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FORMULATING A TRANSNATIONAL HISTORY OF WOMEN IN ENGINEERING AND APPLIED SCIENCE

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> We women want more engineers and scientists because we know more women want to become engineers and scientists; industry wants more women engineers and scientists in the high demand fields to fill its deficits … education wants more women students so it can meet industrial and governmental demands for the most highly qualified graduates … and government wants more women so it can both develop a strategic manpower reserve in critical categories and stabilize the costs of its engineering requirements.

Aileen Cavanagh, President of the Society of Women Engineers, Opening address at the First International Conference of Women Engineers and Scientists, 1964.[1]

> While men are struggling for power [women] are organising themselves into clubs, associations and societies.

Miriam Muwanga, Ugandan engineer, in *The Woman Engineer*, 1969.[2]

INTRODUCTION

Half a century ago, the monumental eighteen-volume *Dictionary of Scientific Biography* (DSB) epitomised the now much-challenged – though arguably still persistent – stereotype of the scientist as a self-sufficient 'white' male discoverer and theoriser.[3] Even as that representation lingered in popular culture, a very different vision was apparent at the first meetings of the International Conference of Women Engineers and Scientists (ICWES). The first, in 1964, was organised by the

USA's Society of Women Engineers (SWE) and the second in 1967 in the UK was organised by the UK's Women's Engineering Society (WES). It was at these meetings that women engineers and scientists from over thirty nations first came together to discuss technological issues of global concern as well as the key challenge of achieving equality for women in technical fields. These international conferences – which continue to this day – offer major examples of transnational exchange between women in engineering and applied science; hence the records of ICWES gatherings in the latter part of the twentieth century can furnish vital evidence of (some) women working in engineering and applied science across a range of countries. This article, in seeking to formulate the beginnings of a transnational history of women in engineering and applied science, uses the first three ICWES meetings as a starting point to understand the early twentieth century origins of transnational exchange. It will explore the creation of the organisation; the global changes in the twentieth century that precipitated more involvement for women in these fields, so enabling so many of them to come together at its conferences, and the importance of ICWES as a forum for participants to discuss the commonalities and differences across nations in terms of what opportunities were (or were not) afforded to women.

Hitherto much research, in particular from feminist studies, has justifiably been on women's exclusion from peacetime scientific and technical work and schemes of training for it.[4] The most recent example is Mar Hicks' insightful study of how numerous female computer programmers, who were the critical skilled electronic workforce of post-Second World War Britain, were then replaced by a predominantly male workforce from the 1960s onwards. This not only had negative consequences for the women themselves but also for the whole British computing industry.[5] But is exclusion the only story? Looking instead to periods of international conflict, there is evidence of

(admittedly small numbers of) women as STEM practitioners who were called upon to participate.[6] Thus, for example, research by Horrocks, Zengin, Canel, Oldenziel and Zachmann shows that women's longer-term employment in such technical professions increased significantly after the First World War in Europe, USA and Turkey, and again following the Second World War.[7] In the Cold War context, Laura Micheletti Puaca has examined how women's involvement in the military-industrial complex in the USA increased as a result of shifting national security concerns and the need for personnel to match the Soviet Union's extensive employment of women in engineering work.[8] Following this trend, while also looking beyond the context of conflict, this article explains how women around the world became so extensively involved in technoscience after the Second World War that they could organise transnational and peace-oriented conferences of female practitioners that have continued since 1964.[9]

This approach to recovering women's roles in STEM relies on the use of a new kind of source: the records of ICWES previously only examined briefly by Margaret Rossiter and Nina Baker.[10] Using ICWES records enables us to identify some of the women, their locations and their fields of study, who were active in STEM disciplines in the second half of the twentieth century. As such, the article draws upon documentary evidence from the first three ICWES meetings in New York, USA (1964), Cambridge, UK (1967) and Turin, Italy (1971) to discuss the key figures, themes and broader patterns of transnational activity.[11]

Previously women's history in STEM has usually consisted of limited nation-specific accounts, for example, of women working in early engineering in the USA and female scientists in the UK during the First World War.[12] [13] Even the collaborative volume of nation-specific Euro-

American histories of women in engineering *Crossing Boundaries, Building Bridges: Comparing the History of Women Engineers, 1870s-1990s,* edited by Canel et al., offers little comment on transnational phenomena.[14] Yet evidence of women's internationally-collective initiatives in knowledge-making is traceable at least to The Women's Building Library at the Chicago World's Fair in 1893, which featured hundreds of books by female writers from the USA, and nearly as many from around the world.[15] Some feminist historical writings on women's early international collaborative projects have understandably focussed on anti-war movements or women's exclusion from the workplace, rather than considering how the broader context of military conflicts actually created opportunities for women's work, as the previously cited examples have shown, even if more indirectly in the Cold War counter currents that are explored here.[16] The shift to a transnational focus on women in STEM follows the recent May 2021 conference *Hidden Histories: Women and Science in the Twentieth Century* (University of Heidelberg and University of Bucharest) which examined the dynamics of women's agency in terms of movement and collaborations across as well as within national boundaries. [17] This article, then, builds on several methodological academic resources to develop a transnational history of women in technoscience, as well as making use of institutional archival resources.[18]

In contrast to previous feminist histories which mapped women's marginalisation in STEM, and in order to begin to formulate a transnational history of women's participation in these areas, this article looks to discover in what circumstances women's labour and expertise were actively sought out for participation in STEM, and by whom.[19] [20] In addition to the context of conflict, it will focus on state-sponsored infrastructure projects as domains that were much more likely to recruit women, and it offers four factors to explain why this move emerged most prominently across

the world in the late 1950s and 1960s. These concern the pattern of women's recruitment in the First and Second World Wars and the Cold War; the specific effects of Sputnik in late 1957 in enhancing women's role in the Cold War space race post-imperial/de-colonial projects in which women were deployed to infrastructural roles to support national 'development' and the recognition of transnational problems in basic sustenance and wellbeing – arguably a traditional transcultural domain of women's authority.

Far from being an enlightened governmental move towards gender equality, these modes of inclusion can be interpreted as evidence of a state-sanctioned instrumental view of women's skills and labour. Although extensive archive work on this has not been possible in current pandemic conditions, it is possible to suggest a pattern whereby governments construed educated women as a person-power resource to be tapped into opportunistically only in times of national crises, especially in the two World Wars and the Cold War.[21] The latter is an important context for the early ICWES meetings, as it coincided with the time when Western nations sought to match the technical success of the Sputnik satellite by emulating the Soviet Union's greater inclusion of women in science and technology.[22]

However, as Puaca has shown with the notion of 'technocratic feminism', women have often worked within the confines of what was available to achieve their professional aims. Puaca shows how women's participation in USA Cold War techno-physics was to some extent an adoption of a pragmatic feminist agenda to secure opportunities by participating in the military-industrial 'Space Race'.[23] Building on this approach, rather than viewing women as mere instruments of political agendas, the article uses the ICWES meetings to examine how women used

their agency, as well as the limited opportunities afforded to them, to become active in engineering and science in limited and specific ways. It also looks at both the Cold War and beyond to consider the broader salience of decolonisation and the growing global population crises of the 1950s and 1960s to understand how women were called upon to work on – but also actively wanted to work towards – solving very practical problems of infrastructure.[24] A focus on the concept of agency enables an investigation into how women bound by social structures have long transformed or fought collectively against those structures. It will become apparent that women active in ICWES – in contrast to the women examined by Puaca – used their collective voice to position themselves outside the mainstream of the military-industrial complex to promote harmonious transnational cooperation among women engineers and scientists to peaceful and welfare-related global ends.[25] As Rossiter points out in her brief examination of ICWES 1, what is striking in its programming is the absence of any discussion about the Space Race and the Cold War.[26]

MAPPING TRANSNATIONAL COLLABORATIONS BETWEEN WOMEN: A STARTING POINT

In the mapping of transnational phenomenon, starting points for the research process can be difficult to locate. However, in the case of this project, it was the resources of one institution that indicated how any attempt to construct a national history of women in STEM unavoidably becomes a transnational story. The Electrifying Women project (University of Leeds/AHRC, 2019-20), from where this research has stemmed, started as a centenary study of the Women's Engineering Society (WES), founded in the UK in 1919. Although it aimed only to explore its origins and early history, the first few decades of WES soon revealed multiple friendly connections with women's engineering in other nations. For example, the WES directory from 1935 showed a mostly female

membership scattered across not just the UK, but the USA, Germany, Australia, Palestine, Egypt, New Zealand and Australia.[27] While some evidently belonged to the British imperial diaspora, for others WES was for a while the world's only women's engineering society, welcoming membership irrespective of nationality or engineering credentials.

In the 1920s, the society's journal *The Woman Engineer* revealed a recurrent interest in both German and American developments, featuring articles by Lillian Gilbreth on her USA-based research on industrial psychology, and Ilse Knott-ter Meer's expertise in the hydraulic engineering of sewage systems in Germany. Matters changed as the Second World War broke out, and amicable alliances were put under severe strain. By 1940, WES supported at least one female engineer refugee; Ira Rischowski, a German-Jewish engineer, who fled to the UK and soon became a pivotal member of the organisation. An article by her in *The Woman Engineer* in 1940 illustrates both her biographical journey into engineering as well as her condemnation of subsequent Nazi restrictions on women's work as professionals. Rischowski ends her article by celebrating WES for supporting the 'solidarity of women in their struggle' to choose their own career 'unhampered by prejudice, in accordance solely with one's choice and capabilities'.[28] Indeed Rischowski's experience in such matters led her to be WES's main contributor to ICWES 1 in 1964 and a leading organiser of ICWES 2 three years later.[29]

Most overseas engineering visitors to the UK, however, came voluntarily and often for educational opportunities. For example, Chinese engineering student Ying Hsi Yuan was a guest at the WES conference in Manchester in 1943, invited by the then-president Gertrude Entwisle. Information about Yuan's education and career supplied by *The Woman Engineer* in Spring 1944

shows that she studied civil engineering at the Tsing Hua National University in Peiping (1935-39) and practised at the Bridge Design Office at the Ministry of Communications in China (1939-41), before enrolling for postgraduate study in civil engineering at the University of Liverpool.[30] What led Yuan to come to Liverpool for her postgraduate studies? Was she an exception or was she one of many Chinese engineers who made such an educational journey in the 1940s? Evidently, a further area of enquiry would be into the ways – and the extent to which – women travelled for their education, both to the UK and other countries, as well as the knowledge exchange that resulted.

One such woman was the Ghanaian zoologist Letitia Obeng who enrolled at the University of Birmingham in the late 1940s to study botany and zoology, later securing a PhD in parasitology from the University of Liverpool School of Tropical Medicine in 1964.[31] Upon attending the second ICWES meeting at Cambridge in 1967, she reflected on the convivial international atmosphere manifest at the event's opening banquet, for *The Woman Engineer*:

> It was a pleasing sight to find, grouped together, a large number of women from many countries, each radiating in her own way characters unique to her world, and, all together, jointly with each other by various modes and attitudes, producing a peculiar oneness in a highly pleasing and relaxed atmosphere.[32]

Others who had studied in the UK found *The Woman Engineer* a vital place to seek support for the challenges they faced in their own nations. The Ugandan trainee electrical engineer Miriam Muwanga, who had studied at a Manchester technical college, joined WES while in the UK, and on her return to Uganda regularly reported in *The Woman Engineer* on her professional situation. Her

1969 article 'Focus your Eyes on Uganda' highlighted the vital role of women in addressing the political aftermath of decolonisation:

> When women gather they do not talk about the wars in various parts of the world or the deceitfulness of world politicians; they discuss educational problems, family planning, home economics; they learn new crafts, and improved methods of looking after the family.[33]

Subsequent reports in *The Woman Engineer* indicate that Muwanga emulated the operations of WES locally in forming a Women's Technical Society of Uganda in 1969; this offered a venue for Uganda's female professionals to discuss their industrial careers and educational engagement.[34] Relatedly, WES invited Letitia Obeng in 1972 to reflect on the role that African women could play in decolonial infrastructure work; her prestigious invited lecture, 'Nation Building and the African Woman', was also published in *The Woman Engineer.* Obeng concluded that 'women could be the repositories of the ingredients for nation building, national progress, and the maintenance of national stability. The African woman is no exception'.[35] WES and its journal thus continued to serve, *inter alia,* as a transnational forum for its African membership to share their views and experiences more widely, even as they were setting up their own national and intra-continental organisations for Africa's rising professional women. In 1988, the eighth ICWES conference was held at Abidjan, Ivory Coast and in 1999 the network for African Women in Science and Engineering (AWSE) was established, building on the earlier growth of connections in the preceding decades.

However, it was not WES but the Society of Women Engineers (SWE), founded in the USA in 1950, that took on the mantle of promoting internationalist ventures in the mid-twentieth century. This was most notable in its founding of ICWES in 1964. At the first meeting the SWE president, Aileen Cavanagh, articulated that the conference's aim was to 'eradicate national prejudices' by 'sharing cultural and technical knowledge among many nations'.[36] Arguably, it was the second ICWES conference, organised by WES, that instituted a much wider international reach, by including newly independent countries from the continent of Africa. The concerted effort on the part of the ICWES 2 organisers to reach out is evident in the deliberations of the executive committee which arranged for English, French, German and Spanish translations at the conference.[37]

Even so, it is not possible to explain how ICWES's regular meetings every three to four years came to thrive in a variety of global locations by reference solely to the diplomatic actions of WES or SWE. Such developments were not inevitable, nor were they simply inspired by or modelled upon WES's or SWE's operations. Hence developments in countries other than the UK or USA must also be considered.

FOUR EXPLANATORY FACTORS FOR WOMEN'S INCREASED POST-SECOND WORLD WAR PARTICIPATION IN STEM

A range of forces operative in the twentieth century directed women collaboratively into active economic roles in peacetime. For example, the United Nations Commission on the Status of Women in 1946 ratified the economic need for all nations to include women in productive activities. In the mid-1960s, this Commission adopted practical measures to support women's socio-

economic participation, with 'developing' nations highlighting the need to create opportunities for women in rural areas. Consequently, in 1975, the UN organised an International Women's Year with the theme of 'Equality, Development and Peace', highlighted at the first global Women's Conference in Mexico City that year.[38] Yet importantly, ICWES had already pursued such concerns in relation to engineering and applied science in the preceding decade, raising the need for future research on the relationship between ICWES and the UN initiatives.

As noted in the introduction, women's interest and participation in this area clearly goes back to a much earlier period, with much less peaceful causes. Indeed, in order to understand how women's work in engineering and applied science expanded in scale both nationally and internationally, it is necessary to look at how military conflict created opportunities for women to receive engineering training, and, to varying extents, employment. For example, when Russia's unexpected defeat by Japan in the war of 1904-05 revealed a catastrophic insufficiency of technical expertise, imperial sanction was swiftly granted for engineering courses at the St Petersburg Polytechnic Institute for Women, which opened in 1906.[39] After the collapse of the Ottoman Empire in 1922, Turkey introduced professional training for women in many spheres, including engineering, with a clear cultural preference for increasing its national technical expertise by educating women from elite families rather than training lower-class men to become professional engineers.[40]

Conversely, historians also agree that it was attempts to restrict women's participation once peacetime came that prompted the founding of several women's engineering organisations. In that context, the aftermath of the First World War generated the UK's Women's Engineering Society in

1919, and the Association Amicale des Femmes Ingénieurs was launched in 1929 in France. In the USA the Society of Women Engineers was founded in 1950 after many women engineers who had participated in the Second World War, inspired famously by 'Rosie the Riveter', sought permanent recognition in the field. [41] In 1957, the Associazione Italiana Donne Architetto e Ingegnere (Italian Association of Women Engineers and Architects) was founded.[42] All of these show the determination of women to establish specialist organisations to articulate their agency under heavy constraints.

By the late 1950s, the political tensions of the Cold War had helped to draw attention to the key technical roles of women. By 1956, the advanced state of the Soviet Union's technical prowess in the nuclear arms race had prompted other nations to look at the underlying causes of its extraordinary success, in order to seek to emulate them. In the same year, the UK's Conservative Government's Ministry of Education produced a White Paper on Technical Education which noted in an appendix that no less than *one quarter* of engineers in the USSR were women. This extraordinary finding prompted the UK government to forecast a major UK skills shortage in engineering within a decade unless a significant number of women were recruited. In response, the Women's Engineering Society organised a major conference on 'Careers for Girls in Engineering' at Coventry in July 1957.[43]

Evidence of parallel plans that drew upon women to expand a technical workforce is clearly also apparent in the newly independent countries across post-colonial Africa, Asia and Latin America. Ghana, for example, declared its independence on 6 March 1957 and immediately instituted its Consolidation Development Plan which involved greatly increasing its provision of

science education for both sexes.[44] Such specific stories about the growth of women in STEM were, as we shall see, enmeshed with the wider geopolitical patterns of the Cold War.

Moreover, arguably one of the biggest spurs to increased recruitment of women in engineering was the launch of the Soviet satellite *Sputnik 1* on 3 November 1957. This achievement stunned the capitalist world, especially the USA, in its demonstration of communist culture's capacity to engender globally visible strategic innovations. The imperative in the USA to recruit more women to high level technical work in the ensuing Space Race in 1958 is most obvious in Margot Lee Shetterly's book *Hidden Figures: The American Dream and the Untold Story of the Black Women Who Helped Win the Space Race*.[45] Through Shetterley's research, many now know how the USA space mission came to rely critically on expert African American female mathematicians. It was Dorothy Vaughan, Mary Jackson, and Katherine Gobels Johnson who, in 1961-62, successfully helped to calculate the required launch trajectory of astronaut John Glenn into Earth's orbit to ensure his safe return.

In a transnational vein it can be noted that during the Cold War women in quasi-independent countries in the USA cultural-political sphere also secured careers through USA sponsorship. For example, as the Cold War heated up in the Sputnik era, the Philippines, although formally independent from the USA since 1946, looked to universities in the USA to provide the highest level of chemical engineering education. At the first ICWES meeting in 1964 – one dominated by attendees from the USA and allied nations – Magdalena Alde Templa reported that no fewer than 72 female Filipino students had travelled to the USA for training in that field in 1957-58 alone.[46] [47] Zenaida Gonzales Gordon, a Filipino engineer who spoke at the second ICWES

meeting in 1967, received graduate training at the Massachusetts Institute of Technology (MSc 1961), before becoming Senior Chemical Engineer at state-sponsored corporation in 1965.[48] Epitomising the characteristic intermingling of transnational activity with nationalist rhetoric, Ms Gonzales Gordon spoke at that ICWES meeting within a nation-building context: 'The Filipino woman professional engineer aspires to build her own image of leadership in the national effort to make her country a good place to live in'.[49]

Less well explored than the USA's sponsorship of 'Western' science during the Cold War, is the impact of post-Sputnik Soviet funding in the newly independent, so-called 'developing' nations. One key example is the effect of the globally-visible Soviet success with Sputnik on socialist Africa states such as Ghana. After gaining independence from the UK in 1957 and becoming a republic in 1960, it sought the support of the Soviet Union and later China in training up a new technical workforce.[50] In the same vein, it is possible to find a broader picture of the developing independent nations in Asia and indeed the Global South in the post-colonial era; one that called upon women and sponsored them to train in technical professions to support the economy. The extent to which this sponsorship of some women's participation was tied up with the politics of the Cold War, as rival powers sought to invest in women of different nations to influence their political affiliations, will emerge from future research, but evidence is already in the UNESCO archives of its efforts to support women's training in technical subjects across the globe.[51] Amidst such constraints and politicised funding, women's agency was also apparent in the way they navigated their own paths through the gendered boundaries of their nations, often with cultural constraints that diverged from any Western-centred expectations.

The fourth factor – largely independent of those outlined above – which enabled women's agency to find new spaces was the growing transnational concern for infrastructural support for food security, among other core subsistence issues, prompted by post-Second World War global population growth.[52] Clearly women's traditional gender prerogatives of care and wellbeing were at the heart of state initiatives to harness women's agency to address this problem. Thus Lyndon B. Johnson as President of the USA in 1964 – in a telegram sent to the ICWES 1 conference organisers – urged women attending the first conference to focus 'attention on the new contributions which Engineering and Science can make to all problems of hunger, disease, disability, and lack of individual opportunity'.[53] The challenges of the 'changing and increasingly technological world', he added would require engagement with the 'untapped potential and ability of talented women'.[54] It was the building of larger infrastructures for rapidly changing technological environments for both warfare and human wellbeing that linked all the extended transnational activities of women's work documented within the ICWES proceedings.

INFRASTRUCTURE AS A THEME IN NATIONAL AND TRANSNATIONAL STORIES

By looking at the routine work of analysis, quality control, infrastructure building and maintenance – all of which are critical for maintaining the modern world – we find a broader range of participants than in the male-dominated 'basic research' that involves highly abstract problem-solving.[55] As historians of the imperial era have observed, the massive infrastructures of colonial rail transport and telecommunications required staffing that could only be sustainably secured in sufficient numbers by training indigenous populations to build, manage and maintain them.[56] The prevalence of women in twentieth century infrastructural activities is a key, yet understated, feature in Andreas Marklund and Mogens Rüdiger's 2017 book *Historicizing Infrastructure*.[57]

The first ICWES was organised by SWE in 1964 with the title 'Focus for the Future: Developing Engineering and Scientific Talent'. SWE broadly categorised the conference foci under two global headings. The first part looked at identifying and planning for the practical needs of the future, including infrastructure, living standards and environment. In this section of the conference there were papers on clothing (Young Sun Lee, Korea), shelter (Consuelo M. Hauser, USA), food (Mary H. Malone et al, USA), energy (J. Cicely Thompson, UK), transportation (Monique Vuillemin and Monique Barbe, Switzerland), environmental pollution (Anneli Hattari, Finland), management of natural resources (John Miller, Republic of Ireland), and the ocean (Zinaida A. Filatova, USSR).[58] The second part of the conference was a 'Symposium On Developing Engineering And Scientific Talent', which focussed on the need to increase the number of women in engineering around the world in order to accomplish the goals outlined in the first part. As will become apparent, subsequent ICWES meetings picked up and developed both these main themes.

For balance, it is necessary not only to consider those who presented on infrastructural topics at ICWES 1, but also the non-presenting female attendees engaged in infrastructural roles. One such example was Ayyalasomayajula Lalitha, commonly credited as the first woman engineer in India. After formal engineering training at Chennai/Madras, her early career centred on electricity and railways in the 1940s, before going on to work on the Bhakra Nangal Dam, India's largest such water-management structure. In the latter part of her career, Mrs Lalitha worked at Associated Electrical Industries in India.[59] Another slightly later example is Ila Ghose, who is claimed to be West Bengal's first female engineer. As with many of the women explored in this paper, Ghose travelled to the UK as part of her training, undertaking an apprenticeship in Glasgow

in the early 1950s. She then went on to work at an ordnance factory in Dehra Dun, before taking up a lecturership in India's fast expanding education sector, first at Delhi Polytechnic then later at Calcutta/Kolkatta. Significantly, not being a member of any women's engineering organisations, records of her early life can only be traced via Indian newspapers which indicate that she attended ICWES 2 at Cambridge in 1967 and was a key organiser of the ICWES meeting in India in 1981.[60] These two examples give a glimpse into the career paths that became available to women in post-independence India, with its demands for infrastructure building, as well as the opportunities for transnational career development through attendance at ICWES meetings.

A further post-independence infrastructure story from Africa, notably not represented at ICWES 1, concerns research by the Ghanian Letitia Obeng. In 1964, she was appointed by her government to head the Institute of Aquatic Biology based at the National Research Council of Ghana.[61] Her research on the substantial artificial Volta Lake would become a central feature of the Ghanaian government's infrastructural policy on increasing fish stocks for self-sufficiency in food supply. She reported extensively on this at ICWES 2 in 1967 in her paper 'Man-made lakes as a source of freshwater fish production in Africa', part of a panel on 'The Application of Technology – Increasing Food production'.[62] This was in turn part of a wider session called 'Enough for Everyone: The application of technology to world food problems'. This session, which ran over several days, elicited discussions from female scientists and engineers from more than twenty countries, with radically different approaches. These representations from former British colonies in the African continent were a striking departure from ICWES 1.

Nigeria acquired independence from Britain in 1960 and the two Nigerian participants at ICWES 2 were both geophysicists trained through Commonwealth scholarships in the UK. These were Deborah Ajakaiye, who studied physics at the University of Birmingham in the late 1950s, and Ebun Adegbohungbe, who received a physics degree from University College of Ghana, and a MSc in Geophysics from Imperial London 1963. By 1963 Adegbohungbe was a lecturer in Physics at the University of Ife, Nigeria and her paper at ICWES 2 'Application of Physics to some Economic problems in Nigeria' argued that physics could be used to address to food supply problems in Nigeria that stemmed, she maintained, from insufficient wealth. Spelling out Nigerian government policy that the key to wealth lay in using Nigeria's mineral resources to fund industrialisation, Adegbohungbe explained how her expertise in magnetometers could locate iron ore for future mining projects. As she concluded 'Nigerian scientists, therefore, must make their own contributions in their various fields of learning and research, to the economic progress of the country'.[63]

A more globally oriented approach to enhancing food supply is evident from the Pakistani scholar Umrana Ahmed, who spoke at the ICWES 2 session on 'Application of Microbiological Techniques to Food Problems'. She too was part-educated in the UK. Her PhD, funded by a commonwealth fellowship, was started at the University of Leeds in 1960 and she worked on this concurrently with a lecturing post at the University of Karachi, where she had just completed her MSc in Microbiology. Ahmed's conference paper focussed on the enhancement of frozen food preservation techniques by identifying and then controlling the most serious sources of spoilage: these were the bacterial pathogens that entered the food preparation process via water supply and factory workers. While her analysis concentrated on the major Karachi export industry of frozen

shrimps, she argued that the anti-contamination techniques she outlined were applicable beyond Pakistan: 'the results of these bacteriological examinations show that the problem of food control is important throughout the world'.[64]

The Japanese contribution to this session of ICWES 2 discussed fisheries research, a key area of Japan's infrastructure. Taneko Suzuki, a Technical Officer at the Tokai Regional Fisheries Research Laboratory and a Representative of Japanese Fisheries Science Society, attended on behalf of these organisations. However, possibly for reasons of fluency in English, the paper 'Importance of fishery in food problems' was presented by the chemist, Katsuko Saruhashi of the Meteorological Institute in Tokyo. This paper highlighted Japan's dependence on fish supply; how it took annually one seventh of the entire global consumption of piscean protein. This prompted the question of whether to prepare for future population growth by increasing marine harvesting, with the attendant risk of over-fishing, or instead by increasing animal protein production by water-intensive land methods. The conclusion was that research was needed on how to 'raise more foods' from marine environments to 'improve the future living standards of the people of the whole world'.[65]

In concluding this section, it is worth noting that at ICWES 1 in 1964, Midori Yamada had delivered a short contribution outlining the significant growth of women's participation in post-war Japan's technical professions. Here it was evident that over a thousand women were employed in chemical or medical sciences (far fewer in physics or engineering), but fisheries science had not been mentioned at all.[66] While this is perhaps evidence of the growing need for solutions to food supply challenges in the mid-1960s, it is revealing that the ICWES programme did not reflect the

national profile of Japanese women in STEM. ICWES instead reinforced the gendering of food concerns by highlighting this transnational issue in its programming.

THE TRANSNATIONAL PROFESSIONAL IDENTITY OF WOMEN IN ENGINEERING

As mentioned above, a major feature of early ICWES meetings was the debate about what it meant for a woman to be an engineer or scientist – and how there were both commonalities and differences across the world. The second ICWES meeting had as its theme for the third, and final, part: 'The Professional Woman Engineer'. This included reports on the contemporary state of women in engineering in various countries, with examples from India, the USSR, the Philippines, Canada and Germany. These reports offer points of national and cultural comparisons, with the contrast between India and the USSR being particularly noteworthy. In her report on India, K.K. Khubchandani wrote:

> [The] Human race can no longer afford to waste the enormous potential of man [sic] power of half of the world's population, not fully tapped yet. In developing countries like India, material and intellectual output of this potential would result in the acceleration of [the] rate of social and economic progress.[67]

Khubchandani continued by pointing out that women in India were not prohibited from entering the engineering profession on the grounds of gender. However, once within the profession, Indian female practitioners were restricted by cultural prohibitions to only certain geographical domains:

> Most of the women engineers are employed in design and development, teaching and research. Most of the members of the engineering profession have recommended these fields of work for women engineers. The psychological climate in this country is not yet ready for women to take up outdoor duties like construction projects, supervision and maintenance work in factories. This type of work needs dealings with unskilled and semiskilled labour force[s and]… at the present juncture, the mental attitude of this class of people is not such as to accept a woman engineer to work with them [or] be supervised by her.[68]

Drawing on statistics from Russian and Indian sources, Khubchandani revealed the proportion of women engineers in four different nations as follows: USSR: 1 in 3; France: 1 in 50; USA: 1 in 100, and India: 1 in 400. The high level of participation for women in the USSR was an area – like the Sputnik episode in November 1957 – in which the Soviet delegation could take pride at the achievement of communist state intervention. While the Soviet Women's Committee did not attend ICWES 2 to deliver their paper, a British WES representative quoted the Soviet boasts that in the USSR there were 18,000 women (of whom about 6,000 are engineers and over 12,000 technicians) out of 28,000 certified specialists at work in specialised assembling organisations and enterprises.[69] Such quantitative comparisons, especially the contrast between India and the USSR, remind us of the differences in cultural expectations and opportunities that constrain how and how far women could exercise their agency to participate in engineering.

This national-thematic specificity is also apparent at the third ICWES conference in Turin, Italy, 1971, in a session dedicated to the challenges faced in 'Women's Professional and Family Duties'.[70] Delegates from France described being discriminated against when applying for senior

positions in engineering, whereas for delegates from Turkey, the problem was insufficient opportunities for women to receive a preparatory education. A Nigerian perspective highlighted how women engineers often had to leave their jobs when their husband's careers led them to relocate.[71] The notes from the debates of this session point to the necessity for state provision of childcare and housing to address the globally common challenge of women engineers raising children while working: 'This new community life must be allowed to a different town structure, to a new transport policy and different hours of work, to enable women to take their full place in technical society'.[72] A presentation from the Soviet Union showed how such facilities were already in place; it was precisely this that allowed women to join the engineering workforce in much large numbers than in other countries. Papers from other countries pointed to similar success in finding ways to improve women's position in engineering and other professions; in Thailand, for example, by 1971 there were over a hundred women working in engineering, compared to just eleven in 1964.[73]

CONCLUSION: PRACTISING TRANSNATIONAL HISTORIES OF WOMEN IN ENGINEERING AND SCIENCE

This paper has explored how a transnational account of women's participation in STEM in the second half of the twentieth century can be achieved through greater geographical and cultural inclusivity, with a particular focus on infrastructure projects since that is where women's participation so often lay. Although the conferences organised by ICWES focussed predominantly on issues of welfare and identity, projects that involved women engineers were typically nation-specific and government-funded in origin, albeit in some cases with strategic sponsorship from the USSR, China or the USA to build infrastructures in alignment with specific political loci of the

Cold War. While evidence of women's participation in different nations' infrastructure building has been located from the records of ICWES meetings, future research is needed to clarify how women's involvement was funded, and under what political-economic constraints. Detailed archival materials concerning ICWES's planning and management has thus far only been located for the first two conferences, although the proceedings of all other meeting are available in the SWE and Institution of Engineering and Technology archives.

It is worth noting that the seven-year period of the first three ICWES meetings coincided with the rise of second wave feminism, certainly within the USA and some European countries, and so there are further questions to be asked about the extent to which the women who organised and attended the early ICWES meetings also took part in feminist movements in their respective countries in their non-professional capacities. Thus far, in all the stories looked at, there is no explicit citation of feminist motivations from the women who attended these meetings, even though their professed goals fit within the broader remit of women's liberation agendas. In the context of the USA and women's movements, Pamela Mack has discussed the limitations of second wave feminism on engineering practices from the 1960s onwards, suggesting that feminist ideas were not necessarily directly brought into the engineering domain, even if the aim of many women's organisations – like SWE – was to increase levels of participation.[74] Most helpful here are the words of Aileen Cavanagh in this paper's opening epigraph: women wanted to participate in engineering and science and thus navigated as best they could through culturally contingent constraints and opportunities to apply their skills and enthusiasm to engineering and applied science. The stories told here are certainly those of women exercising limited forms of agency in an era of global conflict and finding mutual support from other women.

What future methodology could other scholars adopt to expand this transnational story based on women's organisation of conferences? As effective as it is at providing a sense of the kind of practical wellbeing priorities that could bring together women from around the world, just looking at ICWES meetings cannot function as more than a starting point. ICWES meetings do not, after all, provide a comprehensive snapshot of the transnational picture of all women in engineering and applied science in the second half of the twentieth century. Indeed, it might be helpful to see 1964 – the inception of ICWES – as a locus point from which to move backwards and forwards in order to research the various national organisations for women engineers and scientists that came both before and after. Furthermore, it is necessary to look beyond national organisations that were aligned to ICWES. One major gap, for example, is information on the participation of women engineers in Soviet bloc states during the Cold War: Poland was the only communist nation to host an ICWES meeting (the fourth conference of 1975). Yet the legacy of that period is apparent in today's relatively high participation in engineering of women in former Soviet-bloc nations, especially Lithuania and Bulgaria, in comparison to Western Europe.[75]

Wherever we look, however, there must surely have been women engineers who did not have the time, resources or connections to attend a large international gathering like ICWES. Local stories of practitioners, whose lives were too constrained to enable travel or to engage internationally, must therefore be incorporated in any future extension of this international history by tracing their stories through personal archives around the world. Another approach is to use oral history to collect the career stories of as many women engineers and scientists as possible from across the globe while they are still alive and to find a way of depositing their life stories digitally to

ensure accessibility and visibility to posterity. If the scope of this kind of research and writing can be broadened accordingly, then researchers oriented to more transnational histories of women in STEM can respond appropriately to the comments from the 89-year-old multi-talented veteran of motion studies, domestic engineering and industrial psychology Lillian Gilbreth in the opening of the ICWES 2 meeting, who said: 'The world needs the contribution that women engineers and scientists are able to make, and we, in turn, need to be needed.'[76] This article has shown how far and in what ways the last half century has needed the contributions of women engineers and scientists, as well as pointing to women's diverse motivations for joining the national and international networks of science and engineering. It has, moreover, explored how far the opportunities opened up for them thereby gave them roles that – to at least some extent – extended their gender prerogatives beyond the cultural traditions into which they were born and educated.

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[3] Charles Coulston Gillispie, *Dictionary of Scientific Biography* (New York, Charles Scribner's Sons, 1970-1980). A revised addition is more inclusive of women. Noretta Koertge, (ed) *New Dictionary of Scientific Biography* (New York: Charles Scribner's Sons, 2007).

[4] Linda K. Schott, *Reconstructing Women's Thoughts: The Woman's International League for Peace and Freedom Before World War II* (Stanford, CA: Stanford University Press, 1997); Joyce Blackwell, *No Peace Without Freedom: Race and the Women's International League for Peace and Freedom, 1915-1975* (Carbondale: Southern Illinois University Press, 2004); Catia Cecilia Confortini, 'Doing Feminist Peace', *International Feminist Journal of Politics*, 13/3 (2011), 349-370.

[5] Mar Hicks, *Programmed Inequality: How Britain Discarded Women Technologists and Lost its Edge in Computing* (Cambridge (MA): MIT Press: 2017).

[6] A note on terminology: in what follows we will often refer to STEM (science, technology, engineering and mathematics) and aim to maximise inclusivity. Given that countries have different ways of defining 'engineer' (e.g. whether state-accredited practitioners or not), we do not presume any single unifying definition of what constitutes an engineer.

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[8] Laura Micheletti Puaca, *Searching for Scientific Womanpower: Technocratic Feminism and the Politics of National Security*, 1940-1980 (UNC Press, 2014). Puaca reproduces SWE promotional material from 1963

comparing Russia's 30% participation of women in engineering to an average of just 2% in the Western World. Puaca (2014), 121.
[9] Dagmar Schäfer and Simona Valeriani. 'Technology Is Global: The Useful & Reliable Knowledge Debate' *Technology and Culture*, 62/2 (2021), 327-347.
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[11] Subsequent meetings have included Poland (1975), India (1981), and the Ivory Coast (1988). A forthcoming history of ICWES, and the subsequent International Network of Women Engineers and Scientists (INWES), which is being written by founding INWES members, under the auspices of the Canadian Institute for Women in Engineering and Sciences (CIWES), will provide an account of how the conference and its network came into being and how it has since been managed.
[12] Patricia Fara, *A Lab of One's Own: Science and Suffrage in the First World War* (Oxford, Oxford University Press, 2018).
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[15] Sarah Wadsworth and Wayne A. Wiegand, *Right Here I See My Own Books: The Woman's Building Library at the World's Columbian Exposition* (Amberst and Boston: University of Massachusetts Press, 2012). Anon, List of the Books in the Library of the Woman's Building, World's Columbian Exposition (1893). [Last accessed August 12, 2021 https://digital.library.upenn.edu/women/clarke/library/library.html].
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[22] Amy Sue Bix, *Girls Coming to Tech! A History of American Engineering Education for Women* (Cambridge, MA: MIT Press, 2013), 117, 126, 168, 199.
[23] Laura Micheletti Puaca, *Searching for Scientific Womanpower.*
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[29] See the Ira Rischowski papers in the LSE Women's Library.
[30] *The Woman Engineer*, volume 5, part 18 (Spring 1944). 285; the University of Liverpool Special Collections and Archives holds material relating to Ying Hsi Yuan, including her graduate index card, her PhD thesis registration (A048/4) and confirmation of her degree of M.Eng (S2784b).
[31] See https://www.lstmed.ac.uk/alumni-and-friends/alumni-profiles/dr-letitia-obeng [last accessed 26 August 2021]
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[43] See 1956 White Paper in the National Archives at http://filestore.nationalarchives.gov.uk/pdfs/small/cab-129-79-cp-56-40-40.pdf See the Programme for 'Careers for Girls in Engineering', Coventry, UK in July 1957, Ira Rischowski papers, LSE Women's Library.
[44] Abena Dove Osseo-Asare, 'Scientific Equity: Experiments in Laboratory Education in Ghana.' *Isis*, 104/4 (2013), 721.
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[63] *Proceedings of the Second International Conference of Women Engineers and Scientists*, part 2, 6
[64] *Proceedings of the Second International Conference of Women Engineers and Scientists*, part 2, 9; Umrana Zaibar, *The metabolism of soil bacteria capable utilizing cresols as sole source of carbon*, University of Leeds PhD thesis, 1963.
[65] *Proceedings of the Second International Conference of Women Engineers and Scientists*, part 2, 6.
[66] *Proceedings of the First International Conference of Women Engineers and Scientists*, appendix 5, v-3.
[67] K.K. Khubchandani 'Social and Educational Attitudes to Women in Professional Engineering with particular reference to [the] Indian environment' *Proceedings of the Second International Conference of Women Engineers and Scientists*, part 2, 1-7.
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[73] Ibid, 16-17.
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