

Engineering Co-Curricular Role Model Interventions to Develop Women Engineering Students Self-Efficacy at a South African Comprehensive University

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The European Conference on Education 2014
Official Conference Proceedings

Abstract

Women engineers face often negative stereotypes regarding their competence in the workplace. In the same way, women engineering students face various identity and professional obstacles in their study environment that may affect their feelings of self-efficacy. Furthermore, as the engineering environment is often described, as “a man’s world”, engineering is often perceived as a man’s job. Therefore, women are often deprived of women role models in engineering disciplines. Role models can have a positive influence on attitudes, identification with, and intent to pursue a career in the engineering field. This paper is a qualitative, descriptive and interpretive study of the rationale and operational aspects of the Women in Engineering Leadership Association (WELA) interventions to expose WELA members to role models and to create the opportunity for WELA members to be role models. The objectives of this paper are to provide suggestions for the design of the role-model interventions and to provide insight into the process of developing such interventions specifically for women engineering students. It is envisaged that these co-curricular interventions can be implemented at universities and higher education institutions concerned with improving the self-efficacy of women in engineering and other non-traditional employment fields for women.

Keywords: co-curricular interventions, role models, women in engineering

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I. INTRODUCTION

The need for women to enter science, technology, engineering and mathematics (STEM) fields is indisputable, not only to draw on a pool of talent and expertise that has been untapped, but also to foster gender equality and challenge gender stereotypes (Young, Rudman, Buettner & McLean, 2013). Furthermore, it is known that women engineers bring diversity to the monoculture-engineering workforce, and extend the impact of engineering on society (European Commission, 2006). Usually, women show interest in the social aspects of technology and science and in this way, they can make a significant contribution to social and environmental issues (European Commission, 2006).

Although far more women are pursuing engineering qualifications than in the past, they remain under represented in engineering related careers. Nel and Bosch (2011) reported that women represent 9 percent and 14 percent of teaching and research staff in South African engineering faculties respectively. Only 21 percent of all research grants funded by the National Research Foundation are for women scientists. As a result, the engineering environment is often described as “a man’s world” and engineering is perceived as a man’s job (Du Tot & Roodt, 2009). Because of all these factors, women are often deprived of women role models in engineering disciplines. Several authors, such as Young et al. (2013) and Austin and Sax (1996) propose that identifying with a role model has a positive influence on both implicit and explicit attitudes, identification with, and intent to pursue a career in the science, technology, engineering and mathematics (STEM) fields. Role models emerge when others choose to emulate them and when they meet three criteria. Firstly, a woman role model’s success needs to be attainable, secondly, the woman role model must be perceived as similar and, thirdly, the student needs to care about her performance in a certain domain (Marx & Roman, 2002). Identifiable woman role models in STEM fields can also increase women’s implicit identification with these fields, decrease, and invert implicit gender stereotypes in addition to lessening the association of masculinity with STEM. Women role models in STEM could increase how well women students feel they fit into STEM fields, which is a very important aspect in increasing women’s intentions to pursue a career in these fields. Furthermore, implicit stereotypes about STEM impacts on women’s STEM career aspirations.

In an effort to retain and develop women engineering students (WES), a South African comprehensive university based in Port Elizabeth established the Women in Engineering Leadership Association (WELA). The School of Engineering at the university offers formal qualifications in mechatronics, electrical, industrial, and civil and mechanical engineering. In addition, the School of Engineering provides a comprehensive curriculum, offers various informal courses, maintains close links with industry, and includes service departments to assist with co-curricular activities and student developmental activities. One of the initiatives housed in the School of Engineering is WELA, which is one of five projects initiated and managed by the university and the merSETA*¹ (manufacturing, engineering and related services sector education and training authority) chair in engineering development. WELA commenced in 2011 with the goal of focusing on the academic, professional and personal development of women in engineering. Further to these goals, the WELA leadership development programme (LDP) was designed considering the university values, graduate skills required by industry, input from women engineers, women

engineering students (WES) and other national and international leadership development programmes (Lourens, 2013a)

II. OBJECTIVES

The underlying premise of WELA LDP is to improve the feelings of self-efficacy of WES. Self-efficacy can be defined as an individual's belief in their capability to plan and take action to achieve a particular outcome (Bandura, 1986). Efficacy, however, applies to any situation and is particularly important in choosing and executing constructive actions in situations that can be barriers to a desired outcome. In engineering, such a barrier can be negative stereotypes, active discouragement by peers or faculty and/or poor exam results (Marra, Rodgers, Shen & Bogue, 2009). The main sources of self-efficacy includes mastery experiences (having a positive experience in completing a course); social persuasion (social support and mentors); vicarious experiences (the visibility of women in engineering fields), and physiological states (debilitating performance anxiety for those belonging to a group for which there is a negative stereo type related to the task) (Bandura, 1986; Marra et al. (2009).

WELA offers comprehensive co-curricular interventions in the form of a university short learning programme. This paper describes selected role modelling co-curricular interventions developed for WELA members. Other aspects of the WELA programme, such as the design of the WELA programme and the development of a Self-leadership Workshop has also been researched (Lourens, 2013a; Lourens, 2013b; Lourens, 2013c). The role modelling co-curricular interventions and activities discussed in this paper are aimed at improving the third source of self-efficacy, namely, vicarious experiences. Further to this objective, this paper describes the importance of role models to WES and the co-curricular activities designed to expose WES to women engineering role models. For the purpose of this paper, reference is made to the engineering field, whereas the reference can also be applicable to the other dimensions of STEM, namely science, technology and mathematics. This paper also describes an intervention designed to create a role-modelling situation for WELA members to influence women first year students entering, and those considering entering engineering.

III. METHODOLOGY

This paper is a qualitative, descriptive and interpretive study of the rationale behind and design of WELA's interventions to introduce role models to the WELA community. WELA members who attended a seminar with working engineers completed a feedback form relating to the relevance and importance of the speakers as role models. The workshop format is designed to incorporate a three-tiered professional development typology (Bryan & Schwartz, 1998) consisting of formal (a compulsory seminar as part of the formal WELA leadership development programme), non-formal (emphasising orientation, contextualising and motivational intent) and informal aspects (emphasising self-reflection, role modelling and peer support) (Lourens & du Plooy, 2013).

Additionally, feedback pertaining to the yearly WELA publication, "Inspirational Women" was analysed because the feedback related to role models. This paper provides a descriptive and interpretive study of the rationale and operational aspects of WELA's role model seminars from the data analysis. The WELA seminar and the

publications form part on the current longitudinal study on self-efficacy of South African engineering students at the university.

IV. THE IMPORTANCE OF ROLE MODELS TO ENCOURAGE SELF-EFFICACY THROUGH VICARIOUS EXPERIENCES

Darby (1992) proposed that women, to a greater degree than men, consider supportive persons, including role models, as important. Zeldin and Pajares (2000) found that women valued persuasion (direct encouragement) and vicarious experiences (seeing a person similar to oneself succeeding) as opposed to men who valued mastery experiences as critical to their self-efficacy beliefs (Marra et al., 2009).

Further underscoring the importance of role models in encouraging self-efficacy via vicarious experiences is the definition of a role model (Lockwood, 2006) as “an individual who provides the kind of success that one may achieve and also often provide a template of behaviours that achieve such success”. By identifying with an outstanding role model, individuals can become inspired to pursue similar achievements however, it is not clear that matching on dimensions such as race or gender is necessary for a role model to be deemed relevant (Lockwood, 2006).

MALE OR WOMEN ROLE MODELS FOR WES

Men make up the majority of scientists and engineers in most industrialised countries, even if the percentages differ from one field to the next (Blickenstaff, 2005). The implication is that there are fewer role models in engineering fields for women students to follow. Furthermore, a low proportion of women in this field could send a message to woman students that the discipline is unattractive to women and they should avoid it.

Lockwood (2006) argues that women role models might be especially beneficial to women. Outstanding women could function as inspirational examples of success by illustrating the kinds of achievement that are possible for women around them. The women role model could demonstrate that it was possible to overcome traditional gender barriers proving that high levels of success were attainable by demonstrating their competence in traditional male fields. It is thus possible that highly successful women could challenge traditional gender stereotypes about women.

Drury et al. (2011) found that same-gender role models were helpful for women already in the engineering field. It is also proposed that women role models are valuable in preventing women who are highly identified with engineering from underperforming and retreating from the field. Women role models are thus particularly effective in *retaining* women in engineering fields (Drury et al., 2011). In contrast, Drury et al. (2011) and Nauta, Epperson and Kahn (1998) found that when *recruiting* women into engineering fields, providing women role models might not always be more effective than providing male role models.

THE POWER OF ROLE MODELS

Identifying with a role model has a positive influence on both implicit and explicit attitudes, identification with, and intent to pursue a career in the engineering field.

Identifiable woman role models in engineering fields could also increase women's implicit identification with science thereby decreasing and inverting implicit gender stereotypes about engineering fields in addition to lessening the association of masculinity with science and engineering fields (Young et al., 2013). Women role models in engineering could increase how well women students feel they fit into engineering fields, which is a very important aspect in increasing women's intentions to pursue a career in these fields. Furthermore, implicit stereotypes impact on women's engineering career aspirations (Young et al., 2013).

A women role model is particularly influential in areas where negative gender stereotypes exist, additionally, women who reported being influenced by positive role models had higher career aspirations in engineering fields (Marx & Roman, 2002, Nauta et al., 1998). It was found that woman role models who demonstrated that women could be successful in engineering contributed to women engineers' feelings of belongingness (Richman & van Dellen, 2011). An important finding of the Richman and van Dellen (2011) study was that successful women engineers developed means of coping with social identity threat that arose from being a minority in the field. Not only did these women have more experience with being in gender-imbalanced environments but they also felt comfortable in a male-dominated environment.

The European Commission's (2006) findings are corroborated by informal qualitative data collected from 22 South African women engineers working in the engineering field (Lourens, 2013a). These findings were explicit in recommending that women entering the workplace did not make gender an issue and that woman engineering graduates "must just get on with it". The respondents were unwavering in their opinion that woman-engineering graduates must believe in their own worth and value and that they must use their strengths to highlight their abilities, as well as stand behind their opinions and decisions. Women engineers stated that it was important to work well in a team, but, on the other hand, it was also necessary to be self-sufficient and able to work alone and unsupervised (Lourens, 2013a)

FIRST YEAR WES FEARS AND CONCERNS

After considering the findings of various studies, it was evident that the fears and concerns expressed by WES, as illustrated in Table 1, show an apparent lack of confidence necessary to be successful in a male-dominated field. Table 1 illustrates the informal survey results obtained from the 2011, 2012, 2013 first year WES (Lourens, 2013a; Lourens, 2013b)

**TABLE I
FIRST YEAR WES FEARS AND CONCERNS**

YEAR	Percent	CONCERNS
2011	37	Experiencing discrimination and lack of collegial respect
	20	Being Intimidated which leads to demoralisation
	20	Not being taken seriously
2012	50	Being underestimated
	41	Experiencing sexism and not

		being taken seriously
	33	Being seen as emotionally weak
2013	57	Being undermined
	33	Feeling inferior
	30	Not being be taken seriously

In 2011, 37 percent of respondents indicated that they perceived that their biggest obstacles as a woman employee in a male-dominated work place would be discrimination and a lack of collegial respect. A further 20 percent listed intimidation by male colleagues and demoralisation as perceived obstacles, and 20 percent were of the opinion that male counterparts would not take them seriously (Lourens, 2013a)

The 2012 informal survey indicated the greatest perceived challenges were being underestimated (50 percent of respondents); sexism, again in the form of not being taken seriously resulting in not being accepted (41 percent of respondents); and being seen as emotionally weak and unable to cope with a tough working environment (33 percent of respondents) (Lourens, 2013a). In 2013, it was found that 57 percent of respondents listed a fear of being undermined and 33 and 30 percent respectively were concerned that they would feel inferior in a male-dominated environment and that that they would not be taken seriously (Lourens, 2013b).

The survey results clearly indicated that WES displayed fears and insecurities about how they would be accepted and treated in a traditionally male-dominated field, be it as a student or as a working engineer. Based on the findings of several authors, (including Marx & Roman, 2002, Nauta et al, 1998, Richman & van Dellen, 2011, Blickenstaff , 2006), Lockwood, 2006, Drury, Siy & Cheryan, 2011) it was found that exposing WES to role models might lessen their fears and insecurities. Further to these findings, several co-curricular interventions were designed to assist WES, by means of the WELA LDP, to overcome women engineers' fears and insecurities and to improve their feelings of self-efficacy. Section 5 discusses the interventions aimed at introducing role models.

V. CO-CURRICULAR INTERVENTIONS TO INTRODUCE WOMEN ENGINEERING ROLE MODELS

Women in engineering fields often contend with negative stereotypes that can cast doubts in their abilities to perform in these fields (Drury et al., 2011) the fear of confirming these stereotypes is known as stereotype threat and it causes women who are personally identified with the domain to underperform. It is proposed that interventions designed to prevent harmful effects of stereotyping threat could protect women by preventing them from underperforming and leaving the field (Drury et al., 2011).

Explicit in the WELA programme were two interventions created to expose WELA members to women engineering role models.

SEMINAR

At the university, a yearly seminar is organised whereby working woman engineers are invited to address WELA members. The invitees are selected to represent various industries, ages and race. Topics ranges from “Being a woman in a man’s world” (2011), “The road to success: a woman’s perspective” (2012) and “Engineering across borders: a global engineering perspective” (2013).

The 2012 seminar included three women of different ages and educational backgrounds. The panel members shared their experiences in a male-dominated working environment and gave advice on strategies for coping in such an environment. Two of the panel members recommended the following for success in the work place:

Watch your attitude – you do not have to be overly aggressive to prove you are as worthy as your male co-workers. Your intelligence and work product should speak for itself (Louis, 2012).

Do not be afraid to reach out to women or men in senior positions (highlighting the importance of finding a mentor within the organisation) (Louis, 2012). Women in male-dominated fields typically have to work harder to prove themselves. You should remain positive and confident in who you are and what you stand for. It is important for women not to invest in the belief that they are at a disadvantage because of their gender (Gathercole, 2012).

The value of the panel discussion was in the interaction of the WELA members as aspiring engineers with women working in the field. Apart from motivating and assuring the WELA members that they could be successful in a male-dominated environment, the panel members shared their personal work experiences. A valuable lesson taught was that their first job might not be the right job for them and that they had to persevere and not think that it was just because they were women that they could not cope with the job.

The 2013 seminar included two practising male and three women engineers who have been involved in international engineering projects. They were briefed to include in their presentation what the differences were between working in South Africa and working overseas as well as their views on women working in male-dominated environments overseas. The 2013 seminar was seen as particularly relevant in light of predicted trends for engineering leadership education (Graham, Crawley & Mendelsohn, 2009). It was found that global engineering exposure to increase students’ ability to operate in complex international and multi-disciplinary team would become an important factor (Graham et al., 2009). It was also proposed that engineering students had to cultivate a stronger awareness of national and cultural differences in approaching engineering problems (Graham et al, 2009). Furthermore, by extending the invitation to male speakers, the study explored the possibly that WELA students could view males and women and relevant role models.

FEEDBACK

Thirty-two WELA students who attended the seminar 2013 were asked to complete feedback forms (Lourens, 2013c). The feedback form consisted of questions relating to the relevance and importance of the speakers and the seminar itself. Responses were based on a five-point Liker scale (1=strongly agree, 2=agree, 3=not sure, 4=disagree, 5=strongly disagree). Table 2 presents a summary of the averages of the responses.

TABLE II
SUMMARY OF RELEVANCE AND IMPORTANCE OF SPEAKERS

Question	Women speakers	Male Speakers
I can relate to the...	Agree	Agree
I am motivated by the...	Strongly agree	Agree
I would like to hear from them again...	Agree	Agree
They should be invited yearly to speak to WELA members...	Yes	Yes

From Table II feedback, the majority of the students could relate equally to both the male and woman speakers. They were, however, more motivated by the woman speakers than the male speakers, but indicated that they would like to hear again from the male and the woman speakers.

Table III summarises the average responses pertaining to the women speakers only.

TABLE III
WOMEN ROLE MODELS

Question	Response
When I listen to the women engineers, I am happy about my career choice	Agree
I view the working women engineers as role models in their field	Agree
It is important to expose WELA students to women role models	Strongly agree

The responses in Table III clearly indicated that the women engineers confirmed that the students had selected the right career by enrolling for engineering studies. This indicated that they found the seminar and the speakers inspirational and motivating. They also viewed women engineers as role models and felt strongly that it was important to expose WELA students to women role models. The responses confirmed the importance of exposing WELA students to woman role models and the importance of the “Inspirational Women” booklet.

INSPIRATIONAL WOMEN PUBLICATION

Drury et al. (2011) proposed that women who read about a successful graduate from their university in their own field rated themselves higher in success-related traits if the role model was a woman compared to a male. Since the inception of WELA in 2011, a publication called “Inspirational Women” has been distributed to students, schools and Industry. Yearly, the booklet features ten women from the Eastern Cape

across the spectrum of race, gender, religion and age (Inspirational Woman, 2011, 2012, and 2013). The women also represented a variety of industries, such as automotive and related, engineering consulting, fast moving consumer goods, construction, logistics, chemicals, academia and pharmaceuticals. Professional photographs were taken of each woman and they were asked to write responses to the questions listed in Table IV.

TABLE IV
PARTICIPANT’S QUESTIONS

	Typical questions	Rationale for question
1	What do you do?	This question exposes students to a variety of possibilities and employment positions possible with their respective qualifications.
2	What is it like being a woman in a typical male-dominated environment?	These questions aim to orientate WELA students for entering a male-dominated field.
3	What advice would you give to women entering a male-dominated career environment or to those considering a career in a male dominated field?	
4	What is most challenging about your job?	These questions aim to give insight into the day-to-day activities of each featured woman and to prepare WELA students for the world of work.
5	What is a typical day?	
6	What characteristics and qualifications do you need for your current position?	This question allows for WELA students to focus on their strengths and weakness in relation to the career for which they are preparing
7	What are your goals for the future?	This question shows the possibilities for growth and further development
8	What do you do when you are not at work?	These questions allow the women to share personal hobbies and interests, often showing typical woman interests such as cooking and baking. This shows that being a successful engineer in a male-dominated field does not mean that typical woman interests need to be neglected / ignored?
9	If you weren't in this particular career what would you be?	

From Table IV, questions that should be highlighted as facilitating the most impactful response were the questions relating to being a woman in a male-dominated field and advice to women entering a male-dominated field. In their response to these questions, the women often suggested that gender should not be made an issue; they must just believe in themselves and work hard. One women engineer stated that it was important not to be a victim and not to allow the possibility that someone was treating a women differently because they were a woman enter their mind. Realistically, some of the women admitted that it was tough being a woman in male environment, but again stressed that a women engineer needed to earn respect by showing that she was competent and committed. Noticeably, some of the younger women mentioned that women felt more pressure to prove themselves constantly and that men still

undermined their capabilities because they were women (Inspirational Woman, 2011, 2012, and 2013).

This publication was not only inspirational to WELA students and other women in the manufacturing industry, but being selected for inclusion in the booklet was also recognition for the women featured.

VI. WELA STUDENTS AS ROLE MODELS- INSPIRATIONAL STUDENTS' PUBLICATIONS

In conjunction with the yearly Inspirational Women booklet, WELA also published an Inspirational Student booklet. The aim of the publication was not only to showcase WELA students, but it also created an opportunity for them to influence woman students positively by considering engineering careers for themselves as well as for their peers. The importance of this role for WELA members was supported by McIntyre, Paulson, Taylor, Morin and Lord (2011) who stated that woman students might seek role models to which they compare or to collective agents (in-group members). The in-group members might help restore or create feelings of self-efficacy when a woman engineering student felt threatened or reduced.

Upon completion of the first year of the WELA programme, WELA members were also asked to write reflective articles in which they were required to write about themselves, their experiences as WELA members, the benefits of joining WELA and to name their personal highlights.

It might appear as if the questions were not the typical questions that would be asked of a role model. However, it was found that a role model could be inspirational or deflating, depending on how they achieved their success (McIntyre et al., 2011). This is consistent with the reasoning that when role models were perceived as having achieved their success through dispositional ability as opposed to situational advantages, then other members of the group could perceive themselves as able to overcome negative stereotypes and perform satisfactorily (Lockwood & Kunda, 1997). In the WELA student publications, some students referred to themselves as being raised in a single parent household in very trying circumstances, coming from the rural areas and battling to adapt to city life. One student mentioned that she had learnt that she was the only person that could determine her future while another mentioned that when she joined WELA she was unsure if she was coping with her engineering studies, but through the WELA programmes she had gained strength and felt empowered by many of the other WELA members (Inspirational Students, 2012, 2013). Given the definition of a role model (Lockwood, 2006) the WELA members featured in the Inspirational Students booklet had achieved some form of success and agreed that they would inspire woman students interested in an engineering field to pursue similar achievements, and be more comfortable and confident to enter the engineering field.

The majority of the WELA members wrote about how helpful the WELA programme had been to their self-development, confidence and adjustment to not only the university, but also to the Engineering School where 81 percent of students were male. The students' reflective writing pieces were inspirational, showing young woman students considering the engineering field that young women, be it from rural

areas or the city, from different cultures, race, and nationalities could support each other and adapt successfully in not only in a male-dominated course, but also in the workplace.

VII. CONCLUSION

As a developmental initiative, WELA is aimed at the academic, professional and personal development of women engineering students. The role model seminar and the WELA publications co-curricular interventions presented as part of the WELA LDP could be seen as an attempt at increasing the self-efficacy of the WELA members. Specifically, the WELA LDP focused at creating vicarious experiences for WELA members by making women in engineering fields more visible, thus creating role models for WELA members. It was intended that the interventions would advance the self-efficacy in participants, while also encouraging them to act as role models for aspiring women engineering students.

The planned co-curricular interventions to improve the self-efficacy of minority groups, such as women in engineering described in this paper could be implemented by other universities and institutions concerned with establishing role models as well as encouraging and retaining women students in engineering (and science, technology and mathematics). The impact of the seminars and publications, along with the rest of the WELA LDP will be determined statistically and more formally, when the university's longitudinal study on the self-efficacy of South African engineering students that commenced in 2013 concludes.

*1. SETA is an acronym for Sector Education and Training Authority. The members of SETA include employers, trade unions, government departments and bargaining councils where relevant, from each industrial sector. The Skills Development Act (1998) provides a framework for the development of skills in the workplace. Amongst other things, the Act makes provision for skills development by means of a levy-grant scheme and the establishment of sector-specific Education and Training Authorities – or SETAs – to administer the scheme's funds and manage the skills development process [31].

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