

Empowering Tomorrow's Scientists: 'Girls In Control' Workshop Promotes STEM Education For Young Girls

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Abstract: Enhancement of female students' access to and success in STEM-related subjects and courses has acquired an unprecedented level of traction in academia. Considering female students' increased participation in STEM education as a moral imperative, the University of Zululand (South Africa) in partnership with SACAC, South Africa hosted two Girls in Control Workshops at its Science Centre during 2022 and 2023. This article reports on the workshop's purpose and the experiences of the participants. It also makes references to the workshop's implications on various aspects of girls' participation in STEM education in general and control engineering in particular. The article thus places the need for instilling a high degree of receptiveness to STEM-related careers among girls from previously marginalized communities.

Keywords: STEM education, Control Engineering, Girls in Control, Empowering Girls.

1. INTRODUCTION

The goal of the Girls in Control workshops is to inspire young girls at an early age to pursue careers in science, technology, engineering, and mathematics (STEM). The idea of a workshop was sparked in 2020 during the 21st International Federation for Automation and Control (IFAC) World Congress. Here, a group of control engineering experts noticed that there was a problem in STEM education, particularly relating to scarce female representation. Studies had also repeatedly shown that mathematics and science were perceived as male domains, and scientists as predominantly male. Against the backdrop of this reality and as part of the workshops in 2022 and 2023, young girls from two primary schools from the Zululand region visited the University of Zululand (UNIZULU) Science Centre, where they were exposed to the basics of coding and robotics. The girls were also introduced to the basics of control engineering as a field of study. The workshop subscribed to the view that girls need to be exposed to various STEM fields as career options. Instilling a certain degree of confidence in undertaking studies in such fields is thus imperative. The content was translated into Isizulu by the facilitators. This was done to eliminate the language barrier that would otherwise have impaired the isiZulu-speaking participants' understanding of concepts.

In a world where science, technology, engineering, and mathematics (STEM) fields continue to drive innovation and shape our future, the importance of fostering diversity and inclusion cannot be overstated. Recognizing the significant

gender gap in STEM participation, the University of Zululand in partnership with SACAC took proactive steps to address this issue through its Girls in Control Workshop. Originating from a poignant observation made during the 21st International Federation for Automation and Control (IFAC) World Congress, this workshop aimed to inspire and empower young girls to pursue careers in STEM. By providing hands-on experiences in coding, robotics, and control engineering, among other activities, the workshop not only ignited a passion for STEM but also challenged stereotypes and perceptions. Led by the authors and supported by a group of master's students, the workshop imparted knowledge and bridged language barriers by delivering content in Isizulu, the mother tongue of the participants.

The paper is organized as follows. The introduction gives an overview and context. This is followed by current perspectives on control engineering as a career option within STEM education. Section 3 deals with the details of the 'Girls in Control' workshop. Section 4 then deals with how control engineering evolves as a field within STEM in which girls' participation needs enhancement. Finally Section 5 concludes the paper with the authors' views on the potential of such workshops becoming a game changer in girls' success in STEM fields.

2. GIRLS IN STEM-CURRENT PERSPECTIVES

The underrepresentation of women in STEM fields has been a longstanding concern globally. Numerous studies have

highlighted the disparity in gender representation within STEM education and careers, attributing it to various factors such as societal stereotypes, lack of role models, and systemic biases (Jackson et al., 2021). Research indicates that from an early age, girls may internalize the notion that STEM subjects are more suited for boys, leading to decreased interest and participation in these fields. Efforts to address this gender gap have included initiatives aimed at inspiring and empowering young girls to pursue STEM education and careers. Workshops, programs, and outreach activities targeting girls at the primary and secondary school levels have shown promising results in sparking interest and confidence in STEM subjects. By providing hands-on experiences, exposure to female role models, and opportunities for mentorship, such initiatives aim to challenge stereotypes and broaden girls' perceptions of STEM fields.

2.1 Strategies for Encouraging Girls in Control Engineering

The importance of Control Engineering as an appropriate disciplinary choice for girls in this context is emphasized in literature. By addressing societal norms, providing inclusive learning environments, and offering opportunities for skill development and mentorship, stakeholders can work towards creating a more equitable and diverse STEM workforce for which Control Engineering offers immense possibilities. Some of the skills hence developed can be listed as:

A. Early Exposure to STEM Concepts:

Introducing control engineering concepts at a young age exposes girls to fundamental principles of science, technology, engineering, and mathematics (STEM). This early exposure can spark interest and curiosity, laying a strong foundation for future learning and exploration in STEM fields.

B. Critical Thinking and Problem-Solving Skills:

Control engineering education encourages the development of critical thinking and problem-solving skills (Capobianco and Tyrie, 2009). Through hands-on activities and projects, girls learn to analyze problems, design solutions, and test their hypotheses. These skills are valuable not only in engineering but also in various aspects of life and future career endeavours.

C. Empowerment and Confidence Building:

By engaging in control engineering activities, girls gain confidence in their abilities to understand and apply complex concepts. This empowerment is essential for combating stereotypes and societal norms that may discourage girls from pursuing STEM subjects. By fostering a sense of achievement and competence, control engineering education can help girls overcome barriers and pursue their interests with confidence.

D. Career Opportunities and Diversity:

Providing control engineering education to girls in primary schools opens doors to a wide range of career opportunities in engineering and related fields. By encouraging girls to explore STEM pathways early on, educators and policymakers contribute to greater diversity and representation in traditionally male-dominated fields. This diversity brings fresh perspectives, creativity, and innovation to the STEM workforce, benefiting society as a whole.

E. Addressing the Gender Gap in STEM:

The gender gap in STEM fields begins at a young age, with girls often discouraged from pursuing STEM subjects due to cultural stereotypes and lack of representation. By offering control engineering education in primary schools, educators can challenge these stereotypes and promote gender equality in STEM. By creating inclusive learning environments where girls feel supported and encouraged to excel, we can work towards closing the gender gap and ensuring equal opportunities for all.

In summary, the literature seems to suggest that control engineering education for girls in primary schools is essential for nurturing their interest in STEM, building essential skills, empowering them to pursue diverse career paths, and addressing gender disparities in the field (Abe and Chikoko, 2020). By investing in STEM education from an early age, we pave the way for a more equitable and inclusive future where all individuals have the opportunity to thrive and contribute to scientific and technological advancements.

3. HANDS ON EXPERIENCE FOR GIRLS IN CONTROL ENGINEERING

In an era defined by technological advancement and innovation, hands-on experiences play a pivotal role in shaping the future of young minds. Offering immersive opportunities in coding, robotics, and control engineering not only ignites a passion for STEM but also cultivates essential skills in problem-solving, critical thinking, and creativity (Capobianco and Tyrie, 2009). The UNIZULU workshop clearly indicated the transformative impact of hands-on experiences in coding, robotics, and control engineering on the next generation of innovators, highlighting the importance of experiential learning in preparing them for the challenges and opportunities of tomorrow's world.

The workshop also highlighted the need for promoting creativity and Computational Thinking. Coding is the language of the digital age, empowering individuals to create, innovate, and communicate in unprecedented ways. Through hands-on coding experiences, students learn to think computationally, break down complex problems into manageable tasks, and develop solutions using logic and algorithms. Whether programming a simple game or designing a website, coding fosters creativity and encourages students to explore their interests and express their ideas in new and exciting ways (Swecker, 2020). Bringing concepts to life through hands-on exploration, robotics bridges the gap between theory and practice, allowing students to apply their knowledge of engineering, mechanics, and programming to build functional robots (Ramos-Teodoro et al., 2022). Hands-

on robotics experiences enable students to design, prototype, and test their creations, gaining firsthand insight into the principles of automation, control, and feedback systems. Beyond technical skills, robotics fosters collaboration, teamwork, and perseverance as students navigate challenges and iterate on their designs to achieve desired outcomes. Fig. 1 shows an illustration of this.



Fig. 1. Hands on experience in Robotics session.

In the context of shaping the future of automation and innovation, Control Engineering lies at the heart of modern automation, enabling precise regulation and optimization of systems in diverse industries, from manufacturing and transportation to healthcare and beyond. Hands-on experiences in control engineering empower students to understand the intricacies of dynamic systems, analyze feedback mechanisms, and design controllers to achieve desired performance objectives. By engaging in real-world applications and experiments, students develop a deeper appreciation for the role of control engineering in shaping the world around them and driving innovation in the digital age. Hands-on experiences in coding, robotics, and control engineering are invaluable tools for inspiring curiosity, fostering creativity, and preparing students for success in an increasingly technology-driven world.

3.1 Why focusing on young girls to instil an affinity towards STEM

Planting the Seeds of possibility, the journey towards a career in STEM often begins with a spark of curiosity and wonder ignited at a young age. By exposing girls to the wonders of science, technology, engineering, and mathematics through hands-on experiences, engaging activities, and positive role models, we can plant the seeds of possibility and instil a passion for discovery and innovation. From exploring nature's mysteries through simple experiments to building robots and coding their creations, early inspiration sets the stage for lifelong learning and exploration in STEM. Challenging stereotypes and fostering confidence despite progress in recent years is also significant (Guy, 2017). Pervasive stereotypes and biases continue to dissuade girls from pursuing STEM fields, perpetuating the gender gap in these industries. To overcome these barriers, it is essential to challenge stereotypes, debunk myths, and foster a culture of inclusivity and belonging in STEM. By showcasing the diverse achievements of women in STEM, providing relatable role models, and creating supportive environments that encourage risk-taking and experimentation, we can

empower girls to defy expectations, embrace their potential, and pursue their passions with confidence.

By investing in girls' STEM education and providing pathways for advancement, we can break down barriers to entry, bridge the gender gap, and ensure that every girl has the opportunity to realize her full potential in STEM. With such an investment in mind, there has been significant attempts at increasing the number of girls at the middle school level who get an early exposure to control engineering as a career option (Lyden et al., 2012). In this context, the Girls in Control Workshop hosted by the University of Zululand helped the participants in their journey towards gender equality in STEM education. By providing young girls with hands-on experiences in coding, robotics, and control engineering, the workshop ignited a passion for STEM and challenges stereotypes that hinder girls' participation in these fields. As we reflect on the impact of initiatives like the Girls in Control Workshop, it becomes clear that early intervention and targeted programs are crucial in promoting gender diversity in STEM. By inspiring and supporting young girls in their STEM journey, we not only open doors to exciting career opportunities but also contribute to a more inclusive and innovative society (Stoeger et al., 2023).

3.2 A brief report on Girls in Control workshop at Zululand

The primary goal of the workshop was to raise awareness about control engineering and inspire young girls to pursue careers in STEM. This one-day workshop included sessions on science exhibitions, science tours, coding with Scratch, and a robotics workshop conducted by the UNIZULU Science Center at the University of Zululand (UNIZUL), with funding from the International Federation of Automatic Control (IFAC) and the South African Council for Automation Control (SACAC). All 28 participants were primary school girls aged between 9 to 13 years from Nteneshane Primary School, a public school in the Zululand Region of South Africa. Most of the girls who attended the program came from historically disadvantaged families. The first session of the workshop introduced the fundamentals of a feedback loop in isiZulu and demonstrated its application in real-life control problems. The material covering control theoretic principles with practical examples was initially developed by the International Federation of Automatic Control, which was translated into isiZulu to provide the girls with more insight into the exciting career opportunities in Control Engineering and related STEM fields. In the second session, a control engineer from Anglo American gave an online motivational talk about a career in engineering. The speaker highlighted the importance of STEM education in general and possible career choices in related disciplines in her talk. The third session focused on the science tour. The fourth session on coding using Scratch and activities in the Robotics workshop gave the girls a taste of what control engineering entails. Engaging them in coding and exhibitions sparked interest and curiosity in STEM subjects. Many girls were not familiar with STEM fields, including control engineering. The last session on the Light Exhibition of primary and secondary colours gave girls an opportunity to

discover the magical world of colours through light. Through hands-on activities and engaging demonstrations, girls were exposed to primary and secondary colours, sparking their curiosity and creativity.

Fig. 2. shows the results of the pre-workshop survey on learners' interest in a career in control engineering or any other STEM-related discipline. The graph displays the percentage of learners and their reasons for pursuing a STEM career. Interestingly, none of the students indicated that they had role models in their community who were engineers or scientists whom they wanted to follow as a career choice. This highlights the underrepresentation of female role models in STEM fields in rural areas, which affects learners' understanding of STEM and their career options. Workshops like this one open more opportunities for such initiatives, providing learners with greater exposure and mentorship in STEM.

A post-workshop survey was conducted to gather learners' opinions on the knowledge gained about STEM, coding, and robotics after attending the one-day workshop. Fig. 3. indicates the distribution of responses across different levels of knowledge gained after the workshop. Fig. 4. shows the learners' excitement about a career in control engineering or related STEM fields after the workshop. While the overall excitement towards control engineering and STEM fields remained unchanged after the workshop, the girls showed increased enthusiasm and gained more knowledge about robotics and coding using Scratch.

During the workshop, we observed several interesting things. The majority of the girls had never programmed before, yet they quickly learned due to the simple drag-and-drop feature of Scratch software. Providing students with video instructions on how to assemble the parts of the Lego Kits for electric fan in robotics proved very effective. Using online videos for learning is a documented effective pedagogy. It is well known that having role models can improve students' interest in STEM, but none of the students had role models who influenced them to pursue careers in control engineering and STEM fields. Our facilitators who speak in isiZulu to students has been shown to positively influence girls' interest in STEM topics. Keeping young students engaged while learning new techniques/coding is crucial. We achieved this through giving them hands-on activities such as using Lego kits and some coding for the assembly of electric fan in robotics workshop.



Fig. 2. Pre-workshop survey on learners' interest in STEM careers.

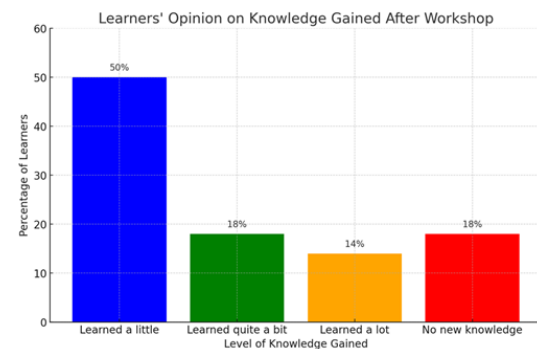


Fig. 3. Learners' opinion on knowledge gained after the workshop.

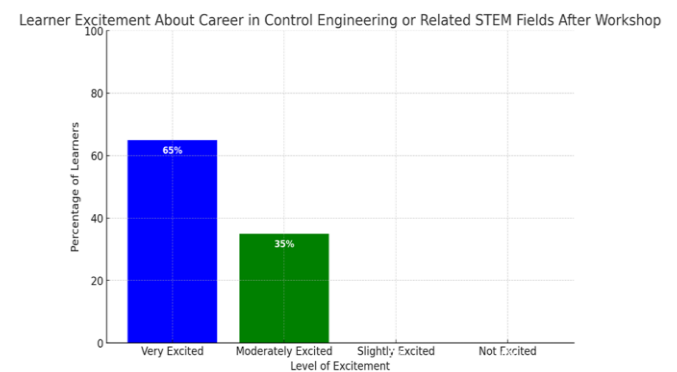


Fig. 4. Learners' excitement about a career in control engineering after the workshop.

4. THE RELATIONSHIP BETWEEN CONTROL ENGINEERING AND GIRLS' STEM EDUCATION

The interface between control engineering and STEM education is multifaceted and holds significant implications for fostering diversity and inclusion in STEM fields. Let us now look at some of those aspects. Introducing girls to control engineering concepts at a young age through educational programs and hands-on experiences can inspire curiosity and interest in STEM. By showcasing the practical applications and real-world impact of control engineering, educators can help girls see the relevance and excitement of STEM disciplines (Filippov and Fradkov, 2012). Control engineering offers a unique blend of theoretical knowledge and practical problem-solving skills. Through engagement with control systems, girls can develop critical thinking, analytical reasoning, and computational skills that are essential for success in STEM fields and beyond. Use of "mathematics for improving control performance" is however fundamental to those skills (White and Smith, 2022) In terms of career opportunities, control engineering is integral to various industries, including aerospace, automotive, manufacturing, and renewable energy.

Control engineering encourages innovation and creativity by challenging students to design solutions to complex problems and optimize system performance. By fostering a culture of innovation, girls can contribute fresh perspectives and ideas to the field, driving forward technological advancements and shaping the future of STEM. The underrepresentation of women in STEM fields, including control engineering, is a persistent challenge that requires concerted efforts to address. By actively promoting girls' participation in control engineering education and providing supportive environments that foster their growth and development, educators can help bridge the gender gap and create a more diverse and inclusive STEM workforce (White and Smith, 2022). Control engineering also plays a vital role in girls' STEM education by inspiring interest, fostering skill development, expanding career opportunities, promoting empowerment and confidence, encouraging innovation, and addressing the gender gap. By leveraging the power of control engineering education, educators can empower girls to pursue their passions, unlock their potential, and become the next generation of leaders and innovators in STEM.

Universities conduct cutting-edge research in control engineering and STEM, pushing the boundaries of knowledge and driving technological advancements. Through research projects, laboratories, and collaborations with industry partners, universities provide students with opportunities to engage in hands-on experimentation, problem-solving, and innovation, fostering critical thinking and creativity. Universities offer experiential learning opportunities, such as internships, co-op programs, and research projects, allowing students to apply their knowledge in real-world settings and gain practical experience in control engineering and STEM fields. These hands-on experiences enhance students' skills, confidence, and employability, preparing them for successful careers in STEM. Universities engage with K-12 schools, community organizations, and industry partners to promote interest and participation in control engineering and STEM education. Through outreach programs, workshops, competitions, and events, universities inspire and support students from diverse backgrounds to pursue STEM careers, addressing disparities in representation and fostering a culture of inclusion and diversity. Universities provide professional development opportunities for educators, practitioners, and professionals in control engineering and STEM fields. By offering workshops, seminars, conferences, and continuing education programs, universities support lifelong learning and skill development, ensuring that individuals stay current with emerging trends and technologies in their respective fields (Edwards and King, 2023).

4.1 Fostering interest in control engineering among girls

Additional efforts can be undertaken to address various barriers and challenges in fostering interest in control engineering among girls. One such effort can be the implementation of outreach programs and initiatives for girls from a young age, introducing them to the principles and applications of control engineering through interactive workshops, hands-on activities, and engaging

demonstrations. Collaboration with schools, community organizations, and industry partners to reach a broader audience and spark interest in STEM early on is therefore essential (Campbell et al., 2022). Showcasing successful female engineers and control engineering professionals as role models and mentors and providing girls with relatable examples of women thriving in the field is worth mentioning in this context. Establishing mentorship programs that pair girls with female engineers or university students, offering guidance, support, and encouragement as they explore their interests in control engineering is yet another avenue for exposure.

Providing girls with opportunities to engage in hands-on experiences and project-based learning activities that allow them to apply control engineering principles to solve real-world problems and design innovative solutions is critical. Creating supportive environments that encourage experimentation, collaboration, and creativity, allowing girls to explore their curiosity and develop practical skills in control engineering is therefore critical as well. Fostering a supportive and inclusive community where girls feel valued, respected, and empowered to pursue their interests in control engineering is a sociological imperative. Establishing clubs, organizations, or extracurricular programs focused on STEM and control engineering specifically for girls, providing a space for networking, peer support, and mentorship can materialize that imperative.

4.2 School-university participation in promoting control engineering

Promoting STEM education and control engineering with an emphasis on career pathways for students is central to school-university participation. Universities can collaborate with schools to align the curriculum with higher education standards in control engineering. This ensures that students receive foundational knowledge and skills that seamlessly transition into university-level courses and programs. Universities can offer professional development opportunities for school educators to enhance their understanding of control engineering concepts and teaching methodologies. This empowers teachers to deliver high-quality STEM instruction and inspire students' interest in the field. Universities can organize hands-on workshops, summer camps, and enrichment programs in control engineering for school students. These interactive experiences allow students to engage with concepts firsthand, fostering excitement and curiosity about STEM careers (Tam et al., 2020).

Universities and schools can collaborate on research projects that integrate control engineering into school curriculum. Students can participate in hands-on research experiences, working alongside university researchers to address real-world challenges and develop innovative solutions. Universities can offer dual enrolment programs that allow high school students to earn college credits in control engineering courses. This provides students with early exposure to university-level coursework and accelerates their progress toward STEM degrees. Universities often have established partnerships with industry organizations involved in control engineering. By leveraging these connections,

schools can facilitate industry-sponsored projects, internships, and career exploration opportunities for students. Universities and schools can co-host community engagement events, such as STEM fairs and open houses, to showcase the exciting possibilities of control engineering. These events raise awareness, foster collaboration, and inspire students to pursue STEM pathways. School-university collaboration in promoting control engineering enriches STEM education, cultivates future STEM leaders, and strengthens the pipeline of talent in the field. By working together, schools and universities can create impactful educational experiences that prepare students for success in control engineering and beyond.

5. CONCLUSIONS

Popularizing control engineering among girls is crucial for several reasons. Firstly, diversity in any field leads to a broader range of perspectives and approaches, which can ultimately result in more innovative solutions to complex problems. By encouraging girls to explore control engineering, we're tapping into a talent pool that may otherwise be overlooked, enriching the field with fresh ideas and insights. Secondly, representation matters. When girls see other women succeeding and thriving in control engineering, they're more likely to envision themselves pursuing similar paths. This visibility helps combat stereotypes and biases that may discourage girls from considering careers in STEM fields. Furthermore, control engineering plays a vital role in many aspects of modern life, from developing sustainable energy systems to advancing medical technology. By involving girls in control engineering early on, we're preparing them to contribute to and shape the future of these critical fields.

To popularize control engineering among girls, it's essential to provide accessible and engaging educational opportunities, showcase diverse role models, and create supportive environments where girls feel empowered to explore their interests in STEM. This could include initiatives such as workshops, mentorship programs, outreach events, and highlighting the real-world applications and impact of control engineering in fields that girls may already be passionate about. By fostering a culture of inclusion and encouragement, we can inspire the next generation of female engineers and innovators. By hosting events like the "Girls in Control" workshop, the University of Zululand is not only helping to break down barriers and stereotypes but also fostering a sense of community and belonging among female students interested in STEM. This type of programming is essential for encouraging more girls to pursue careers in control engineering and other traditionally male-dominated fields, ultimately leading to a more diverse and innovative workforce. The downloaded version of 'scratch' was available only in English and not in isiZulu. Participants had language-related challenges with the use of the software which is designed in English. However, facilitators helped with the translation and hence the understanding of the codes. These challenges become more problematic when learners are on their own when using the software without the assistance of others. This contributes to some degree of reluctance among

learners due to the language barrier. More emphasis on practical under supervision will be therefore advisable at the school level.

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ACKNOWLEDGMENT

Financial support provided by SACAC, I live to learn and the facility provided by the UNIZULU Science Center for the community outreach project are here by acknowledged.