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FROM VISIBILITY TO ATTAINABILITY: WOMEN IN STEM AND ENGINEERING EDUCATION IN SOCIETY 5.0

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Abstract:
The underrepresentation of women in Science, Technology, Engineering, and Mathematics (STEM) study programs remains a significant educational and societal challenge. This paper examines the role of gender-sensitive communication in promoting STEM programs among women. The analysis is situated within the frameworks of Society 5.0, ethical engineering, human-centered design, and skills development, where technological progress is understood not only as innovation, but also through inclusion, responsibility, and social purpose. Drawing on literature on women in STEM, higher education communication, media representation, role models, belonging, and engineering education in Industry 5.0, the paper proposes a conceptual framework structured around visibility, belonging, and attainability. While communication alone cannot eliminate structural inequalities, it can reduce symbolic distance and frame STEM pathways as accessible, socially relevant, and achievable for prospective female students.

Keywords: *Gender-sensitive communication, Women in STEM, Society 5.0, Ethical engineering, Engineering education, Human-centered design, Skills development.*

Introduction

The underrepresentation of women in STEM remains a significant educational and societal challenge. Charlesworth and Banaji emphasize that gender differences and inequalities continue to appear across STEM fields, although their form and intensity vary across disciplines and career stages [1]. A study prepared for the European Parliament also points to continuing gender bias and inequality in STEM and the digital sector, including computer science, information technology, artificial intelligence, and cybersecurity [2]. In the Serbian context, UNICEF Serbia also identifies gender stereotypes, prejudices, and cultural norms as factors shaping girls' and young women's aspirations and decisions in ICT education and careers [5].

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This paper examines the role of gender-sensitive communication in promoting STEM study programs among women. The analysis is organized around three dimensions: visibility, belonging, and attainability. These dimensions are used to explain how communication may influence the way prospective female students perceive STEM programs and their own possible place within them.

1. Conceptual Background: Women in STEM, Communication and Society 5.0

Higher education communication is relevant in this context because universities do not only communicate formal information about curricula, admission requirements, and institutional procedures. They also shape impressions about who belongs in certain programs, what kinds of futures are possible, and which values are connected with particular fields of study. Schüller and Chalupský analyze marketing communication management in higher education institutions, which confirms that communication is already part of institutional activity in this sector [4]. Digital communication is also part of this institutional practice, as shown by Kisiołek, Karyy and Halkiv in their analysis of Internet marketing communication tools used by higher education institutions [7].

The Society 5.0 framework gives this discussion an additional dimension. Troisi, Visvizi and Grimaldi argue that the 5.0 paradigm should not be understood only through technological development, but through the integration of technological, human-centered, social and knowledge-based dimensions [13]. In a similar policy-oriented direction, the European Commission presents Industry 5.0 as an approach that moves beyond efficiency and productivity as sole goals and supports a sustainable, human-centric and resilient European industry [16].

Engineering education is also increasingly discussed in relation to broader competencies rather than technical knowledge alone. Vieira's systematic review identifies competencies relevant to Industry 5.0 and discusses how engineering learning environments may prepare students to develop them [12]. This is important for STEM promotion because communication can influence whether future students understand engineering and technical fields as distant, purely technical domains or as socially meaningful and human-centered educational pathways.

2. Gender-Sensitive Communication: Visibility, Belonging and Attainability

Steinke argues that media images of STEM professionals may provide contextual cues that influence adolescent girls' STEM identity formation [6]. Communication that presents women as competent and recognizable STEM actors can therefore broaden the symbolic field of STEM.

Herrmann and colleagues link female role model interventions with academic performance and persistence among women in STEM [8]. Research on female and counterstereotypical role models also suggests relevance for girls' STEM preferences, stereotypes, and career choices [10], [11].

The meaning attached to STEM careers also matters. Diekman and colleagues argue that STEM careers are often perceived as less likely to fulfill communal goals, such as working with or helping other people [3]. Later research further indicates that beliefs about communal opportunities can influence attraction to STEM careers [9].

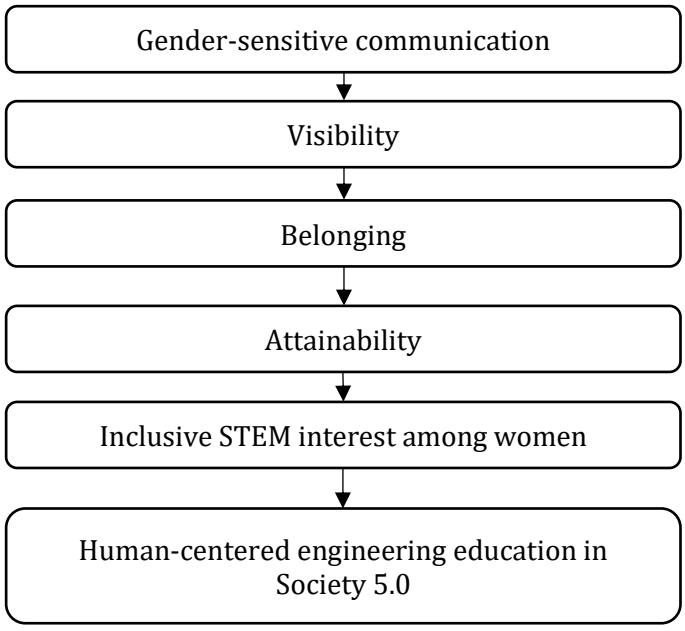


Chart 1. *Conceptual model of gender-sensitive STEM communication in Society 5.0*
Source: Authors' own synthesis based on the conceptual analysis.

Table 1 further specifies these three dimensions.

Table 1: *Communication dimensions and their relevance to Society 5.0-oriented engineering education*

Communication dimension	*Function in STEM promotion*	*Society 5.0 / engineering education relevance*
Visibility	Makes women recognizable as legitimate STEM actors	Supports inclusive representation in technological and engineering fields
Belonging	Helps girls imagine themselves in STEM learning environments	Strengthens human-centered and inclusive education
Attainability	Presents STEM pathways as realistic and reachable	Connects skills development with accessible STEM and engineering pathways

Source: Authors' own synthesis based on the conceptual analysis.

3. Implications for Higher Education Institutions

A first implication concerns the visibility of women in STEM communication. Institutions can use websites, social media content, admission materials, student stories, interviews, and examples of graduate careers to present women as legitimate STEM actors. Such representation should avoid tokenism. Women should not be shown only as exceptions, but as competent and recognizable participants in STEM learning and professional environments.

A second implication concerns belonging. Promotional messages should not only describe study programs, subjects, and technical content. They should also help prospective students understand what kind of learning environment they may enter and whether they can imagine themselves in that environment. Communication can therefore support belonging by making institutional culture, student experiences, and support structures more visible.

Attainability also needs clearer communication. STEM programs are often presented as demanding and highly technical. This is not incorrect,

but it may create unnecessary psychological distance if support structures, learning pathways, student experiences, and gradual skills development are not made visible. Broo, Kaynak and Sait argue that engineering education in the age of Industry 5.0 should be redesigned through lifelong and transdisciplinary learning, sustainability and human-centric design modules, data fluency, and human–machine interaction experiences [14]. This supports the view that STEM communication should not present engineering education only as technical training, but also as a pathway for developing broader and socially relevant competences.

In the context of Society 5.0, STEM can be communicated as a field connected with sustainability, digital transformation, social innovation, and human-centered technological development. This is consistent with the Engineering Education 5.0 perspective, which emphasizes that engineering education should move beyond the development and application of technology and should also include ethics, humanism, sustainability, and responsibility for a more sustainable and caring future [15].

From a Society 5.0 solution-design perspective, Bartoloni et al. suggest that human-centric technological and social solutions can be developed through a Quintuple Helix–Design Thinking approach, which enables knowledge flow among different actors involved in the design process [17].

This perspective suggests that gender-sensitive STEM communication should not be designed only as a top-down institutional message, but also through dialogue with prospective students, current female students, educators, employers, and wider social stakeholders.

4. Conclusion

This paper proposed a conceptual framework structured around three dimensions: visibility, belonging, and attainability. The analysis suggests that gender-sensitive communication cannot eliminate structural inequalities on its own, but it can reduce symbolic distance and frame STEM pathways as more accessible, socially meaningful, and achievable for prospective female students.

Situated within the broader context of Society 5.0 and human-centered engineering education, the paper also indicates that STEM promotion should not be treated only as recruitment-oriented institutional communication. Rather, it should be connected with ethical engineering, inclusive representation, skills development, and educational pathways in which future female students can imagine themselves as belonging and participating.

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