BRIDGING TECHNICAL AND LEADERSHIP COMPETENCIES: INTEGRATING CDIO WITH THE SUSI YWLP

Chynar Garlyyeva[1], Ayna Annayeva[2], Jennet Movlamova[2], Gurbangul Sapargeldiyeva[3], Ayshirin Soltanmyradova[4], Yslam Orazov[1]

Cyberphysical Systems department[1], Philology (technical English and Japanese) department[2], Genetics and Bioengineering department[3], Electronics and nanoelectronics department[4], Oguz han Engineering and technology university of Turkmenistan

Sodgerel Gansukh

Graduate School of Environmental Studies, Tohoku University

ABSTRACT

This paper explores the integration of leadership training into engineering education, addressing the increasing need for engineers to possess both technical expertise and effective leadership skills in today's complex world. It proposes the CDIO (Conceive-Design-Implement-Operate) framework as a robust approach to achieving this integration. The CDIO framework, with its emphasis on hands-on learning, teamwork, and project management, equips students with essential soft skills alongside their technical knowledge. This paper argues that combining CDIO with initiatives like the Study of the U.S. Institutes (SUSI) Young Women Leaders Program (YWLP) can particularly benefit female engineering students. The SUSI YWLP empowers young women with the leadership skills and confidence necessary to excel in various fields, including engineering. By integrating CDIO and SUSI YWLP, female students gain a unique opportunity to develop technical proficiency and leadership potential, effectively preparing them for the challenges they face in a field where women are often underrepresented. The paper highlights these challenges, such as the lack of visible role models and limited leadership opportunities, and emphasizes the importance of mentorship, networking, and creating inclusive environments. This integration of CDIO and the SUSI YWLP offers a comprehensive approach to fostering leadership development among female engineering students. It provides a synergistic framework that combines CDIO's practical, project-based learning with the SUSI YWLP's focus on empowering women leaders. This approach not only cultivates essential leadership skills but also addresses the specific obstacles women encounter in engineering education and the profession. Ultimately, this paper contributes a theoretical foundation for future research and practice, paving the way for a more inclusive and effective model of engineering education that equips all students, particularly women, with the leadership skills needed to drive innovation and succeed in their careers.

KEYWORDS

CDIO, SUSI YWLP, Women in Engineering, Leadership Development, Theoretical Framework, Conceptual Framework, CDIO Standard 4

INTRODUCTION

In the dynamic and fast-evolving field of engineering, technical expertise alone is insufficient to tackle the complexities of modern challenges. Engineers must also develop strong leadership skills to guide interdisciplinary teams, innovate solutions, and manage projects effectively. The increasing complexity of engineering projects demands that engineers possess not only technical proficiency but also the ability to collaborate, communicate, and lead diverse teams (Paul & Falls, 2015). This necessity is further emphasized by the evolving demands of the industry, which increasingly seeks engineers who can effectively manage projects and lead teams, highlighting the critical role of leadership capabilities in the engineering profession (Miska et al., 2022).

However, within the engineering profession, there is a significant underrepresentation of women in leadership positions. This disparity is not simply a matter of numbers; it reflects systemic challenges that hinder women's advancement in engineering. These challenges include the lack of visible role models, gender bias in the workplace, and limited access to mentorship and networking opportunities. Research indicates that women in engineering often feel isolated and unsupported, which can impede their professional growth and aspirations for leadership (Schmitt, 2021; Mullet et al., 2017). For instance, Mullet et al. (2017) highlight that social identities play a crucial role in women's success in STEM fields, noting that women, particularly women of color, may not see themselves as part of the engineering community due to a lack of relatable role models.

While the importance of leadership development for all engineers is recognized, there is a lack of a cohesive theoretical framework that specifically addresses the unique challenges and needs of women in engineering leadership development.

Addressing this gap is of paramount importance for several reasons. A strong theoretical framework for understanding women's leadership development in engineering is essential to guide the design and implementation of effective educational programs and interventions. It can also help organizations create more inclusive and equitable workplaces, fostering a culture where women can thrive and contribute their full potential. Furthermore, empowering women to assume leadership roles in engineering can drive innovation and enhance problem-solving by bringing diverse perspectives to the forefront (Eagly & Carli, 2003).

To address this gap, this paper proposes a novel conceptual framework that utilizes the CDIO (Conceive, Design, Implement, Operate) framework as a structural foundation, incorporating the leadership development strategies of the SUSI (Study of the U.S. Institutes) Young Women Leaders Program (YWLP). The CDIO framework offers a structured approach to engineering education that emphasizes hands-on learning and the development of both technical and leadership skills (Borrego & Bernhard, 2011). The SUSI Young Women Leaders Program provides targeted leadership training and mentorship opportunities specifically designed to empower women. This paper contributes to the theoretical understanding of how these two approaches can be combined to foster women's leadership development in engineering.

The remainder of the paper is structured as follows: Section 2 provides an overview of the CDIO framework and the SUSI Young Women Leaders Program. Section 3 details the proposed conceptual framework, explaining how the two approaches can be integrated. Section 4 discusses the potential benefits of this integration for women's leadership development in engineering. Finally, Section 5 concludes the paper and outlines directions for future research.

UNDERSTANDING THE CDIO FRAMEWORK AND SUSI YOUNG WOMEN LEADERS PROGRAM

This section provides an overview of the CDIO framework and the SUSI Young Women Leaders Program, highlighting their key components and relevance to leadership development, particularly for women in engineering.

The CDIO Framework

The CDIO framework is an educational model that emphasizes active learning through real-world projects, where students engage in the engineering lifecycle from conceiving and designing to implementing and operating solutions.

One of the primary advantages of the CDIO framework is its intentional development of managerial and leadership competencies among engineering students. Research indicates that incorporating teamwork and project-based learning, central to the CDIO framework, significantly enhances students' communication and leadership skills, which are crucial for their professional development (Salazar, 2024; Paul & Falls, 2015). The CDIO model fosters a collaborative environment that mirrors the dynamics of the engineering workplace by encouraging students to participate in real-world projects. This experiential learning is vital in preparing students to assume leadership roles, where they must effectively navigate complex team interactions and project management challenges (Bertoni & Bertoni, 2019; Miska et al., 2022).

The SUSI Young Women Leaders Program

The SUSI Young Women Leaders Program is a focused initiative designed to equip young women with the leadership skills necessary to excel in leadership roles across various fields, including engineering. The program fosters a global network of women leaders by providing leadership training, mentorship, and opportunities for personal and professional growth. Participants are encouraged to address social, political, and economic challenges, with a particular emphasis on leadership in areas where women are traditionally underrepresented, such as STEM.

The SUSI YWLP recognizes that the underrepresentation of women in engineering is significantly exacerbated by the lack of visible role models. Mullet et al. (2017) highlight that the absence of relatable role models can lead women, particularly women of color, to feel excluded from the engineering community and internalize the perception that they do not belong in these roles. This is further supported by research that highlights the prevalence of gender bias and discrimination within engineering workplaces, which can create hostile environments and limit women's opportunities for advancement (Catalyst, 2018). Additionally, the lack of family-friendly policies and support systems within engineering can disproportionately affect women, who often bear a greater share of caregiving responsibilities (National Academies of Sciences, Engineering, and Medicine, 2019).

A key component of the SUSI Young Women Leaders Program is its focus on mentorship and networking. Participants are paired with experienced female leaders who offer guidance, share career insights, and help students navigate the complexities of leadership. This mentorship is crucial for female engineering students, as it provides a model for how women can successfully balance technical careers with leadership responsibilities. As Pruitt et al. (2023) highlight, mentorship can provide valuable insights and support for women in academic leadership. Furthermore, research has shown that effective mentorship programs can increase women's confidence, improve their career satisfaction, and enhance their likelihood of staying in engineering (NASEM, 2019).

The networking opportunities within SUSI also enable students to connect with other young women from diverse backgrounds, fostering a sense of solidarity and community. These connections are vital in a field where women often face isolation and underrepresentation. Chesler et al. underscore the effectiveness of same-gender peer mentoring in addressing the unique challenges faced by women faculty, providing crucial networking and support often lacking in male-dominated environments. This aligns with Schmitt's findings, which emphasize the vital role of social support in helping women engineers adapt to the engineering culture and advance into leadership positions (Schmitt, 2021). Initiatives like the Women's Initiative at various institutions aim to establish supportive networks that enhance the visibility and retention of women in engineering (Donohue & Vallas, n.d.). Moreover, professional organizations such as the Society of Women Engineers (SWE) play a critical role in providing networking opportunities, professional development resources, and advocacy for women in the field (SWE, n.d.)

CONCEPTUAL FRAMEWORK FOR CDIO AND THE SUSI YWLP INTEGRATION

This paper proposes a novel conceptual framework that integrates the CDIO framework, as a model for engineering education, with the leadership development curriculum and mentorship components of the SUSI Young Women Leaders Program (the SUSI YWLP). This integration aims to create a unique educational experience for female engineering students, addressing the underrepresentation of women in engineering leadership and enhancing their overall career potential. The framework is designed to synergize the strengths of both CDIO and the SUSI YWLP to foster a more holistic development of female engineering students.

Framework Overview

The proposed framework positions CDIO as the primary structural model for engineering education. CDIO's emphasis on the "Conceive, Design, Implement, and Operate" stages of real-world engineering projects provides a robust foundation for developing practical engineering skills (Borrego & Bernhard, 2011). This approach inherently fosters teamwork, project management, and problem-solving abilities, which are essential for future engineering leaders.

Integrated within this CDIO structure are key elements of the SUSI YWLP. Specifically, the framework incorporates the SUSI YWLP's targeted leadership development curriculum and mentorship components to address the specific challenges faced by women in engineering. The leadership curriculum provides focused training in areas such as strategic thinking, communication, and ethical decision-making, while the mentorship component offers guidance and support from experienced female leaders.

Core Components and Integration

The framework is composed of the following core components:

- **CDIO-Based Engineering Education:** This component provides the context for students' learning experiences. Students engage in CDIO projects that require them to apply engineering principles to solve real-world problems.

- **SUSI YWLP Leadership Development:** This component provides targeted leadership training that is integrated into the CDIO experience. For example, students may participate in leadership workshops as part of their CDIO projects or receive mentorship from female engineering leaders.
- **Mentorship and Networking:** This component, drawn from the SUSI YWLP, provides female students with access to mentors and networking opportunities. Mentors can provide guidance, support, and role modeling, while networking opportunities can help students build connections with other women in engineering.

Synergistic Effects

The integration of CDIO andthe SUSI YWLP creates several synergistic effects:

- **Enhanced Skill Development:** By combining CDIO's focus on technical skills with the SUSI YWLP's emphasis on leadership development, the framework equips students with a more comprehensive skill set that is highly valued by employers (Miska et al., 2022).
- **Increased Confidence and Empowerment:** The supportive environment and mentorship provided by the SUSI YWLP can help to increase female students' confidence and empower them to take on leadership roles (Schmitt, 2021).
- **Challenging Stereotypes:** By providing female students with opportunities to lead and succeed, the framework can help to challenge traditional stereotypes about women in engineering (Donohue & Vallas, n.d.).
- **Development of Role Models:** The framework supports the development of female students as role models, inspiring future generations to pursue STEM fields and leadership positions.

In summary, this framework leverages the structured, project-based learning of CDIO with the targeted leadership development and support of the SUSI YWLP to create a powerful educational experience for female engineering students.

POTENTIAL BENEFITS OF THE CONCEPTUAL FRAMEWORK

The integration of the CDIO framework and the SUSI Young Women Leaders Program offers several potential benefits for female engineering students, addressing key challenges they face and enhancing their leadership potential. This section outlines these benefits, focusing on empowerment, real-world leadership preparation, mentorship and networking, and the enhancement of long-term leadership potential.

Empowering Female Engineers through Leadership Integration

Within the CDIO framework, female students can develop essential leadership qualities through practical experience. For instance, leading project meetings, managing timelines and budgets, communicating with team members and stakeholders, and navigating conflicts provide invaluable opportunities to develop skills such as:

- Communication and Interpersonal Skills: Effectively conveying ideas, actively listening, and building strong relationships (Salazar, 2024).
- Decision-Making and Problem-Solving: Analyzing situations, evaluating options, and making timely, informed decisions (Bertoni & Bertoni, 2019).

- Teamwork and Collaboration: Fostering collaboration, delegating tasks, and motivating team members (Paul & Falls, 2015).
- Conflict Resolution: Identifying and addressing conflicts constructively to maintain a positive team dynamic.

The SUSI Young Women Leaders Program complements this by providing an additional layer of support and encouragement. The mentorship component of the SUSI YWLP, in particular, offers female engineering students valuable insights into navigating the challenges of leadership in male-dominated fields and developing a strong leadership presence (Pruitt et al., 2023). By participating in both initiatives, students gain a unique combination of technical expertise and leadership experience, better positioning them for future career success.

Real-World Leadership in Engineering

The synergy between CDIO's leadership-focused engineering curriculum and the SUSI YWLP's broader leadership training equips female engineering students to navigate the challenges of leadership in both technical and non-technical environments. This combination ensures that students not only gain the technical expertise needed to thrive in engineering but also develop the leadership mindset required to drive change, manage teams, and address global challenges.

The Role of Mentorship and Networking

A key component of the SUSI Young Women Leaders Program is its focus on mentorship and networking. Participants are paired with experienced female leaders who offer guidance, share career insights, and help students navigate the complexities of leadership. This mentorship is crucial for female engineering students, providing models for balancing technical careers with leadership responsibilities and offering support in overcoming gender biases (Chesler et al., n.d.).

The collaborative environment fostered by the CDIO framework further enhances these networking opportunities. By working in interdisciplinary teams, students practice leadership in diverse settings and interact with peers from a range of technical backgrounds, preparing them to lead diverse teams in their future careers.

Enhancing Long-Term Leadership Potential

The integration of CDIO and the SUSI YWLP enhances female engineering students' long-term leadership potential. Early exposure to leadership training increases the likelihood of women pursuing leadership roles (NASEM, 2019). By integrating leadership into the technical curriculum, CDIO prepares students for leadership roles from the outset, while SUSI helps build their self-confidence and leadership mindset. This integrated approach equips graduates with the technical skills, team management abilities, and understanding of organizational dynamics necessary for leadership positions in engineering. It also encourages them to mentor future generations of female engineers, contributing to a cycle of empowerment within the engineering community.

Future Research and Conclusion

This paper has presented a conceptual framework that integrates the CDIO framework with the SUSI Young Women Leaders Program, offering a theoretical approach to enhancing the leadership potential of female engineering students. The integration addresses the identified gap in engineering education, where a lack of explicit leadership development, particularly for women, can hinder career advancement and perpetuate underrepresentation. By combining CDIO's emphasis on practical, project-based learning with the SUSI YWLP's focus on leadership skills, mentorship, and networking, this framework offers a synergistic model for fostering well-rounded engineering graduates.

Future Research Directions

This theoretical framework lays the groundwork for future research and practical implementation. Future research should focus on empirical validation of the framework's effectiveness. Specifically, studies could investigate the following:

- **Impact Assessment:** Quantitative and qualitative studies could assess the impact of implementing this integrated framework on female engineering students' leadership skills, self-efficacy, and career aspirations.
- **Comparative Studies:** Research could compare the outcomes of students who participate in the integrated program with those who participate in traditional engineering education or standalone leadership programs.
- **Longitudinal Studies:** Tracking the career trajectories of graduates from programs implementing this framework could provide valuable insights into its long-term impact on women's leadership in engineering.
- **Implementation Strategies:** Research is needed to develop effective strategies for implementing this framework in diverse institutional settings. This could include exploring optimal ways to integrate leadership modules into CDIO projects, recruit and train mentors, and create supportive learning communities.
- **Cross-Cultural Applicability:** Given the global nature of engineering, future research should examine the cross-cultural applicability of this framework and identify any necessary adaptations for different contexts.

Conclusion

Integrating the CDIO framework with the SUSI Young Women Leaders Program offers a promising approach to developing the leadership potential of female engineering students. This theoretical framework provides a foundation for future research and practical implementation, with the potential to contribute to a more inclusive, innovative, and effective engineering workforce. By equipping women with both technical expertise and leadership capabilities, this integrated model can help to break down barriers, drive change, and foster success in a globalized world.

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BIOGRAPHICAL INFORMATION

Chynar Garlyyeva is a 2nd year student of the Cyberphysical systems Faculty of Oguz han Engineering and technology university of Turkmenistan. She is the alumna of SUSI YWLP 2024, and an active member of CDIO team at the university. She studies Mechatronics and Robotics, alongside taking part in cultural and scientific exchange programs.

Ayna Annayeva is a professor at the Economy of Innovations Faculty of Oguz han Engineering and technology university of Turkmenistan. She leads the English Olympiad team at university. She teaches English for profession lessons, specifically engineering majors.

Jennet Mowlamova is a professor at the Economy of Innovations Faculty of Oguz han Engineering and technology university of Turkmenistan. She teaches Technical English for engineering majors, also she mentors younger teachers and shares her experience in Pedagogy.

Sodgerel Gansukh is a Graduate student at the Graduate School of Environmental Studies, Tohoku University. She has Bachelor's degree in International Relations She is the alumna of SUSI YWLP 2023, and actively working on implementing her project on connecting environmental protection with STEM projects that focuses on women in those fields.

Gurbangul Sapargeldiyeva is a 4th year student of the Biotechnology and Biology Faculty of Oguz han Engineering and technology university of Turkmenistan. She is the alumna of SUSI YWLP 2024, and an active member of BioLab team at the university. She studies Genetics and Bioengineering, alongside taking part in cultural and scientific exchange programs.

Ayshirin Soltanmyradova is a 4th year student of the Cyberphysical systems Faculty of Oguz han Engineering and technology university of Turkmenistan. She is an active volunteer at the university, taking part in several in-campus projects. She studies Biomedical Electronics, which is a very interdisciplinary subject.

Yslam Orazov is currently head of the Cyberphysical systems department at Oguz han Engineering and technology university of Turkmenistan. He holds a Ph.D. degree in physical and mathematical sciences. While his interests include natural science, he is also chair of the committee which is responsible for the International relations of the Oguz han Engineering and technology university of Turkmenistan.

Corresponding author

Yslam Orazov
Oguz han Engineering and technology university of Turkmenistan

Taslama №100, Koshi, Ashgabat, Turkmenistan

oguzhantech25@gmail.com