Attraction, Education and Retention of Technical Women in South Africa

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Abstract - **Women engineers form a small but integral part of the South African and global engineering fraternity. The resultant gender disparity in all technical professions presents a significant challenge to women in the sector, as well as to governments, corporates and higher education institutions. If the future of engineering aims to be more gender equitable, the attraction, education and retention of technical women must be understood and addressed effectively. Research was conducted over a two-year period with nine technical women in South Africa to gain a deeper understanding of these factors. The respondents agree that a future exists for women engineers, but that current policies, education structures and financial systems must be restructured to make engineering a more attractive career for women. The paper presents the research findings and strategies for the future education and retention of technical women in the engineering and built environment sectors.**

Keywords—**women in engineering; education, retention; South Africa**

I. INTRODUCTION

Globally women engineers represent 6% to 11% of the engineering workforce and only 60% of graduating female engineers are retained in the profession [1]. The under-representation of women in engineering is not only evident in South Africa, but persists as a worldwide concern. In the United States of America women continue to lag behind men in engineering and computer sciences [2]; and in the United Kingdom (UK), the annual loss to the country's economy due women scientists, engineers and technologists who are unemployed, inactive or working below their level of qualification is estimated to be £2 billion [3]. The Diversity Leadership Group for the Royal Academy of Engineering explains why the retention and progression of women in science, engineering and technology is such a critical business imperative: "The UK Industry needs to recruit, retain and inspire the best talent available to build and retain a competitive position in the Science, Technology, Engineering and Mathematics (STEM) business sector. As long as women represent such a small proportion of our workforce, especially at senior levels, we know that we are missing out on a rich pool of talent" [4].

Africa holds great promise as an emerging continent. 40% of its population is under the age of fifteen [5] and it has untapped natural and intellectual resources. The 2007 UNESCO International Report on Science, Technology and Gender confirm that "educational attainment is, without a doubt, the most fundamental prerequisite for empowering women in all spheres of society" [6].

Few countries, however, are more sensitive to the impact of inequality than the citizens of South Africa; and albeit women represent more than half of the total citizenship of the continent, no profession is more gender-biased than engineering. A study was conducted over a two-year period with practicing women engineers and academics to provide insight to their professional and personal lives. The findings from the study are presented and provide understanding of the influences that women engineers experience during their corporate careers; as well as strategies for the future education and retention of women in engineering.

II. METHODOLOGY

A qualitative research study was designed and conducted over a two-year period with nine technical women who range in seniority, age and ethnicity. The population for the study was women who were elected as finalists in the annual Excellence in Engineering and Technology Awards from 2011 to 2013 hosted by the University of Johannesburg and Group Five Women in Engineering and the Built Environment (WiEBE) Program. Twenty-one women were originally chosen for the research but only nine finally responded.

The research instrument was a protocol formulated by the authors with twenty questions that covered topics sourced over five years through observation, informal discussion, document review and formal interaction with technical women. These formal and informal meetings included the annual UJ-Group Five WiEBE Summit where one hundred and fifty women participated annually from 2009 to 2014; dinner debates with between ten and twenty women per debate; as well as professional and informal interaction with women in industry and academia. Document review included academic journals; industry reports by global organizations; and Africa-focused gender reports. The protocol was issued to twenty-one women of whom nine responded in writing to the questionnaire. The initial submission was followed-up by discussions with the respondents to ensure that the authors fully understood and extracted the participants' meanings about a particular research question. This strategy also contributed to ensuring validity of the response interpretations.

Emergent themes were identified from the manual transcription of the participants' feedback and interviews; followed by the grouping of corresponding and divergent responses per theme. These themes included: gender influence in engineering; gender equity and empowerment;

the impact of culture on women engineers; the attainment of work-life balance; education of young engineers and their future in the country; and leadership and agency by women engineers in practice.

Validity of the findings was promoted with several strategies: (a) the use of comprehensive descriptions to portray the varied perspectives about a particular theme; (b) some descriptions were returned to participants to check for accuracy and correct interpretation of the respondent's meaning; (c) follow-up interviews were conducted with several respondents to clarify or elaborate on meanings; (4) reflectivity by the researchers to identify and eliminate their personal bias in the study; (5) the inclusion of discrepant, negative or unexpected findings in the narrative; and (6) spending a prolonged time in the field which allowed the researchers to have an in-depth understanding of the phenomenon under study [7]. The authors do not claim that the findings can be generalized since the research was conducted in a particular setting and context, namely the study of gender experiences by technical women in South Africa.

III. RESULTS

A. Gender Influence in Engineering

The participants responded very differently to whether gender influences their careers in engineering. Younger colleagues believe that engineering is a male-dominated and patriarchal industry and that they must work twice as hard to prove themselves and to be taken seriously. In the African culture addressing a man on his first name is a sign of disrespect and hence men are not prepared to take instructions from younger women. The black-empowerment legislation imposed in South Africa does not facilitate the acceptance or recognition of young women engineers either. One of the participants, an Indian woman engineer, provides her view informed by the current legislation [8]: "Working in any South African company probably implies that there is an employment equity ratio and that females are employed to fill employment equity gaps rather than be employed due to their talent. There are many occasions when I can recognize females in my environment being employed as tokens because they are underqualified for the role ".

Interestingly, the executives responded that gender has and does influence their career, but to a fairly limited extent. One colleague noted that "as an individual, I feel that my gender does not compromise my work output in any way. However, I am conscious that many people with whom I interact have trouble seeing past my gender. This reality is what reminds me to be gender aware as I go about my work, sometimes needing to convince and reassure clients and colleagues that I have the necessary training and experience to carry out my work" [9].

Two observations emerge from the participants' responses. The first is that senior and experienced women are not affected to a significant degree by their gender, and compared with younger women, are less influenced by perceived or real discrimination in their work place. The second is that being a female engineer has its advantages - everybody knows you as the woman engineer on-site or in the company and people enjoy having you on their team. Having a partner or husband engineer also adds to shared professional interests and consulting opportunities.

B. Gender Equity

The women engineers' perspectives on gender equity were strikingly similar. They summarized gender equity as equal access to opportunities for all people regardless of gender and race; the availability of equitable resources to both men and women; and equal representation of women in all decision-making forums such as meetings, boards and committees. This planned strategy for equal representation in all formal and informal structures of the organization promotes a culture of respect, recognition, dignity and value – and implicitly contributes to the advancement and retention of women in engineering.

Another important finding from the research was that women engineers expect the same from their careers as do their male counterparts. In 2014 the Harvard Business Review reported that "the vast majority of women anticipated that their careers would rank equally with their partners, but many of them were disappointed" [10]. Women engineers were emphatic that they have the same expectations for promotion, earnings and recognition as men do; and that it is incumbent on companies to recognize a professional woman's ambition if expected to benefit from the value and innovation that women engineers bring to a firm or project.

In the design and transition of new systems where a women's role in society is considered equitably, the rise in the role of formidable women and balanced men will require earnest consideration. Growing evidence indicates that more men will decide to make a trade-off between careers and spending time with their families, whereas women will become more powerful in their roles at work. These shifts will strongly influence the way that companies respond to demands from both genders in future.

C. Gender Empowerment

The central emergent themes of gender empowerment are power and growth. Power described as the ability to negotiate work hours; the right of a woman to choose her role in society, albeit it as professional engineer, partner, mother or a combination of all these positions; the right to be politically and economically active – and the power to exercise and implement these rights as a contributing and positive participant in society.

The second theme of gender empowerment was professional and personal growth and being offered the opportunity to do so. Women engineers expect to be offered similar opportunities to grow professionally, whether it be in an operational, managerial or leadership role. They want effective training and mentorship with the financial

resources to develop their specific set of skills; and they expect those skills to be rewarded and recognized accordingly. It remains a fact that women engineers are still paid 25% less compared to their male peers for the same position and deliverables [11]. Albeit recognition of work remains the primary motivator for employees, the women engineers believe that financial reward is a true yardstick of a person's ability, level of education and experience.

D. The Impact of Culture on Women Engineers

Culture is a sensitive yet powerful influence in South African economy, business and families. It is important to recognize that the expectations from the various role-players in the structure and hierarchy of families strongly influence the role and power of women in companies.

The engineers concur that cultural diversity and personal culture have a significant impact on both their personal and professional lives. Many women were raised in homes where the man assumes the professional role in the family whilst his wife occupies the domestic and dependent role. Patriarchal families therefore find it difficult to accept when their daughters assume an independent and equal position in a company and asserts that same influence at home. The African, Indian and Afrikaans cultures in particular demand a more traditional and subservient role from their women than the English culture does.

Most women engineers, however, consider themselves fortunate for having grown up in a complex and diverse country such as South Africa. They believe that the various perspectives prevalent in the country contribute to an enriched understanding and acceptance of being different – and that diversity provides an opportunity to gain exposure to alternate viewpoints and solutions. Respecting cultural diversity remains a challenge not only to societies and countries as a whole, but to the employees of companies and to members of families.

E. Work-Life Balance

The women engineers believe that work-life balance is attainable but that it comes with responsibility and requires diligent planning. Collectively the participants strongly emphasized the role and value of personal and professional support systems. Professor Lynda Gratton, author of The Shift: The Future of Work is Already Here, states that: "In a world that could become increasingly fragmented and isolated, I believe that connectivity, collaboration and networks will be central" [12].

A support system does not constitute family structures, but also includes colleagues at work, information sharing and delegation. For engineers that work an average of eight to twelve hours a day, the work environment and collegial relationships contribute significantly to achieving work-life balance. Career burn-out is a serious concern for women engineers and may well be one of the primary reasons for women engineers leaving the industry. Delegation and stress management are therefore critical skills and must be conscientiously managed. Strategies that may reduce stress include working flexi-time; securing hired help at home; blocking off dedicated times at the office for different priorities; and enforcing a regular exercise routine.

In a technological age where it is easy to be detracted by noise, the success of women is highly determined by how they focus their energy and resources. Greg McKeown argues that the idea that a person can have it all - at the same time - is a highly damaging myth, particularly in our time with too many choices and too much pressure [13]. To avoid burnout and live a balanced life, McKeown advises cultivating the mind set of an essentialist, a person who removes noise from life, exercises individual choice on how to spend time and energy, and accepts the reality of trade-offs at various stages of life.

IV. DISCUSSION

The challenges women engineers encounter vary with the positions they occupy and the phase of their lives in which they find themselves. The first is prioritization amongst the many demands of their lives; and the second is the conservative nature of the current engineering sector in South Africa which allows little room for diversity and innovation.

Despite the significant challenges that women experience, they still make a remarkable contribution to engineering, including contributing to professional societies; establishing new educational and social programs; influencing engineering curricula; collaborating with higher education institutions; and mentorship. These second careers and contribution by the participants demonstrate their sense of agency; and their expression of agency becomes a path towards self-actualization.

The World Development Report of 2012 defines agency as follows "…the ability of an individual or group to make effective choices and to transform those choices into desired outcomes" [14]. If a woman has the right and freedom to make her own empowering choices, she can consequently influence the world around her, leading her towards self-actualization.

The participants agree that leadership through team work, transparent dialogue, practical example, hard work and effective communication achieve successful projects and sustainable change. Continuous personal improvement by reading widely is another important tool in developing leadership skills. Younger women believe they must take responsibility for their own lives and professional development; and that they need not settle for work that they do not feel passionate about it - they would rather use their energy and abilities to get involved in activities they care about.

The fact that only 60% of graduate women are retained in engineering portrays poor labor practice and bodes an untenable future for the profession. There are many interventions available to government, higher institutions and companies that can contribute to a more sustainable engineering career for females. Government usually lays

the foundation for equitable treatment amongst citizens in its' country and it may consider the inclusion of clear, independent and enforceable policies and legislation to demonstrate commitment to gender empowerment.

Companies too must recognize that they need to up their game if they want to attract and retain talented women. Leaders in companies should be accountable for progressive change and commit to eradicate bias wherever and whenever it occurs. Companies could equalize the number of executive and senior managers and remunerate professional peers equitably in relation to their positional expectations and roles. Yet, as mentioned previously, women are recompensed at significantly lower levels than their male counterparts. One of the main reasons for this discrepancy in South Africa is the perception that women do not need to be paid as highly as men because they are generally the ancillary bread-winners in the family. Statistics from South Africa in 2011 show how incorrect this assumption is: 79% of African urban single parents are female, as are 84% of colored, 64% of Indian, and 69% of white such parents [15].

The structure of governmental and company boards, committees and decision-making entities is also indicative of commitment to gender equity in engineering. Access to information and transparency are less apparent but very powerful mechanisms for equality. If a woman does not have access to the relevant information that is necessary for the execution of her responsibilities, she is unable to make well-informed decisions and consequently deemed ineffective in her role. The same holds true for a situation where she is excluded from decision-making committees or forums. Transparency in information dissemination and sharing creates trust in an organization, and higher trust alleviates isolation and silos amongst employees, in turn boosting morale and productivity.

Offering women alternatives in working conditions is critical. Women in the age group 25 to 35 are most in need of flexible working conditions since personal commitments compete fiercely with their ambition to advance their careers. On- and off-ramps for women during this time may also contribute to the retention of women in the field. Such ramps allow women to increase or decrease responsibilities in their current positions and this may positively benefit both the company and the employee. Women who have experienced these progressive employment practices testify that they remain deeply committed to the company for many years after having the responsibility of raising young children.

More suggestions on working conditions include allowing for care facilities within close proximity to the office and ensuring that maternity leave is fair and substantively supported. Comfortable and safe offices positioned in pleasant surroundings could also promote employee retention. Women are creative and efficient in architectural spaces that promote high-level thinking and interaction. This may include the use of color in offices, glass partitions to allow for both privacy and interaction, art, indoor plants, as well as breakaway spaces for informal discussion. Most companies realize that many ideas emerge from informal discussion and the interior design of modern buildings now allow for this added advantage. Companies situated in densely-populated areas should also consider the debilitating impact that traffic has on employee productivity, and include areas such as gyms and salons to compensate for stress and efficiency, if possible. The more supportive the physical environment is, the more productive its people. As the cost of fuel and energy increases, it is predicted that companies will be transformed by the way that work is accomplished. Technology and internet connectivity will enable more home-based and virtual working, as well as flatter and more flexible organizational structures.

The participants suggested several strategies for attracting young women to a career in engineering. The first is by sharing success stories of women engineers, and showing that there is significant personal and professional benefit from the choice. Joint ventures and partnerships between young women and strong mentors with experience is a second strategy. Also, visibility of engineering at school level is an essential marketing tool in creating an interest in engineering and may include information sessions, technical educational material that appeals to girls, a strong skill set in math and science educators, role models and bursaries. Recently, the toy company Lego® recognized the need for girls to relate to female technical toys and educational material by launching the first female scientist figures in their 2014 range, including an astronomer, a chemist and a paleontologist [16].

Role models are imperative to young women. A finding of the 2012 World Development Report is that gender stereotyping impairs a woman's intellectual performance by affecting her self-concept [14]. Role models are therefore invaluable in that, when women discover that other women – officials, entrepreneurs, public figures, engineers and scientists – do not submit to prevailing norms, they feel more comfortable and inclined to question those norms. Media exposure of engineering role models can significantly influence the choices that women make in their lives.

Peer support in the establishment of young people forums is another excellent intervention in engineering education. Several such programs exist in South Africa, and these programs are run by women engineering students who offer guidance and opportunity for young girls interested in studying engineering. Not only do they support one another, they also develop strong leadership, networking and study skills – and motivate one another to stay committed and enthused in their studies. The 2012 World Development Report also found that clubs managed by young women provide girls with increased access to peers, social support, information, and ways to learn the value of and mechanisms for collective action.

V. CONCLUSION

Engineering to women is an opportunity to leave a legacy for future generations, and to be mentors for

younger women. Innovation, creativity and work diversity are appealing aspects of engineering; and the opportunity to display creative talent in a tangible way towards the improvement of human and socio-economic conditions is invaluable to women engineers. Young engineers believe that engineering is endlessly diverse and holds many unexplored areas for innovation and social contribution.

Despite the fact that women engineers are passionate about their careers, they are less enthusiastic about the prospect for young women in engineering. The respondents agree that a future exists for women engineers, but that the current policies, governance and education structures, and financial systems in South Africa must be restructured to make it a more conducive and attractive career for women. The Commission on the Status of Women (2014) found that the "growing representation of women in higher education has yet to translate into proportional representation in the labor market, particularly in leadership and decision-making positions" [17]. Academia in South Africa, as example, is considered as a more appealing and flexible career for women engineers, but reported only 2% of female academic staff as professors in 2009 [17]. The quality of mathematics and science education in South Africa is the lowest it has ever been, with South Africa ranked last out of 144 countries in the 2014 - 2015 Global Competitiveness report [18]. Math and Science are therefore not attractive to secondary learners and given that the technological content in the primary and secondary school material contains no gender-specific examples, it still remains modules pursued by boys rather than girls.

In Sub-Saharan Africa it is estimated that 2.5 million engineers and technicians are needed to improve access to clean water and sanitation – a sector that heavily influences the lives of women and girls [19]. All the participants agree that change is needed but how change should happen is debatable. Some argue that deep and real change occurs slowly, taking time to grow roots and flourish. They advise that quick fixes and shallow policies should be avoided; and that change should be integrated and supported towards a more equitable demographic; allowing skills, structures and development to occur naturally. The younger engineers argue that sustainable transformation is not enough to achieve what needs to be accomplished in the next few decades - disruptive change, rather than sustainable transformation, is needed to create an environment where women can thrive. The members of Engineers-Without-Borders South Africa make the following visionary statement [20]:

"To take this leap, we need engineers that think differently, that challenge traditional ways of doing things and that bring a passion for humans and life to the table. Young women who choose engineering have the character traits required to shift the engineering profession. However, it will require courage, faith and commitment to get there. Engineering does not offer a stage for performance, just real and honest reward for pioneering thinking and earnest solutions."

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