopalan 2019). Geospatial data can help predict human and infrastructural exposure to hazards, can help to formulate plans like evacuation strategies, and design interventions during disaster events like for response and recovery actions in vulnerable areas. A prime example of how crowd mapping has made its mark is how a worldwide community of mappers digitized buildings and roads based on high resolution imagery after the 2010 Haiti earthquake, allowing for emergency response by aid organizations (Albuquerque et al. 2016). The Haiti efforts led to the formation of Humanitarian OpenStreetMap Team (HOT), a community of practitioners who built a network that aids and assists with creation of maps for disaster and international development issues on OSM. Studies suggest that crisis situations provide motivation for volunteers to join humanitarian campaigns (Poiani et al. 2016). While predominantly evolved as a response to disaster situation, this approach was soon scaled to produce maps on an anticipatory basis before any crisis.

Mapathons (or mapping parties) have become one important way to engage participants with mapping exercises (Coetzee et al. 2018). Not only does mapping give

lay volunteers an opportunity to contribute to society, it is also an opportunity to learn new technologies (Poiani et al. 2016). Given their relatively low entry cost, mapping exercises also help develop spatial literacy skills as participants learn core concepts of mapping and GIS technology (Quill 2018) while focused on the mission of the map. These activities in the practitioner sector began to attract the interest of students as well (after all OpenStreetMap was originally invented by a graduate student). Clearly, humanitarian mapping exercises have a potential to help students gain for their careers, as noted, but the social and soft-skill dimensions of being a part of something worthwhile, to make a difference, is also a significant motivator (Solís and Rajagopalan 2019).

Established as a space to give voice and leadership opportunities, and to grow the community of students within the broader community of communities of OSM, YouthMappers was designed to support the emergence of global citizens in the making (Solís et al. 2020). Adaptations to the typical use of the tools, mapathons, and even project tasks have grown the possibilities for OSM as a whole. For instance, given the challenging timing of engaging university students in adhoc disaster response which may hit during final exams, sponsors began seeking additional robust end use cases for the mapping tasks, expanding into slow moving disasters such as chronic health stresses (Solís et al. 2018a, b) and linking to the research interests of YouthMappers own local research topics through fellowships and fieldwork support. In these and other ways, YouthMappers efforts have successful in enhancing soft skills like 'teamwork' and 'creative thinking' as per students' own perceptions. This dimension speaks to the intrinsic aspect for youth participation at the level of individual motivation (Budhathoki 2010) or how being a part of a community motivates open mappers (Budhathoki and Haythornthwaite 2012). In this sense, then, the mapping tools serve as a window on a global society, where youth can connect to other people and places through the OSM as a community device. We expect that how they utilize which tools, how they perceive themselves and each other will differ by characteristics of the mappers, including their self-perceptions as global citizens, gender and where they call home, be it in the Global North or Global South.

5 Performance: What do they map and where?

To track and monitor the mapping activity and growth of YouthMappers, we analyzed the entire OSM database to identify contributions from mappers known to be associated with a YouthMappers chapter. First, we curated a list of OSM usernames for each responding YouthMappers chapter. These were collected through both the annual chapter surveys (for rosters) and an online form (for individuals). We then quantify their contributions to the map using the same approach to OSM data analysis presented in by Solís and Rajagopalan (2019). This contributor-centric approach to OSM data analysis allows us to efficiently process an entire planet's worth of geospatial information and extract individual map edits performed by known YouthMappers through the analysis of OSM data and the metadata describing who edited the map, when, and where. This allows us to account for both the number of individual mappers as well as the quantity and types of contributions they make to

OSM. This differs from other OSM metrics that measure presence based on specific hashtags (such as #youthmappers) in OSM changeset comments. We find these hashtags to be noisier than expected because thousands of mappers not associated with YouthMappers have contributed to humanitarian mapping tasks that include a #youthmappers hashtag. Chapter response rates are estimated at 78%, so metrics are conservative but appear to be representative of the community as a whole.

We present this quantified editing activity back to the YouthMappers community through an interactive map and dashboard available at activity.youthmappers.org. This map contains a filterable dropdown menu of active accounts so that YouthMappers can quickly visualize the mapping performed by themselves, their peers, or entire chapters. In addition, the map includes a link to submit missing OSM usernames for tracking if a user cannot find themselves or their peers in the dropdown menu (as well as the ability to remove their username from the list if desired). At small-scale views, the map shows a heatmap of editing activity for the entire globe. Individual features last edited are highlighted at higher zoom levels (Figs. 1, 2).

In the case of humanitarian mapping, the most common contributions to the map are buildings and roads. Globally, YouthMappers have edited over 9 million buildings on the map and 145,000 km of roads. The effect of mapathons on monthly participation can be clearly seen in Fig. 3 where there are significant spikes during specific months with large mapping events that appear to correspond to the academic student rhythm (Fig. 3).

6 Results from a global survey across learning contexts: What do they use and how do they do it?

A 2019 YouthMappers survey of students affords a unique opportunity to explore the following questions: *Which open geospatial tools for collection or analysis are being used? How proficient are they as users? How confident do they feel in using them? How prepared might this make them for the future? And how do these patterns vary across the global digital divide? or across the digital gender divide?* We also offer some reflection to interpret some of these findings with respect to how they correspond or fail to align with the original vision for establishing the YouthMappers community within the broader OSM community.

In mid-March 2019, a global online survey of questions was issued via surveymonkey to email addresses of all known YouthMappers contacts. These included students who had registered for participation in any activity, mentors, individuals signing up to receive the newsletter, and others (including non-students). In all, 2607 direct survey invitations were sent. Because YouthMappers network organizers only manage the roster of student officers, and not all regular chapter members, a social media campaign on Facebook and Twitter followed, with a direct weblink that encouraged all students to respond. The survey was open for 8 weeks to mitigate the staggered timing of semester exams or university breaks that unfold across world

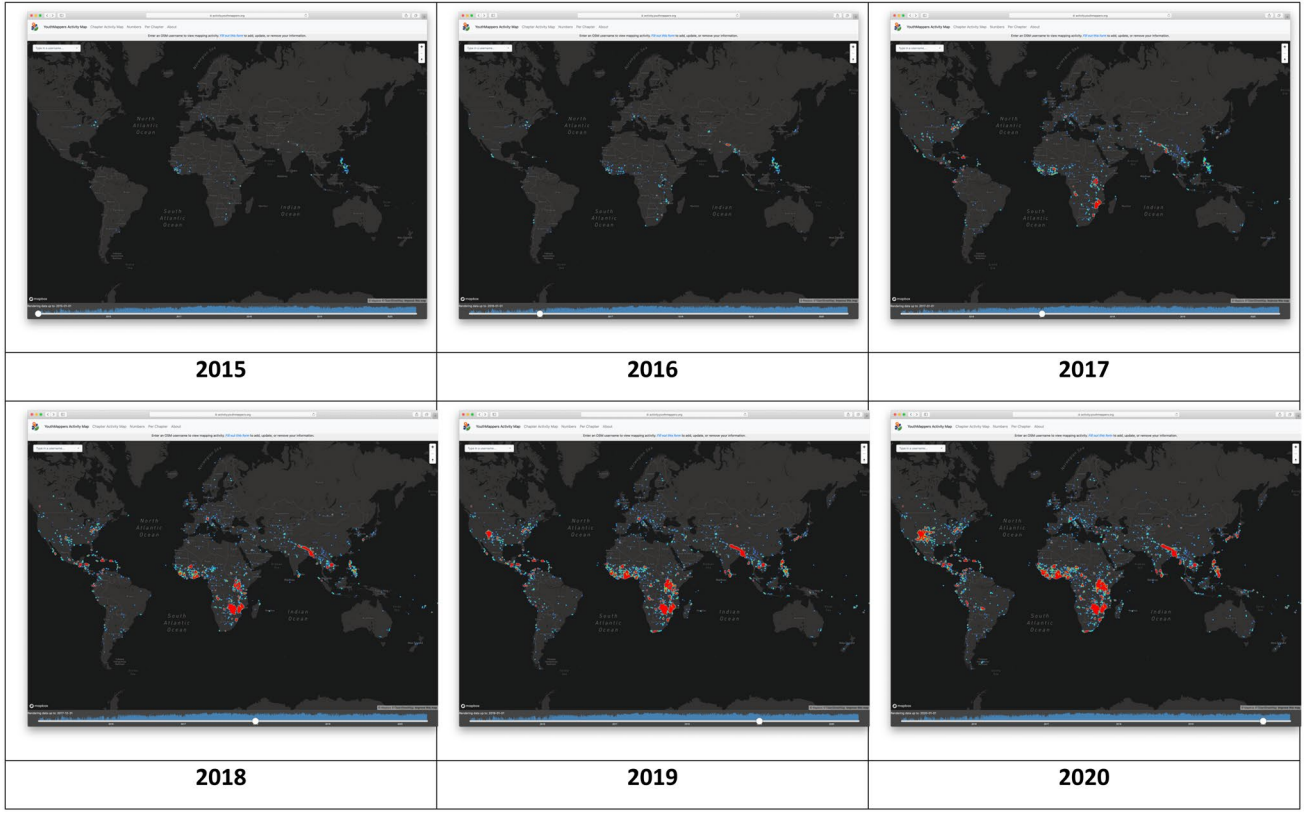


Fig. 1 Cumulative changes made to OpenStreetMap by YouthMappers, by year (2015–2020)

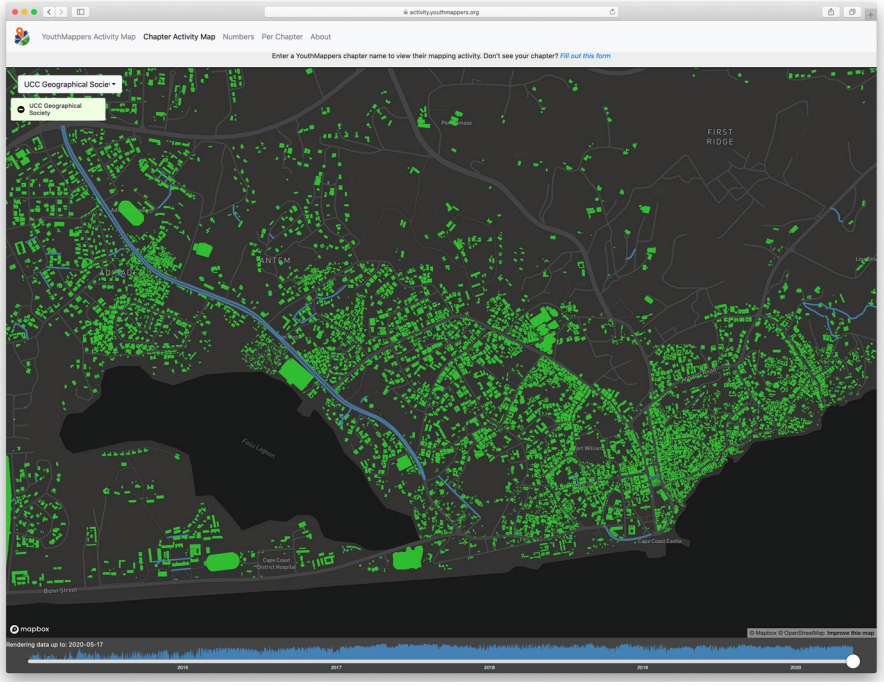


Fig. 2 Example Cape Coast, Ghana local mapping by YouthMappers (features in green and blue were last edited by a member of YouthMappers at the University of Cape Coast)

regions differently. At the time of ending survey data collection (May 2019), YouthMappers numbered 151 university campus chapters in 42 countries.[1]

Of the 456 respondents, some were mentors or affiliates and were directed to a different questionnaire. Respondents indicating status as students and participants of YouthMappers numbered 338, of whom 30% were female. After removal of incomplete responses, and sorting for participants who had provided any answers to the subset of questions explored in this paper, a final $n=214$ was used for the analysis presented here. Of those, 64 or 30% identified as female. Respondents came from 32 different countries, spread across Asia, Africa, Europe, North America and Latin America, and Caribbean. The responses were grouped into two categories—global South (90%) and global North for purposes of summary regional comparison. Additional analysis of this survey is reported elsewhere, including results on workforce competencies (Solís et al 2017; Solís and Rajagopalan 2019).

[1] Evidence of continued strong growth of the interest in open mapping among the world's student population comes from the consistent addition of YouthMappers chapters since founding, sometimes at the rate of one new chapter per week: at the time of manuscript submission 6 months after the close of the survey, the network had increased to 212 chapters in 50 countries.

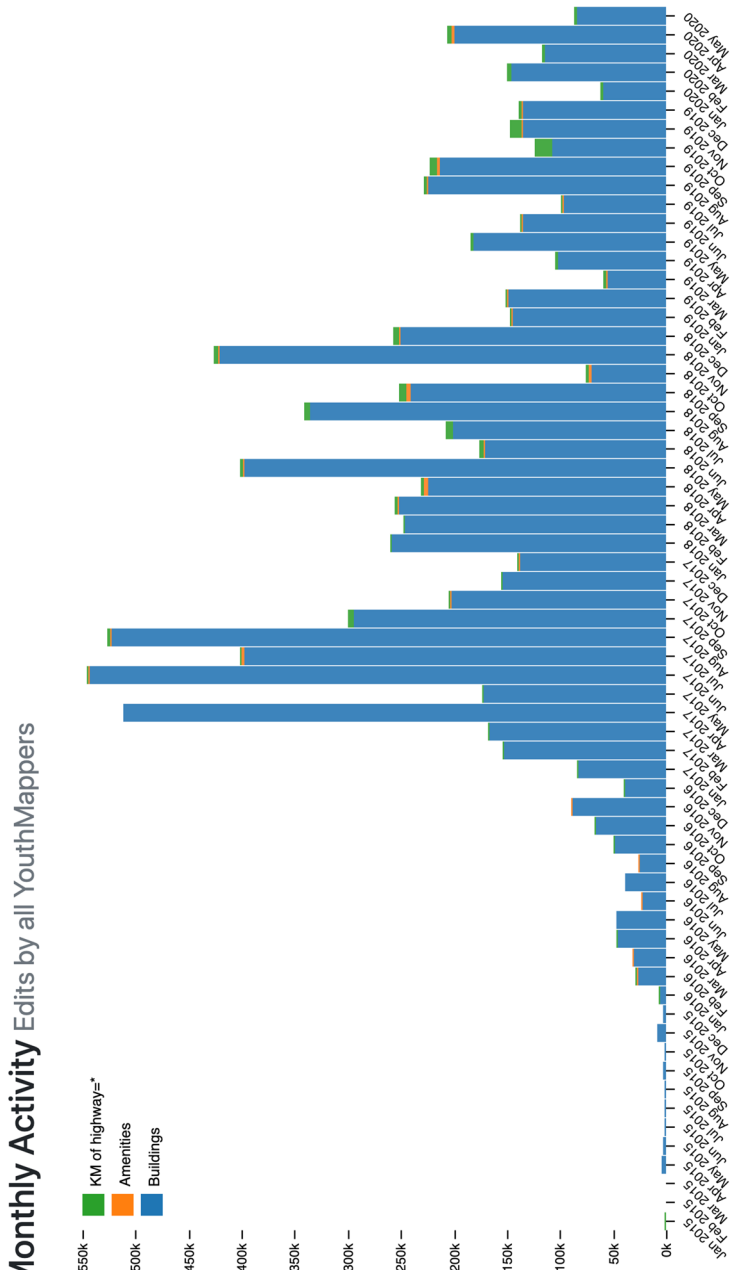


Fig. 3 YouthMappers edits to OpenStreetMap, by month

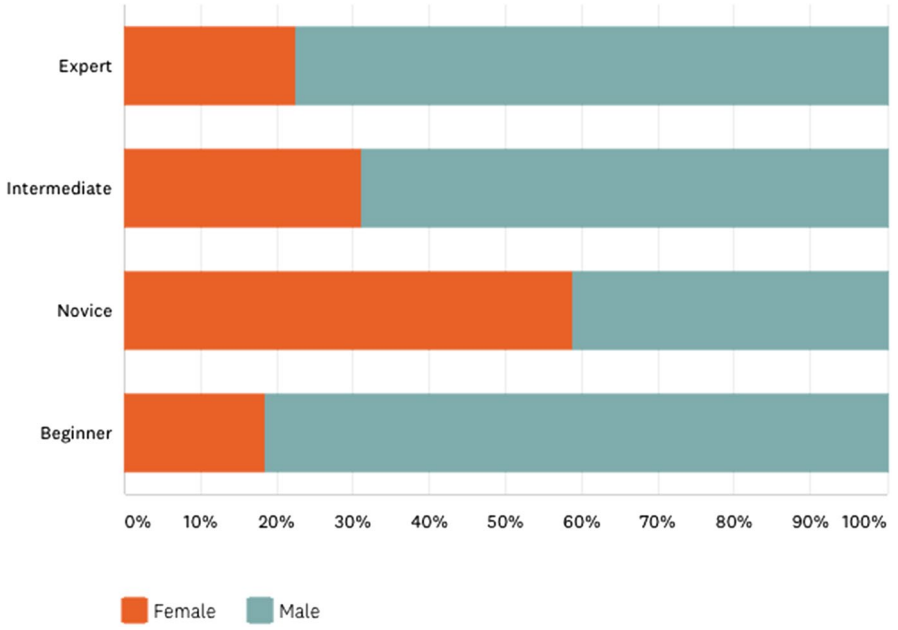


Fig. 4 Breakout of self-reported expertise by gender

In addition to basic data such as gender, country, university/college status, the survey presented a series of Likert scaled statements for respondents to indicate the degree to which they 'agree' or 'disagree'. Responses were grouped across three main axes of interest: gender, region, and stated level of expertise with open geospatial tools. To analyze responses and differences, the mean, standard deviation, variance, degrees of freedom was calculated for each relevant question. An independent *t*-test for statistical significance was computed on the differences between respondents by global South and global North, level of claimed expertise, and by male and female participants. Respondents were also divided between three groups of time spent with YouthMappers (*Group 1*—less than a year; *Group 2*—between 1 and 2 years; *Group 3*—2 years or more). We used χ^2 tests to calculate differences in responses among the three groups (Fig. 4).

Respondents were asked to first identify which "open geospatial tools you currently use" then self-rate "your general level of proficiency in using these tools overall" from beginner, to novice, to intermediate, to expert. While female students were slightly less likely to answer that they were beginners, they were also less likely to answer that they were experts. They identified at the "novice" level more frequently compared to their male counterparts, but these differences in self rating expertise were not found to be statistically significant among responding YouthMappers. Interestingly, the percentage of students who consider their skill level as 'expert' in geospatial tools increases with the time spent participating in YouthMappers activities. Overall, 38% of students with 2 years or more participation in YouthMappers consider themselves as 'expert', while only 24.5% with

Table 1 Self-reported proficiency of geospatial tools, by duration of participation

	Beginner	Novice	Intermediate	Expert	Total
Years spent with YouthMappers, all respondents[a]					
Less than 1 year	20	11	40	13	84
1–2 years	1	1	38	13	53
2 years or more	2	4	43	30	79
Total respondents	23	16	121	56	216
Years spent with YouthMappers, Male respondents[b]					
Less than 1 year	16	4	26	11	57
1–2 years	1	1	28	9	39
2 years or more	1	2	29	24	56
Total males	18	7	83	44	152
Years spent with YouthMappers, female respondents[c]					
Less than 1 year	4	7	14	2	27
1–2 years	0	0	10	4	14
2 years or more	1	2	14	6	23
Total females	5	9	38	12	64

[a]A χ^2 test indicated that the relationship between years spent with mapping and self-reported proficiency of tools by all respondents was significant [χ^2 (6, $N=216$) = 40.230, $p<0.05$]

[b]A χ^2 test indicated that the relationship between years spent with mapping and self-reported proficiency by males was significant [χ^2 (6, $N=152$) = 30.573, $p<0.01$]

[c]A χ^2 test did not find any statistically relationship between years spent with mapping and self-reported proficiency by females

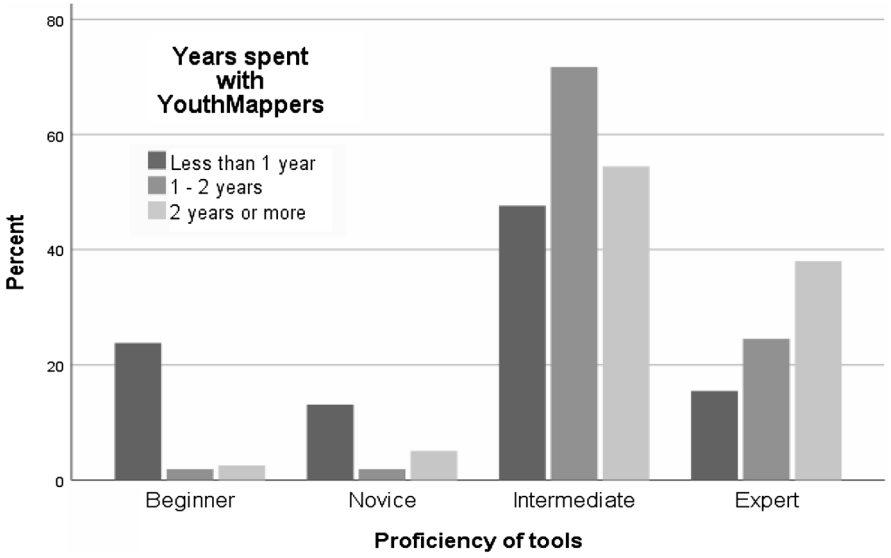


Fig. 5 Self-reported proficiency of geospatial tools, by duration of participation

Table 2 Open geospatial tools used by YouthMappers students, by gender

	FEMALE MAPPERS			MALE MAPPERS			DIFFERENCE
Average number of tools	3.484375			3.593333333			0.10895833
Total tools named	212	*% among named list*	*% among n=64 respondents*	502	*% among named list*	*% among n=150 respondents*	
JOSM	38	17.9%	59.4%	107	21.3%	71.3%	12.0%
Other Tool	12	5.7%	18.8%	42	8.4%	28.0%	9.3%
IdEditor	26	12.3%	40.6%	68	13.5%	45.3%	4.7%
Mapillary	2	0.9%	3.1%	11	2.2%	7.3%	4.2%
Python	0	0.0%	0.0%	5	1.0%	3.3%	3.3%
ENVI	0	0.0%	0.0%	4	0.8%	2.7%	2.7%
Google Earth / Maps	1	0.5%	1.6%	6	1.2%	4.0%	2.4%
Maps.Me	2	0.9%	3.1%	8	1.6%	5.3%	2.2%
ODK-OMK	3	1.4%	4.7%	9	1.8%	6.0%	1.3%
Geoserver	1	0.5%	1.6%	4	0.8%	2.7%	1.1%
OSMtracker	2	0.9%	3.1%	6	1.2%	4.0%	0.9%
Umap	1	0.5%	1.6%	3	0.6%	2.0%	0.4%
FieldPapers	1	0.5%	1.6%	2	0.4%	1.3%	−0.2%
SAGA	1	0.5%	1.6%	2	0.4%	1.3%	−0.2%
OSMAND	2	0.9%	3.1%	4	0.8%	2.7%	−0.5%
PostGIS	2	0.9%	3.1%	3	0.6%	2.0%	−1.1%
ERDAS	3	1.4%	4.7%	4	0.8%	2.7%	−2.0%
Geoda	2	0.9%	3.1%	1	0.2%	0.7%	−2.5%
ArcGIS	16	7.5%	25.0%	33	6.6%	22.0%	−3.0%
R	3	1.4%	4.7%	2	0.4%	1.3%	−3.4%
KoboCollect	6	2.8%	9.4%	8	1.6%	5.3%	−4.0%
QGIS	46	21.7%	71.9%	97	19.3%	64.7%	−7.2%
OSM	54	25.5%	84.4%	111	22.1%	74.0%	−10.4%

Compared by gender, the number of tools as a percentage of named tools, t=-1.67, p=0.0503; and as a percentage of respondents naming each tool by gender, t=0.05, p=0.476; neither reaching statistical significance by gender.

1–2 years do so; meanwhile 15.5% of those with less than 1 year of participation claim the same. A χ^2 test indicated that the relationship between years spent with mapping and self-reported proficiency of tools was significant across all respondents at $p < 0.05$. Further breakdown by gender revealed that this result held for male respondents, significant at $p < 0.01$ but we did not find any statistically relationship between years spent with mapping and self-reported proficiency by females (Table 1; Fig. 5).

The survey collected an open-ended list of all tools each respondent identified as using. As seen in Table 2, female YouthMappers named an average of 3.48 tools to the 3.59 named by their male counterparts. This difference was not found to be statistically significant by gender, whether calculated as the number of tools named or calculated as a percentage of respondents naming each tool. Nevertheless, there are subtle patterns of difference in the use of specific tools visible across the responses. Ordered by use predominantly by male students (top, blue) to use predominantly by female students (bottom, orange), Table 2 presents an array of multipurpose open (and some proprietary) tools to collect, analyze, and visualize geospatial data under the context of humanitarian mapping. Interestingly, the three most often named tools, OSM, JOSM, and QGIS are at polar ends of the use spectrum: male mappers more often list JOSM, while female mappers most often list OSM and QGIS. R is used in greater proportion by female respondents (despite that they make up a smaller proportion overall) (See also Bivand 2020). Those tools that are among the

Table 3 Use of open geospatial tools and skills acquired, by duration of participation

Statement	Means and standard deviation in different groups						Results of ANOVA	
	0–1 year		1–2 years		2 years or more		*F*-value	*F*-prob
	Mean	SD	Mean	SD	Mean	SD		
Count of reported number of tools currently using	2.60	1.670	3.59	2.407	4.18	2.768	9.281	0.000
Number of skills learned through participation in YouthMappers activities or informal trainings	4.34	3.831	5.22	3.653	6.37	4.318	5.333	0.005

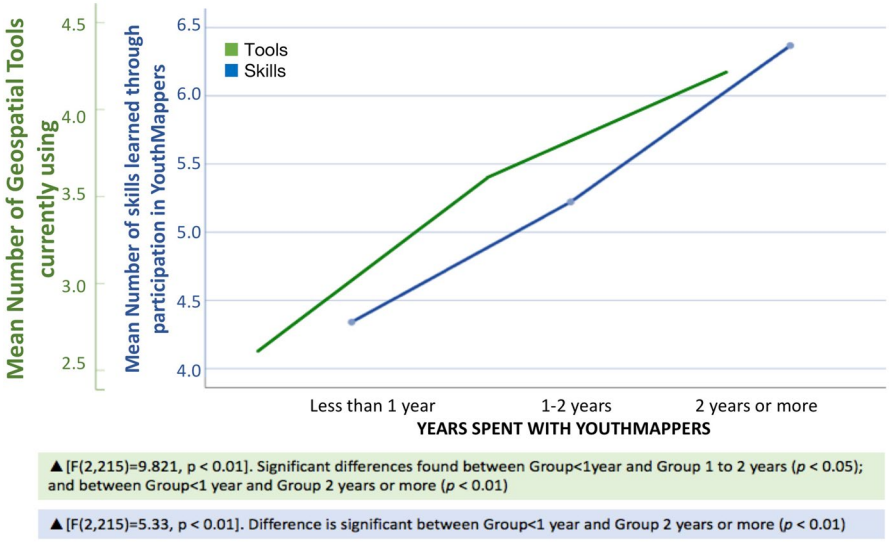


Fig. 6 Count of geospatial tools and skills, by duration of participation

least often mentioned also are among the most used on par by respondents of any gender.

Closer examination of the number and type of tools used by gender reveal at the lowest and highest levels, the differences are strongest, where beginning female mappers name on average one less tool, but female mappers claiming that they are experts are using nearly one more tool than male counterparts. Expert female mappers report using both JOSM and GIS at near universal rates. Despite that these descriptive differences are interesting, the strength of these patterns is not found to be statistically significant (Table 3; Fig. 6).

With respect to the duration of participation, a one-way ANOVA was conducted to compare the mean number of geospatial tools used by the students revealing a

significant difference [$F(2,213) = 19.211$, $p < 0.01$] between three categories of time spent participating in YouthMappers activities. Post hoc comparisons using the Tukey test show that there was a significant difference between students participating 'less than 1 year' and '2 years or more' ($p < 0.01$), with students in the latter category on average using 1.58 geospatial tools more than those from 'less than 1 year'. There was also a significant difference between 'less than 1 year' and '1–2 years' ($p = 0.037$) where students participating in YouthMappers activities for 1–2 years on average use 0.99 more geospatial tools those from 'less than 1 year' group. One-way ANOVA also reveal a significant difference in mean skills learned among the three groups. Post hoc comparisons show a significant difference between 'less than 1 year' and '2 years or more' ($p < 0.05$) whereas YouthMappers with 2 years or more of participation have on average claimed to have learned 2.03 more skills than those with less than 1 year. These results support the idea that the longer YouthMappers students participate, the greater number of open tools they will use and the more skills they will acquire (Table 4).

Neither are there statistically different results in terms of whether respondents say they "understand what is meant by open geospatial data." However, when it comes to confidence levels, the differences are statistically significant at $p < 0.01$. Female mappers are less likely to strongly agree, more likely to disagree, that they are confident in their ability to use the technologies, even when controlling for proficiency levels (Table 5).

On the other hand, when the respondents are categorized according to their region of origin, Global South or Global North (including US and European chapters), the "confidence gap" is not significant. Neither are the number of tools, or patterns of use for JOSM or QGIS. However, the meanings of "open geospatial data" are statistically significantly less clear for YouthMappers in the Global South at the $p < 0.05$ level (Table 5; Figs. 7, 8).

What this means for students who learn to use open geospatial tools is that they feel very prepared for professional careers, especially among those who have developed proficient expertise. Those who rate themselves as experts are more likely to feel very prepared when compared to those who are intermediate, who are more likely to only feel somewhat prepared ($p < 0.05$). Even among those simply exposed as beginners, a large majority feel somewhat or very prepared for the geospatial workforce. We found no statistically significant difference between male and female respondents. Results show that 65.7% of students "strongly agree" that "their frequent participation with geospatial/mapping technology through YouthMappers make them a stronger candidate for employment". Likewise, 62.3% feel that their YouthMappers experience has been "very helpful" in preparing students for a professional career, where answers were statistically significantly higher for female respondents at $p < 0.05$ level. Respondents from the Global South ($M = 3.52$, $SD = 0.74$) feel their experience with YouthMappers has been more helpful compared to respondents from the Global North ($M = 3.10$, $SD = 0.79$) and the difference is significant at $p < 0.05$ (Fig. 9).

In order to attempt to identify the ways in which these tools were utilized in the activity context of YouthMappers, we asked respondents to indicate whether they were able as a direct result of their chapter participation, to enjoy a set of

Table 4 Open geospatial tools usage and responses to likert statements by self-rated expertise, by gender

	Beginner	Novice	Intermediate	Expert						
	(a) Please rate your general level of efficiency in using these tools overall[a]									
Females	5	9	38	12						
Males	19	8	84	44						
Total	24	17	122	56						
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
	(b) I understand what is meant by geo-spatial data[b]					(c) I am confident in my ability to use technology[c]				
Females	35	28	2	0	0	31	30	3	1	0
Males	97	53	3	2	0	110	44	2	0	0
Total	132	81	5	2	0	141	74	5	1	0

[a]No significant association between gender and self-reported proficiency of tools

[b]No significant association found

[c]A χ^2 test indicated the relationship was significant [χ^2 (3, $N=216$) = 12.813, $p<0.01$]

Table 5 Open geospatial tools usage and responses to likert statements by global region

	Beginner	Novice	Intermediate	Expert						
	(a) Please rate your general level of efficiency in using these tools overall[a]									
Global North	2	2	15	3						
Global South	22	15	105	53						
Total	24	17	120	56						
	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
	(b) I understand what is meant by geo-spatial data[b]					*(c) I am confident in my ability to use technology*[c]				
Global North	20	2	0	0	0	17	5	0	0	0
Global South	111	79	5	2	0	124	68	5	1	0
Total	131	81	5	2	0	141	73	5	1	0

[a]No significant association between region and self-reported proficiency of tools

[b]A χ^2 test indicated the relationship between region and the statement was significant [χ^2 (3, $N=219$) $=9.880$, $p<0.05$]

[c]No significant association found

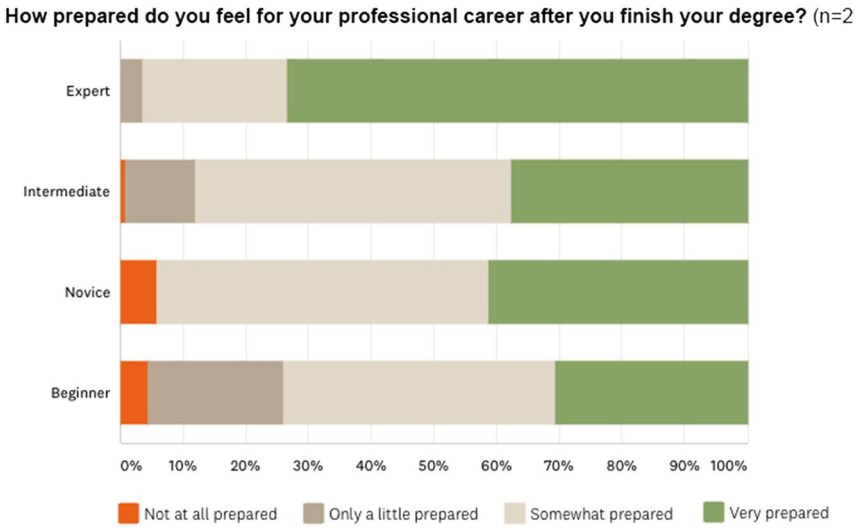


Fig. 7 Career preparedness

professional development or job opportunities. Activities such as field mapping with open tools (70 male to 48% female), or teaching local community members how to use open mapping (59 male to 30% female) were predominantly undertaken by the male members of student groups, up to twice as likely. This resonates with the above pattern of gendered use of data collection versus analysis tools. In any case, the responses suggest that increased engagement led to greater chance for internship and job offers. For most activities, there is no clear statistically significant relationship to getting a job, with three notable exceptions: (1) the combination of taking formal coursework in open geospatial technologies and having a previous internship increased the likelihood of landing a paid job; (2) incorporating formal reflection on learning processes such as through journaling was more likely to reflect the difference between having only an internship and also getting a job ($p < 0.05$); (3) χ^2 test of independence reveals a significant relation [χ^2 (6, $N = 196$) = 20.43, $p < 0.01$] between years associated with YouthMappers and getting either Internship or job offers as a result attributed to participation in YouthMappers (Table 6).

Respondents reported that 'teamwork' is the most acquired soft-skill due to participating in YouthMappers, which is followed by 'creative thinking'. Males and females have different perspectives in terms of which soft skills were gained as a result of their participation in YouthMappers activities. Higher percentages of female students report 'teamwork', 'creative thinking', 'global learning' and 'written communication' compared to males. As students spend more time with YouthMappers activities, the results of chi-squared tests show there is a self-reported increased general acquisition of soft skills by students. Higher percentages of students who have spent 2 years or more with YouthMappers report enhancing soft skills compared to those who have spent less than a year with the community.

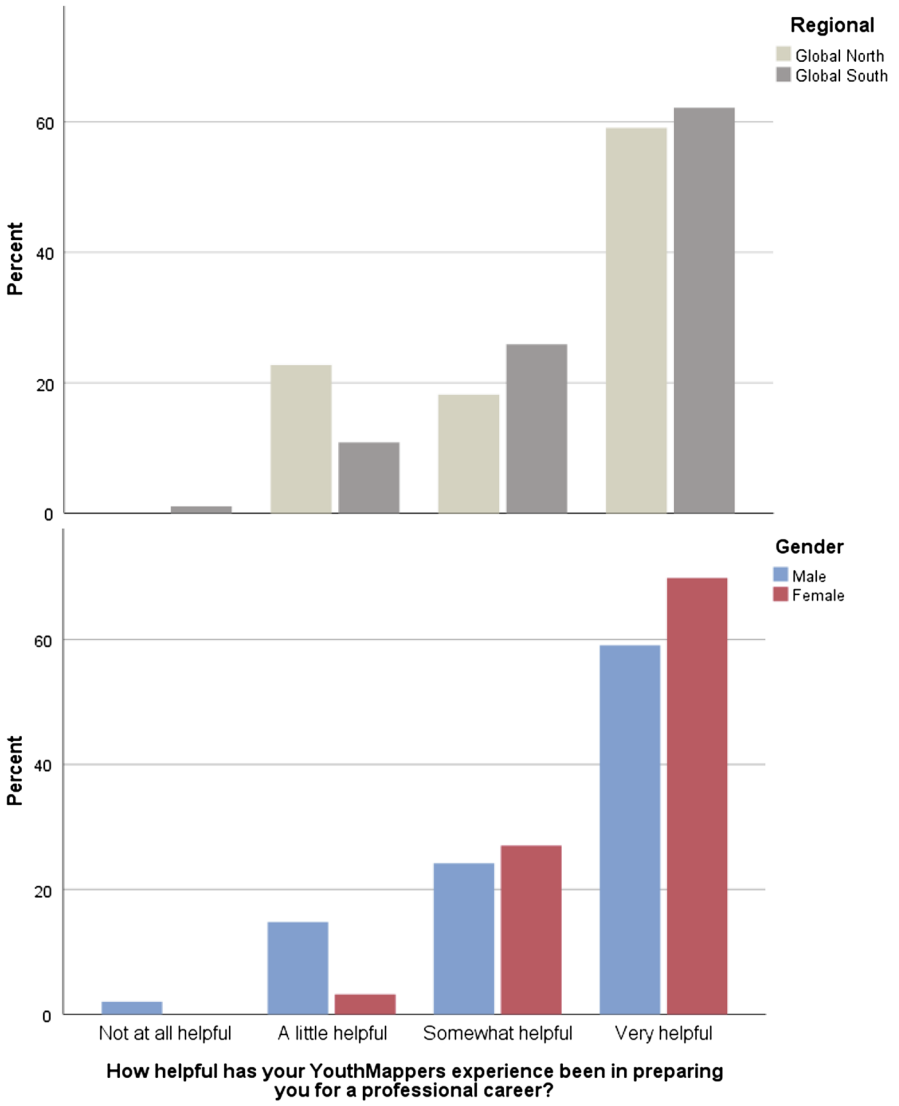
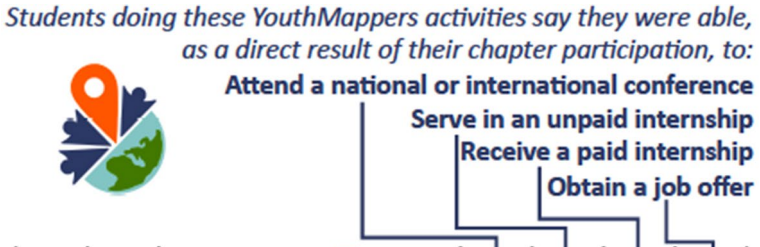


Fig. 8 Helpfulness of participation in YouthMappers, by gender and by global region

These soft skills are not only important for the workforce development, but also relative to preparing as global citizens. In prior related research (Solís and DeLucia 2019: 530) we found that comparing groups before and after doing purposeful open mapping for the first time significantly changed their level of agreement with the importance of being a good citizen. With these results, we confirm that in the global network of YouthMappers, there is widespread agreement about



MALE	FEMALE	ACTIVITIES ▼				
83%	80%	Attended or organized a Mapathon	46%	13%	24%	5%
78%	88%	Received training	47%	17%	20%	6%
28%	27%	Initiated a local chapter-led project	47%	18%	23%	5%
70%	48%	Conducted field mapping	48%	17%	26%	6%
55%	53%	Recruited new members to their chapter or for a new chapter	50%	16%	22%	5%
59%	30%	Taught local community members how to use open mapping	48%	15%	25%	8%
18%	16%	Took college curriculum with humanitarian mapping	51%	11%	26%	9%
17%	9%	Completed a formal university course dedicated to humanitarian mapping	55%	6%	29%	13%
33%	28%	Conducted online exchange with another chapter	53%	14%	24%	10%
28%	17%	Performed outreach to local secondary, middle or primary schools	57%	11%	21%	4%
57%	55%	Served as an officer or leader of their local YouthMappers chapter	51%	14%	26%	6%
28%	23%	Participated in an in-person exchange with another chapter	63%	20%	29%	8%
14%	13%	Served as a mapping Intern	63%	29%	25%	11%
23%	31%	Received a YouthMappers Leadership or Research Fellowship	76%	16%	30%	4%

Fig. 9 Outcomes of open geospatial participation in YouthMappers, by gender

Table 6 Reported soft skills acquired, by gender and by duration of participation

Soft skills	% Overall	% of male	% of female	χ^2	% in less than 1 year	% in 1–2 years	% in more than 2 years	χ^2
Civic engagement	**30.6**	31.8	27.7	*0.373*	28.2	29.6	31.2	*1.073*
Creative thinking	**42.0**	35.4	40.1	*0.847*	35.3	37.0	49.4	*3.783*
Critical thinking	**38.7**	41.4	32.3	*1.602*	37.6	37.0	43.0	*0.673*
Global learning	**40.5**	40.1	41.5	*0.038*	36.5	38.9	46.8	*1.932*
Written communication	**23.9**	22.3	27.7	*0.739*	24.7	18.5	26.6	*1.204*
Oral communication	**35.1**	36.3	32.3	*0.332*	36.5	29.6	39.2	*1.318*
Teamwork	**51.4**	49.7	55.4	*0.598*	51.5	46.3	55.7	*1.135*
Critical reflection	**20.7**	21.7	18.5	*0.286*	22.4	14.8	24.1	*1.775*
Others	**2.3**	0.9	3.2	*0.002*	3.5	1.9	3.8	*.436*

*$p < 0.05$

**$p < 0.01$

the importance of being a good citizen (96.0% of respondents think it is very important or extremely important). However, when examining the proficiency that mappers gain in the open geospatial tools, it may be a matter of degree: student experts felt it was extremely important (84.9%) versus being just very important (9.43%) while mappers at intermediate levels are in slightly lower agreement (extremely 65.5%, very important 31.9%), with a difference significant at the $p < 0.05$ confidence level.

7 Discussion: Towards open tools for an undivided future

From the findings above, a few notable observations and questions arise. Given the varied use of particular tools across genders, patterns of a gendered division of labor may be visible. In particular, activities that require public engagement, field excursion, or community-based data collection require some particular tools that are more frequently used by male members of chapters. On the other side, female students more often report using tools that could be deployed in a campus lab setting, and that may be more typically related to analysis of data that would have been field collected. However, this survey did not explore in depth the applications of such different toolsets, so the results should inform future queries that unravel a more sophisticated understanding not only of the digital divide, the gender digital divide, but a gendered division of labor and use that could be used to target the specialized roles that female mappers are assuming, in ways that leverage rather than directly confront socio-cultural norms, in order to promote tool learning that can begin with easier uptake, and move towards a full array of adoption.

The relatively few instances of finding statistically significant differences by gender are intriguing. Despite that female students name a similar number of tools they are proficient in, and distribute themselves similarly along a spectrum from beginner to expert, they still reveal a "confidence gap," when it comes to utilizing the technology. This finding would support efforts to explicitly build confidence through well-designed interventions that may include an "overdetermined" set of components that are known to support women's participation (Solís et al. 2018a, b).

Most interesting, however, is the finding that with growing self-reported proficiency, a commitment to the ethic of being a good global citizen increases. Future research should explore the mechanisms by which learning how to use open geospatial technologies for authentic humanitarian mapping might lead to such understandings, and how exactly this practice might diverge or converge in different educational contexts.

In terms of where YouthMappers are mapping, we see evidence of both participation in global humanitarian mapping efforts as well as local mapping. For example, a very active YouthMappers chapter in Ghana, The University of Cape Coast Geographical Society, mapped over 100,000 buildings across Zimbabwe, Kenya, and Ghana in the first half of 2017 before mapping thousands of buildings locally in Cape Coast in the latter half of that year. Similarly, the University of Dar Es Salaam YouthMappers was very active in mapping buildings in Mozambique in 2016 and has subsequently added thousands of buildings and roads in their home city in the

years since. These anecdotes highlight the mission of YouthMappers to "not just build maps, but built mappers" in that these students are introduced to OSM through humanitarian mapping, and then choose to continue mapping outside of the humanitarian context, contributing to open data in their own communities, and likely their own research initiatives.

There are a number of important limitations of this study. First of all, given the lack of gender significance for many questions does not necessarily indicate that gender differences are not present; merely that the survey did not detect them in this study. Indeed, the lack of gender differences can be an enlightening result in itself, particularly when there may be biased assumptions about the way female versus male students use geospatial tools, or how they contribute to data systems. Also, the open geospatial tool ecosystem is a rapidly changing one, and students may not be able to articulate their full engagement through open-ended questions. For instance, no respondent mentioned the Tasking Manager, yet YouthMappers global campaigns are always posted on the HOT TM and local chapter-initiated efforts appear on the TeachOSM instance of TM. Furthermore, our YouthMappers have contributed to the testing and early use of AI-assisted mapping tools, namely Facebook's RapID tool. Other augmented tools, or artificial intelligence technologies such as machine learning were not explicitly queried, yet represent one of the fastest growing areas for development. Finally, the lack of availability of a control group to compare these results, means that future longitudinal research should be implemented in order to illuminate changes and shifts in results.

8 Conclusion

The findings presented here confirm that the YouthMappers design contributes to key capacity building elements for students to prepare for geospatial careers, which include positive results for female mappers and for students in the Global South. The study indicates areas for further research and potential awareness-raising among participants about the value of extracurricular humanitarian mapping. By increasing geospatial skills among university students to prepare them for employment and careers, along with its efforts to eliminate gender disparities in acquiring such skills and deploying such activity in service to humanitarian and development purposes, YouthMappers makes important contributions to the global spatial community of communities that characterizes OpenStreetMap.

On the basis of our findings, this paper hopes to stimulate discussions around the need to introduce such purposefully-designed extracurricular activities like YouthMappers in universities/colleges to both enhance the learning experience, and develop additional job market skills, in order to better prepare university/college students for working as global citizens in a geospatial workforce. The key role of tools in developing these skills and experiences underscores the critical interface between users and technology within geospatial systems (See et al. 2019). This system should carefully consider the role of higher education, which continues to reevaluate the place for learning within a new global reality (Care et al. 2018; Trilling and Fadel 2012; AACU 2007). As we have witnessed the rise in the open use of technologies,

open source development of software, open data platforms and mechanisms, and open massive learning trends (Chronicle Review 2016), these open tools are presumed to hold a unique potential to support—or at least influence—the realization of twin ambitions: optimal technological performance in an information society, and global understanding of the meaning of living in that society through technological collaboration. In order to effectively break open the gender divide (Borgonovi et al. 2018) and the digital divide (Lane 2009), open systems and open tools have thus been promoted as integral to 21st century learning (South and Stevens 2017). Within this complex narrative and accompanying critiques, there is a particularly unique role for geospatial tools, and for open projects to map across a digital divide to inclusively enlist global workforce talent, while acting in the interest of global citizenship.

Among various efforts in geographic disciplines aiming to realizing the educational promise for open geospatial tools, YouthMappers is one program that is uniquely poised to explore a dual goal of using open platforms and tools for both workforce development and developing global geographic understanding around humanitarian issues. Indeed, in the industry of geospatial technologies as a major component of this digital transformation, two forces that parallel these trends are notable: first, the rise in geospatial jobs in nearly every country on the planet (Dempsey 2019); and secondly, the rise in the utility of geospatial technologies within the "digital humanitarian" landscape by a vast array of actors, drivers, participants and beneficiaries (Meier 2015; Gómez-Barrón et al. 2019; Haworth 2018). Digital humanitarian mapping efforts are one-way for students to gain valuable experience for workforce preparation, contribute to authentic development needs, and network across a global landscape of actors serving to apply open geospatial tools for social benefit. While the digital divide may still be present within the open geospatial realm, humanitarian uses of mapping tools appear to be far better balanced, evidenced by the participation rates of women in communities such as OpenStreetMap at large to be estimated at 10% or less, but within the Humanitarian OpenStreetMap Team to be 28%; and among students even greater participation rates are estimated, where women are nearly 40% of YouthMappers (Holder 2018).

In the end, the dual aims of education to build a strong, digitally enabled workforce while citizens live in a globalized society should be continuously questions and re-examined in light of our own geospatial technology revolution. As Cinnamon (2015) reminds us, this transformation is unfolding in what is "in actuality a vast, shifting, and heterogeneous land-scape of spatial data production approaches." As such, assessing the experiences of the YouthMappers community within the OSM community promises an insightful foray into questions about how open geospatial tools for humanitarian data creation, analysis, and learning play out or not. If we succeed in capitalizing on open geospatial technologies like OpenStreetMap for twenty-first century education, how will that change the platform and tools we use? And might we enable a new generation of young leaders to not only map their world, but define their world by mapping it?

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