THE VITRUVIAN WOMAN FROM PATRIARCHAL DESIGN TO GENDER EQUITY THROUGH ERGONOMICS EDUCATION

Eran FRANCO
Shamir Medical Centre, Israel, Tel Aviv University, Israel, Holon Institute of Technology, Israel and Jerusalem Multidisciplinary College, Israel

ABSTRACT
The physiological differences between women and men result in higher musculoskeletal disease risk for women. Despite this, industrial design has historically tended to rely on men as the "average person", often overlooking women's characteristics. This male-default bias aggravates women's health risks, limits their function and constrain equitable participation in professional domains, evident in fields like medicine. For example, surgical instruments are generally designed for large hands and grip strength, systematically disadvantaging women and small-handed surgeons by increasing physical strain and reducing usability. Moreover, such design choices function as structural gatekeepers, creating barriers to equal professional participation and dictating terms for career entry and success.
Industrial design education has a responsibility to eliminate this inherited bias. Drawing on research in ergonomics, medical device design, and design pedagogy, this paper proposes a gender-responsive ergonomic pedagogical model for industrial design education as a change agent aimed at deconstructing and counterbalancing patriarchal dominance historically embedded in industrial design paradigms. The model integrates biomechanical and anthropometric analysis, experiential product interaction, reflective case-based critique, and role modelling through female designers, to equip students with tools to identify and correct gender disparities within the design process.
By repositioning ergonomics as a generative and critical design competence rather than a technical check, the proposed framework aims to embed gender equity within core design reasoning. In doing so, it contributes to the formation of designers capable of producing products that are safer, more functional, and inclusive across genders, while reinforcing the broader societal role of design in advancing social equity.

Keywords: Design education, ergonomics, pedagogical model, gender, inclusion

1 INTRODUCTION: TRANSFORMATIVE DESIGN EDUCATION - HARNESSING ERGONOMICS FOR GENDER EQUITY

Sex-related physiological differences between women and men place women at a higher risk of developing function-related musculoskeletal disorders. These differences include variations in hand size, height, grip force, and biomechanical loading, which are directly relevant to the interaction between users and physical products [1]. Although men may present with more severe or complex individual cases, epidemiological evidence indicates that orthopaedic and musculoskeletal diseases are substantially more prevalent among women than men [2,3]. A significant proportion of these disorders arise, in part, from inadequate ergonomic product design and prolonged exposure to ergonomic risk factors associated with product use [4]. Despite this evidence, design practices have historically tended to treat men as the "average person", often overlooking women's unique characteristics [5].
This paper addresses the persistent dominance of patriarchal design within industrial design practices and presents the ergonomics discipline as an agent of change, through educational strategies aimed at mitigating the negative impact of such an inequitable approach. In this context, this paper proposes a gender-responsive ergonomic pedagogical model for industrial design education, offering a framework to guide the development of more gender-balanced design practices.

2 BACKGROUNDS: MALE-DEFAULT BIAS IN MEDICAL DEVICE DESIGN AS GENDER GATEKEEPER

The male-default worldview not only aggravates risk and harms women's health but also fails women by undermining their ability to function optimally and by creating barriers to equal participation in various domains, including medicine.

Surgical handheld instruments are typically designed for large hands and significant grip strength. Historically, they have been designed by men, for male users, with limited adaptation to the changing demographic composition of the surgical workforce (currently, women make up 50.5% of medical school students, and nearly 30% of surgeons are women). Additionally, the names of surgical tools are mostly derived from their inventors - predominantly male surgeons - which further reflects the male-centred legacy embedded in medical device design. Although the gender gap in innovation is shrinking, at the current rate it is estimated it will take another 118 years to reach gender parity. [6].

Surveys indicate that up to 60% of surgeons, predominantly women and small-handed users, report difficulties operating standard surgical instruments, and nearly 90% of surveyed female surgeons report musculoskeletal injuries associated with instrument use [6]. These findings highlight how the often-invisible design bias systematically disadvantages women (and surgeons with smaller hands), creating both functional barriers and health risks. Thus, instrument design itself acts as a gatekeeper, undermining equal participation in medicine and highlighting the urgent need for ergonomically inclusive solutions.

Empirical studies further demonstrate that design solution challenges are not solely a matter of scaling instruments down. Surgeons with glove sizes ≤6.5 report significantly higher rates of discomfort and pain compared to those with larger glove sizes, with women reporting more problems than men even when hand size is equivalent [1]. This suggests that sex-related biomechanical and ergonomic factors extend beyond size differences and require more comprehensive design responses. Current instruments often compel surgeons to adapt their posture and technique to the tool, rather than the tool accommodating human variability [1].

Endoscopy represents a well-documented example of persistent mismatch between technological advancement and product design. Although imaging and diagnostic capabilities have evolved substantially, the endoscope–human interface has remained largely unchanged since the 1980s, with minimal attention to user ergonomics [7,8]. Career-long prevalence of endoscopy-related injuries exceeds 60%, with female gender identified as one of the significant risk factors, in addition to higher procedural volume and years in practice [8]. Female trainees report higher rates of neck, shoulder, and upper limb pain, partly due to smaller hand size, shorter stature, and equipment dimensions optimised for male users [9].

Beyond product design, research in design and engineering education emphasises the importance of integrating ergonomics as both a technical and reflective discipline. Educational approaches that link ergonomic theory with hands-on design practice support students' ability to recognise human variability and translate it into inclusive design solutions [10]. Inclusive teaching methodologies in design education have been shown to enhance awareness of equality, diversity, and representation, particularly when experiential and reflective learning strategies are employed [11]. Furthermore, exposure to gender-equality information has been shown to positively influence students' attitudes and motivation toward STEM fields (science, technology, engineering, and mathematics), indicating that education can actively shape professional mindsets rather than merely transmit technical knowledge [12].

Together, this body of literature demonstrates that gender bias in product design, particularly in medical devices, has measurable health and participation consequences, and that design education represents a critical intervention point for addressing these inequities. Therefore, industrial design education bears a profound responsibility to break this inherited bias and redefine what it means to design for humans.

3 METHODOLOGIES: A GENDER-RESPONSIVE ERGONOMICS PEDAGOGICAL MODEL FOR INDUSTRIAL DESIGN EDUCATION

The proposed pedagogical model integrates ergonomics education into product design curricula with an explicit gender-responsive perspective, thereby empowering the next generation of designers to create gender-equitable products.

The model guides students to identify male-default assumptions, apply ergonomic biomechanical and anthropometric principles, and design tools that ensure healthy, effective, comfortable, simple, and safe use for all genders.

Unlike conventional ergonomics instruction, which often emphasises generalised usability principles, the proposed model explicitly integrates gender-responsive analysis, reflective critique, and experiential examination of structural design bias within core product design education.

The educational framework combines four complementary components: (1) theoretical instruction of gender-informed ergonomic concepts and guidelines, based on key physiological and anatomical sex-related differences that impact functionality and design, (2) experiential learning through physical interaction with products, (3) reflective discussion on design responsibility and equity, and (4) role modelling through the introduction of pioneering female designers.

The first component equips the students with gender-analytical biomechanical and anthropometric knowledge and sex-disaggregated ergonomic design tactics that significantly affect comfort and musculoskeletal load, such as providing multiple alternative ergonomic grip options within a single product, positioning the product's center of gravity within the user's hand, encouraging force exertion through larger muscle groups rather than isolated distal effort, or employing dynamically variable handle dimensions to accommodate a wider range of users. The practical application of these gender-responsive ergonomic tactics is demonstrated through representative product examples (Figure 1). Although illustrated here through consumer products, these ergonomic principles are transferable across diverse design domains, including medical device design.

Figure 1. Examples of gender-responsive ergonomic design strategies in handheld products

(a) Alessi "Forma" Cheese Grater, integrating multiple ergonomic grip options within a single configuration to accommodate different hand sizes and task demands

(b) Dyson "Supersonic" Hair Dryer, positioning the motor within the handle to shift the centre of gravity into the user's hand, reducing wrist torque and improving balance during use

(c) Fiskars "SmartFit Bypass Pruner," incorporating dynamically adjustable handle dimensions to accommodate varying hand sizes and enhance grip comfort and force transmission

(d) Joseph Joseph "Rocker" Garlic Crusher, enabling force generation through larger proximal muscle groups via a rocking motion, reducing reliance on distal finger strength

Source: Images reproduced from the official websites of Alessi, Dyson, Fiskars and Joseph Joseph

The second component is active experiential learning: students interact with physical products that exemplify gender-inclusive design solutions, allowing them to experiment and directly experience how small modifications can dramatically improve usability for women without compromising male users. Live demonstrations are used to illustrate how gender-sensitive ergonomic principles can be applied in real-world product design. This hands-on engagement provides actionable insights that students can easily adopt, translating theory into replicable practice, and consistent with prior findings on ergonomics education in design contexts [10].

The third component incorporates case-based analysis, focusing on real-world products with documented ergonomic implications, for example in medical device design. Students are required not only to analyse products in terms of function, usability and health risks, but also to critically examine the gendered implications of product design, including the specific burdens that women may bear as a result of using these products. This approach is supported by research demonstrating that reflective learning strategies can enhance awareness of equality [11].

The last component highlights pioneering and influential female designers as role models, providing inspiration, addressing the lack of visible female achievement in the field, and expanding students' perceptions of leadership in design fields historically dominated by men. This component aligns with evidence showing that exposure to gender-equality information can influence students' motivation and attitudes toward design professions [12].

Overall, the model positions ergonomics not merely as a technical approach, but as a critical design competence with direct implications for health, equity, and professional participation. The methodology is replicable and adaptable, allowing integration into diverse design education contexts without requiring extensive curricular restructuring.

4 DISCUSSIONS: IMPLICATIONS FOR INDUSTRIAL DESIGN EDUCATION

The findings synthesised in this paper indicate that male-default bias in product design is not only a representational issue but a functional and health-related concern. When design is tacitly modelled on male bodies, women may experience reduced usability, increased physical strain, and professional disadvantage. Medicine serves here as a salient example, yet similar dynamics exist in other professional domains. The consequences extend beyond compromised comfort or efficiency: limited ergonomic compatibility may constrain career advancement by effectively closing professional pathways. In clinical contexts specifically, diminished performance potential may also affect patient outcomes, as suboptimal tool–user fit can influence precision, endurance, and overall procedural quality.

Within industrial design education, such bias often persists not through explicit exclusion but through unexamined assumptions about the "average user," embedded in standards, precedents, and teaching practices.

The pedagogical model proposed in this paper addresses these issues by reframing ergonomics as a critical analytical instrument for identifying bias and generating inclusive design solutions. Rather than treating ergonomics as a compliance checklist, the model positions it at the conceptual core of the design process, where user definition and dimensional assumptions are first established.

Importantly, the model avoids framing gender-responsive design as a zero-sum correction. The objective is not to substitute one normative body for another, but to expand the design reference frame and strengthen product adaptability across user populations.

The framework is designed for practical implementation within undergraduate industrial design education, both through ergonomics or human factors courses and through integration into core studio-based design projects.

For industrial design programs, the implications are structural rather than symbolic. The model achieves maximal impact when it is not delivered as an isolated theoretical module, detached from the core curriculum, but embedded in direct linkage with foundational studio projects. When students are required to apply gender-aware ergonomic analysis within their primary design projects, inclusive thinking becomes operational rather than declarative. In turn, this integration influences studio instructors and project mentors, allowing gender-responsive ergonomics to permeate the broader academic paradigm. Under such conditions, inclusive design principles shift from supplementary content to an integral component of the institutional DNA.

By combining evidence-based theory, hands-on exercises, real-world case studies, structured analysis, and applied studio implementation, the proposed pedagogical model demonstrates how gender-conscious ergonomics education can shape not only better-designed products but also a more inclusive

and equitable design culture.

5 CONCLUSION & REFLECTIVE PRACTICE

Male-default assumptions in product design are sustained not only by industry practice but by the ways designers are trained. Addressing this structural bias therefore requires intervention at the educational level.

The proposed framework equips future designers with ergonomic methods that render gender disparities explicit and correctable within the design process. Ultimately, this educational model fosters a professional mindset in which gender equity is treated as a design standard, ensuring products are functional and empowering for all genders and reinforcing the role of design practice in advancing social equity.

REFERENCES

[1] Basager A., Williams Q., Hanneke R., Sanaka A. and Weinreich H. M. Musculoskeletal disorders and discomfort for female surgeons or surgeons with small hand size when using hand-held surgical instruments: a systematic review. *Syst Rev*. 2024 Feb 7;13(1):57.

[2] Biz C., Khamisy-Farah R., Puce L., Szarpak L., Converti M., Ceylan H. İ., Crimì A., Bragazzi N. L. and Ruggieri P. Investigating and Practicing Orthopaedics at the Intersection of Sex and Gender: Understanding the Physiological Basis, Pathology, and Treatment Response of Orthopaedic Conditions by Adopting a Gender Lens: A Narrative Overview. *Biomedicines*. 2024 Apr 29;12(5):974.

[3] Salerno S. (2022). Gender and Ergonomics: The Recognition of Women's Occupational Diseases. In: Francisco Rebelo and Marcelo Soares (eds) Advances in Ergonomics in Design, Usability & Special Populations: Part III. *AHFE (2022) International Conference*. AHFE Open Access, vol 20. AHFE International, USA.

[4] Van Eerd D., Munhall C., Irvin E., Rempel D., Brewer S., van der Beek A. J., Dennerlein J. T., Tullar J., Skivington K., Pinion C. and Amick B. Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. *Occup Environ Med.* 2016 Jan;73(1):62-70.

[5] Criado Perez C. *Invisible Women: Exposing Data Bias in a World Designed for Men.* London: Chatto & Windus; 2019.

[6] Weinreich H. M., Jin V., Crowell L., Skovlund S. M., Williams Q. L. and Buhimschi I. A. Surgical Instrument Designers and Inventors-Where are the Women? *Am Surg*. 2023 Nov;89(11):4835-4841.

[7] Shergill A. and Harris Adamson C. (2019). Failure of an Engineered System: The Gastrointestinal Endoscope. *Techniques in Gastrointestinal Endoscopy*. 2019; 21(3): 116-123.

[8] Oliveira R., Roseira J., Estevinho M, M., Tavares de Sousa H., Rolanda C., Meining A. and Walter B. Endoscopy-Related Musculoskeletal Injuries: A Systematic Review and Meta-Analysis on Prevalence, Risk Factors and Prevention. *United European Gastroenterol J*. 2025 Jul;13(6):1012-1030.

[9] Suhail F. K., Luo Y., Williams K., Advani R., Campbell K., Dunleavy K., Rizvi A., Persaud A., Williams R. L. and Rabinowitz L. G. Sex differences impact ergonomic endoscopic training for gastroenterology fellows. *Gastrointest Endosc*. 2024 Feb;99(2):146-154.

[10] Safin S., Pintus P. and Elsen C. Ergonomics in design and design in ergonomics: Issues and experience in education. *Work*. 2020;66(4):917-931.

[11] Brischetto A. and Iacono E. (2024). Mapping Inclusive Teaching Methodologies in Design Education: A Benchmarking Study on Digital and Traditional Tools for Equality, Diversity, and Inclusion. *Strategic Design Research Journal*. Volume 17, number 01, January -April 2024. 87-106.

[12] Ikkatai Y., Inoue A., Minamizaki A., Kano K., McKay E. and Yokoyama H. M. Effect of providing gender equality information on students' motivations to choose STEM. *PLoS One*. 2021 Jun 23;16(6): e0252710.