Invited paper

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The gender gap among scientists in Africa: results from the global survey and recommendations for future work

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Abstract: Science in Africa is expanding, but it is important to establish whether the scientific community experiences a gender gap. Where survey results from the project "A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to Measure It, How to Reduce It?" are available for Africa, they indicate that the gender gaps in science are comparable to those in other regions of the world. The major significant survey result for Africa is that approximately 22 % of respondents who are women, and 4 % of men, report first-hand experience of sexual harassment. Recommendations are quoted from the regional meeting of African scientists at the final conference of the project. The activities of the International Union of Pure and Applied Chemistry (IUPAC), the International Union of Pure and Applied Physics (IUPAP), and the International Mathematical Union (IMU) in Africa are described, and ways of working for change are recommended.

Keywords: Africa; gender gap; science; scientists; STEM.

Introduction

Science on the continent of Africa has been growing. An estimate using World Bank figures for scientific and technical articles [1] shows growth from a world share of 1.2 % in 2005 to 2.3 % in 2018. The figures are estimated through a set of journals covered by Science Citation Index (SCI) for physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

The results of the international, inter-Union project "A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to Measure It, How to Reduce It?" (the Gender Gap project) have recently been published [2]. The gender gap, defined in the project as any difference between women and men in terms of their levels of participation, access, rights, or remuneration and benefits, is of particular interest in Africa, because the scientific community is growing, but access to education, resources, and opportunities all need improvement. The relevant data from the survey described below have not yet been analyzed on a geographical basis, but in 2020, 45 of 53 countries were classed by the World Bank as low or low middle income countries, and only two countries, both island states, are classed as high income [3].

Article note: A collection of invited papers on the gender gap in science.

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In this article, a brief overview of some significant results of the Gender Gap survey project [2] for Africa is given, followed by notes on potential further work. Remarks on the activities of some of the partner Unions and organizations in Africa are provided, and recommendations for actions are given.

The gender gap study

Three tasks were undertaken: a global survey, a data-backed study of publication patterns, and a database of good practices. African results from the final report are summarized for the first two tasks here, and the database of good practices is mentioned in the recommendations.

The survey task: preparation

The Global Survey of Mathematical, Computing, and Natural Scientists was designed to explore comparisons in gender gaps across regions, disciplines, and level of development of countries of respondents. The methodology and analysis will be found in the project book [2]. The snowball methodology was chosen to allow the survey to reach countries where there are very small numbers of scientists and very few partnering organizations, and provides results only for those who responded to the survey.

An important part of the survey design was to review the initial draft of the questionnaire, to provide input on the full survey instrument to ensure that the questions worked for the region and for all disciplines. To enable dialog with African Scientists, a Workshop of the project was held at the African Institute of Mathematical Sciences (AIMS), in South Africa. Representatives were enabled to attend from 16 countries spread across five regions of the African Union. The sixth region of the African Union, the African diaspora, estimated to be between 140 and 170 million people [4], was covered by the survey in other countries.

The participants raised a number of topics, among which were distribution, anonymity, gender categories and language. The points made may be of assistance to other global surveys. Distribution and collection of the survey presented some challenges in Africa. Dedicated high-speed physical links to home and offices are not available widely. Mobile broadband access has grown from approximately two to approximately 30 subscribers per 100 inhabitants between 2010 and 2019, but remains the lowest worldwide; this attributed to costs that are higher than those in middle-income countries, and the highest prices relative to income in the world [5]. For this reason it was important to make it clear that the respondent could save the survey and come back to it later.

Traditional roles in the family are strong across many cultures of Africa, and in many science departments in universities women find themselves less respected than men for this reason. Noting this, participants stressed that anonymisation and secure curation were of vital importance. It is also notable that gender identity was approached with consideration and sensitivity since in 34 of 54 African countries only binary gender identification was acceptable.

As a direct result of the workshop, one of the seven survey languages was Arabic. Arabic, English, and French are spoken as a second language or a home language by about 17, 13, and 12 % of Africans, respectively [6]. The assurance was given by workshop participants that most scientists speak at least one of these languages sufficiently well to participate in the survey. It was expressed that the inclusion of Arabic was an important issue in terms of inclusivity of Africans, noting that the addition of a language raised the cost of the survey.

In spite of efforts to overcome these barriers by publicizing the survey, using local organizational contacts, and encouraging personal contacts, there were only 1277 responses from Africa, or 4 % of the 30 500 respondents who had completed the survey by January 2019. These were distributed across 44 countries, of approximately 54 countries in Africa. Of the respondents from Africa, 61 % indicated that they were female. At the final conference of the project, participants in the African workshop suggested that access to computers,

online facilities and privacy in which to complete the survey were all factors, and also that there may have been an effect related to the word "gender" which is sometimes associated only with benefits for women.

The survey task: results

In the survey analysis [2], it is considered that there is sufficient evidence of a gender gap if $p < 0.002$, where p is the probability of finding the observed, or more extreme, results when the null hypothesis is true. In the figures showing results for geographic regions below, green and orange bars indicate responses from women and men, respectively, where a statistically significant gender gap was found; grey bars indicate that a statistically significant gender gap was not found.

Two questions where the results exhibit a statistically significant gender gap are summarized here. A result which is unequivocal emerged for the question "Have you ever encountered sexual harassment at school or work?". For the African region (Fig. 1a), 22 % of women and 4 % of men reported that they personally encountered sexual harassment. This is comparable with other regions. The report quotes the comment of a respondent (not necessarily from Africa): "My institution does not have a defined sexual harassment policy. I reported a supervisor for sexual harassment and had a terrible experience during the Human Resources (HR) investigation". It is likely that this comment will resonate with many women and men who have encountered such investigations, and underlines the need for both sound policies and supportive, thorough training of those who take the responsibility of implementation.

The questionnaire queried the extent to which scientists' careers were affected by becoming a parent (Fig. 1b). While clear gender gaps exist in all regions, Africa shows the highest percentages among all regions of both women and men whose career did *not* change significantly on becoming a parent. This may count as an advantage for African scientists in terms of their professional careers. It may be speculated that, given the relatively high demographic growth in Africa (noting that the number of births per woman in Sub-Saharan Africa [7] has fallen from 6.8 in 1977 to 4.7 in 2018) that there are more scientists in Africa who are supported by extended families who are willing to take care of children.

Analysis by region did not find gender gaps of statistical significance in Africa in many questions which are of considerable importance in planning interventions. Clearly, it would be useful to know whether the cause can be attributed to the low number of respondents, or to a low gender gap. However, results were also analyzed with low or high HDI (Human Development Index) [8] as a variable. There are significant gender gaps in the responses to "my employer treats everyone fairly" and "my co-workers are respectful of everyone" in both low and high HDI categories, with both men and women in the low HDI countries providing more negative responses. The following exchange among participants in the African workshop at the final project conference sheds light on the problem: "We refuse to be treated unfairly – we protest!" … "But in our country, we can't protest".

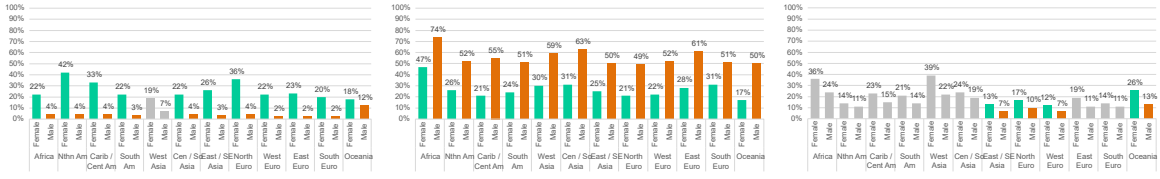

Fig. 1: Respondents by geographical region[1] indicating (a, left) that they personally encountered sexual harassment at school or work, (b, center) that their work or career did not change significantly after becoming a parent, (c, right) that they had significant interruptions in their doctoral studies [2].

1 Nthn Am: North America, Carib/Cen Am: Caribbean and Central America, South Am: South America, Cen/So Asia: Central and Southern Asia, East/SE Asia: East and South Eastern Asia, Euro: Europe.

Although gender gaps cannot be identified with confidence in many cases, Africa demonstrates a unique profile in the survey in certain respects. For example, data on the frequency of interruptions of doctoral studies in Africa do not show a gender gap of significance in the results but did show results higher than those in other countries: 36 % of women and 24 % of men reported such interruptions (Fig. 1c).

An observation named the Gender Gap paradox was described by Stoet and Geary [9]. Countries with high gender equality, measured through high Global Gender Gap Indices [10], tended to exhibit higher gender gaps in science. Previous investigation of data for women in physics did not exhibit the paradox [11]. It would be of interest to test this paradox within the Gender Gap survey data.

The bibliometric task

Although papers are not the only output of a career in science, they are strongly tied to success in promotion, visibility, and recognition in academic careers, and this is true in Africa as well as in other countries. The authorships of just over three million papers were analyzed as part of the bibliometric task of the Gender Gap study. Automated Gender Recognition was used to tag names as “male”, “female”, or “unknown”, using published benchmarks and well-researched methodologies [2]. Geographical information was extracted, where possible, from author affiliations, and the research output per country was provided on this basis. The proportion of work for each country in Africa where data was available, normalized by the population of the country, was below 1 % in the astronomy database ADS, and in the mathematical database zbMath for all countries except Tunisia. The authors explored the relative deviation from the average global proportion of women authors by the country of affiliation and found negative deviations (fewer women authors) where significant data were available for six African countries in each of zbMath and ADS. Further exploration of aggregated African data may be useful.

At the final project conference, a discussion on the low fractions of publications by African authors identified a number of barriers. Participants noted that many Africans move out of developing countries and publish with affiliations outside Africa. A contrast was observed by some authors between publishing with a famous supervisor, when they encounter a smooth and fast process, and publishing alone from Africa, with long processing times and more refusals. There is a body of opinion emerging that publications dominated by the global North may be subject to bias on a geographical basis. Payment of journal subscriptions, licenses, and Article Processing Charges (APCs) is unaffordable for many, if not most, African institutions. High publication costs mean that papers are sent to lower impact, lower cost journals. While the African Open Science Platform [12] and SciELO [13] offer hope, APCs in prestigious journals are likely to be beyond the reach of most institutions, and publications from Africa are not always covered by automated analyses.

Overcoming the barriers posed by journal expenses leads to the known need to increase funding for research across Africa. Collaboration is one path towards improved acceptance by journals, and working towards better findability and indexing on a geographical basis would achieve more exposure for African authors.

The final conference

At the final project conference, an African regional workshop was held. Discussion of some of the conclusive results was included in sections above. Issues for which the gender gap survey results were inconclusive also produced discussion and comment, some of which sheds a useful light on challenges as follows.

> We are not comfortable with the way evaluation and remuneration are done in our countries. When the same rules are used for men and women, it may be harder to women to satisfy the same condition. One point of view is that it is harder for women to reach specified numbers of publications or conferences attended, so replace these with other conditions. From another viewpoint, leave the criteria the same but provide funding specifically for women, so that the proportion of women in top positions can rise, more students can work with female supervisors, and more women can publish.

Funding is very hard to obtain in Africa in general; internet searches reveal national research funding in some countries, notably South Africa, and opportunities for post-graduate bursaries, but little research funding originating in Africa.

> Why are we not as productive as we should be with the intellectual capacity that we have? We are still overcoming the barriers of going to look for internet access, going to other countries for a Ph.D., and coping with an environment that is not conducive to research.

A longing was expressed for working in serene, neat, stimulating environments where internet access is provided.

Some organizational initiatives in Africa

IMU, the International Mathematical Union

IMU does not have committee dedicated to Africa, but has a commission for Developing Countries (IMU-CDC) and a Committee for Women in Mathematics (IMU-CWM). The IMU-CDC has the mission to manage, strengthen and promote the programs of the IMU in developing and economically disadvantaged countries, to search for funding to support the corresponding activities, and to establish institutional partnerships with scientific organizations with common goals. It has a fellowship program to support postgraduate studies in a developing country, as well as grants for mathematicians in three forms: conference support program, research travel grants and project grants. During the last International Congress of Mathematicians (ICM 2018), the IMU-CDC managed travel support, and organized a panel discussion and poster session on Strengthening Mathematics in the Developing World.

Since its creation in March 2015, IMU-CWM has hosted the World Meeting for Women in Mathematics $(WM)^2$ as a satellite event at ICM 2018, produced the film "Journeys of Women in Mathematics", presenting the diversity and common passion of women mathematicians worldwide, and created the exhibition "Remember Maryam Mirzakhani" [14] in honor of the Iranian recipient of the Fields Medal, the most prestigious award in mathematics. IMU-CWM calls annually for funding for networks, workshops and other activities.

IMU-CWM created the website of the African Women in Mathematics Association (AWMA) [15]. The first AWMA congress and workshop was held in Kenya in 2015 and had been followed by a multitude of conferences in Tunisia, Morocco, South Africa, Ethiopia, Nigeria, and Cameroon. These included regional meetings of AWMA, conferences of the West African chapter of AWMA, a conference of African Women in Mathematics, and satellite events at the Pan African Congress of Mathematicians. The webpage [16] "Portraits of role models of African Women Mathematicians" was set up in 2018.

IUPAC, the International Union of Pure and Applied Chemistry

IUPAC does not have a Committee for Gender issues or a Committee for African Affairs; instead, it works through national adhering organizations, such as the South African Chemical Institute (SACI) and the Chemical Society of Nigeria (CSN). However, women chemists in Africa participate in global IUPAC events, such as the IUPAC Global Women's Breakfast (GWB), which was started in 2019 to establish an on-going virtual network where women in the chemical and related sciences can connect with each other in a meaningful way to support their professional aspirations. The first GWB was held in 2019, as part of the 100-year anniversary of IUPAC, with the theme "Empowering Women in Chemistry: A Global Networking Event". The first breakfasts began in New Zealand at approximately 07:00 local time, initiating a global hand wave around the world ending in Hawaii. In South Africa breakfasts were organized in Stellenbosch, Durban and Johannesburg, and were attended by more than 160 women in total.

The 2020 event was held with the theme "Bonding to create future leaders". Four countries in Africa participated in 2020: South Africa, Nigeria (held at more than 20 chapters of CSN across Nigeria), Egypt and Mauritius. A similar event is planned for 9 February 2021. A new GWB task group was recently constituted for greater coordination and communication within countries and regions. Two of the task group members are from Africa: Prof. Ghada Bassioni, Cairo, and Dr. Sadhna Mathura, Johannesburg.

IUPAC celebrates the achievements of women chemists in Africa. Prof. Gloria Obuzor from Nigeria is currently serving on the IUPAC Bureau. IUPAC instituted awards for Distinguished Women in Chemistry or Chemical Engineering in 2011. Over the past decade two women chemists from Africa have been awarded, both from South Africa: Prof. Liliana Mammino, 2013, and Prof. Susan Bourne, 2019. Lastly, in celebration of the 100th anniversary of IUPAC in 2019 and the International Year of the Periodic Table, IUPAC and the International Younger Chemists Network (IYCN) created a Periodic Table of Younger Chemists [17] to honor a diverse group of 118 outstanding younger chemists from around the world. Nine young chemists from Africa were included of whom six are women, originating from South Africa, Egypt, Ghana, Nigeria, Mauritius and Benin.

IUPAP, the International Union of Pure and Applied Physics

IUPAP instituted Working Group 5 on Women in Physics in 1999 to gather information about women in physics, to analyze and report the data, identify barriers to entry into the field and difficulties in maintaining and advancing careers for women in physics, and to recommend ways to improve the observed situation. Among the outputs of the Working Group in fulfilling its mission are the Global Survey of Physicists of 2010 [18], which provided impetus for the Global Gender Gap project survey task, and the Waterloo Charter [19], which makes concrete recommendations for women in physics.

A major initiative of the Working Group is the International Conference on Women in Physics, which has been organized every three years. The conference was hosted by South Africa in 2011. This is a working conference; resolutions go directly to the IUPAP General Assembly, to the Working Group, and to the community for action. The conference is by invitation to Country Teams, formed by a country leader, and consisting of no more than five delegates unless the country sponsors team members from developing countries on a one-for-one basis. A team of five should have one student and one man. Country Teams are formed for two reasons: firstly, they work for change in their own country; and secondly they allow small, less developed, or island countries to have a voice as important as large, well-resourced countries. Men are specifically included in this initiative. Funding is raised to bring team leaders and members to the conference from developing countries. There are country teams in at least 20 African countries; each team leader is responsible for reporting at the conference on progress in her or his country in the previous three years. Conference proceedings include both country papers and scientific papers [20]. Plenary speakers have included Malala Yousafzai, Nobel Laureate. An African regional meeting takes place at each conference. The conference is family friendly. Because it is a conference of about 90 % women, some participants are able to attend who would not otherwise be allowed to travel to a conference for cultural or religious reasons.

Recognizing that women find it difficult to find funding to travel to conferences, IUPAP provides 20 to 30 travel grants annually for women from developing countries to travel to physics conferences of their choice.

The IUPAP Working Group has representatives of broad general regions, one of which is Africa. The IUPAP Gender Champion monitors and ensures that all IUPAP structures and conferences include women. It is notable that recent Presidents have been vigorous gender activists. The Working Group drafted the policy on sexual harassment that is implemented for IUPAP-sponsored conferences [21].

Recommendations specifically affecting Africa

The full recommendations of the Gender Gap study are applicable in Africa [2], but the points raised in Section 2 will be addressed here. Additional points are provided from the work of the authors and from the final

conference workshop on Africa, in answer to the question "What are the most successful initiatives to support in the regions of Africa?"

Any sexual harassment is intolerable, and the level in Africa reported by the Global Survey is unacceptable. It is quite clear that intervention is required at all levels: policy and law at national level, policy and sympathetic implementation at organizational levels, and a change of culture in science departments at universities. The formulation of procedures that respect complainant and defendant are necessary in order to diminish the fear that the complaint process is too harrowing or damaging to invoke. Policy makers should keep gender in mind and consult our women scientists and administrators, in the spirit of "nothing about us without us". Scientific Unions are able to define and advertise best practices to prevent, report and address sexual harassment and discrimination in professional spaces, promote professional conduct expectations, and to put practical policies, as well as practical first response plans, in place for their conferences [21], but only local communities are able to address the specific cultural context.

At the level of local organizations, the recommendations call upon departments and workplaces to promote a respectful, collegial working atmosphere in organization, and on universities to monitor support, well-being and mentoring of female academics.

Departments can display portraits of women in science on the walls, especially local women, because every country has its own cultures. Campaigns for Women in Science Day on 11 February, International Day of Women and Girls in Science, amplify the messages.

In terms of underlying traditional roles in society, and respect in the scientific community, African society should encourage women in science, technology, engineering and mathematics (STEM), by accepting that a woman is an individual in her own right and has the qualities of mind to make her own decisions, and acknowledging that she can equally contribute immensely to the development of a nation through knowledge acquired from STEM.

For the education of "the young ones", there are many recommendations, among which is the training of girls on how to create an email and save their work on a computer. In many African countries, primary school teachers are women without high qualifications; they must be provided with capacity building opportunities and access to science culture.

The data show that there is a significant gender gap in the impact of parenthood on careers in Africa. The study recommends addressing this and introducing proper accounting for childcare responsibilities when evaluating candidates in hiring and promotions processes. Policies should refer to primary parents, rather than to women, to allow traditional roles to change and to prevent the perpetuation of stereotypes.

In terms of publication, free help with English and with scientific writing is needed where universities do not employ English language editors. In terms of research, empowerment of women with access to ICT (Information and Communications Technology), especially in environments that are safe for women and safe for study at night, is sorely needed.

In Africa, access to resources and opportunities depends on funding, and funding is in very short supply [22]. The provision of funding opportunities specifically for women is critical, given the gender disparities in research productivity, recognition and funding; the South African example is documented by Sá et al. [23]. Success in obtaining funding brings promotion and respect. Governments must encourage women in STEM research work through funding. Collaborative national and international research work and teamwork should be highly encouraged and sponsored. National policy, funding initiatives, call processes, selection processes, inception of new institutions, and institutional strategy, are all opportunities for avoiding built-in barriers.

One of the objectives of this study was to find and recommend practices that had been evaluated and shown to have a positive impact. Only five evaluated initiatives in Africa were found and included in the Database of Good Practices, and the reader is referred to the original publications [2]. There was consensus amongst Africans at the final project conference meeting that evaluation of initiatives is needed, so that it is known what has been shown to work in a particular culture or environment. It is recommended that that scientific unions and associations encourage the evaluation and publication the results of African initiatives.

Gender mainstreaming activities must be encouraged. The COVID-19 pandemic has shown that this can be achieved to a significant extent through virtual networking (especially on a continent that is approximately

8000 km north-south and east-west). An example is the National Research and Education Network of Kenya [24], which experienced an order of magnitude more virtual meetings in June 2020 in comparison to March 2020. The figure for internet penetration in Africa, which was 25 % in 2017, 26 % in 2018, and 29 % in 2019, increased suddenly to 39 % in 2020 [25].

Women in science in Africa need to be open and have a team spirit in their own work, with no antagonistic attitudes, no disunity, or tribalism [26]. Committees for women should be formed to oversee the promotion of participation of women in STEM. Success in lofty aims often eludes us; scientific unions can provide support, experience and best practice, and can contribute to practical implementation, as can organizations such as the Organization for Women in Science for the Developing World, and Women in Science Without Borders. As the report [2] says, "No longer alone!".

Conclusions and further work

The level of sexual harassment reported by scientists is the clearest conclusion from the survey for Africa. This must be addressed, in the context of local culture, with the help of scientific Unions and organizations.

In spite of the low number of respondents for the Gender Gap survey, and the low findability of papers published within Africa in the bibliometric study, recommendations have emerged which are relevant to Africa, and considerably more await the further exploitation of the data. There is additional scope to use the survey database to gain insight into the experiences of African scientists in general by aggregating answers for women and men.

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