Gender equality: the need for explicit address and actions in ICT and Socio-Technical Systems agendas

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Abstract

In this position/experience paper we address some issues related to gender and technology with the firm stand that the empowerment of girls and women has to rely non only on the access to technology on the utilizer side, but also – and maybe above all – on the inclusion of women *on the producer side*, and that achieving such objective demands engagement and explicit actions from stakeholders at different levels, including the educational and the scientific levels. In particular, we outline a virtuous chain in which society favors the interest of girls in ICT and their engagement in ICT studies, education professionals prepare girls for ICT careers, and the scientific/technology community explicitly acknowledges the beneficial role of women in the design process. With this goal in mind, after discussing example actions at *societal level*, we briefly present main features and results of the PinKamP program, an initiative at *educational level* organized by the Department of Information Engineering, Computer Science and Mathematics of the University of L'Aquila and addressed towards girls of the 3rd and 4th classes of high schools to promote girls' interest in and engagement with STEM studies. Finally, we launch a "call for action" at *scientific level* within the socio-technical systems community, trying to lay the basis for a discussion within the STPIS workshop.

Keywords

Gender issues, STEM, ICT, socio-technical design, learning by doing, experiential learning

1. Introduction

The United Nations (UN) 2030 Agenda for Sustainable Development [31] sets itself as an urgent call for actions and strategies that improve health and education, reduce inequality, and spur economic growth. Gender equality and women issues, in particular, are given special attention up to the point that the 17 Sustainable Goals are introduced as explicitly seeking "*to realize the human rights of all and to achieve gender equality and the empowerment of all women and girls*" [31] and the Agenda envisages "*a world in which every woman and girl enjoys full gender equality and all legal, social and economic barriers to their empowerment have been removed*" [31]. In particular, within Goal 5 a number of subgoals are somehow associated with issues that, in the current society, cannot be viewed as independent from Information and Communication Technology (ICT), thus acting as cultural and strategic challenges that scholars and professionals working in technology-related disciplines have to take up (see Table 1). We have to reason on what we are (or are not) doing at scientific and education level and evaluate the efficacy of our approaches/proposals/studies, specifically from gender equality and women empowerment perspectives.

It has to be observed that, though subgoal 5.b in Table 1 refers to the *use* of information and communication technology, the very problem goes beyond the use. Actually, as Boyer discusses in [5], women approached technology already at the end of the 19th century, when the financial services sector underwent a technological "revolution" with the invention of the typewriter, Dictaphone, and Hollerith machine (to the point that in North America by 1950 clerical work accounted for at least one-quarter of all women workers and by 1970 it reached one-third with women accounting for 70 – 75 per cent of all

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clerical workers [6]). Furthermore, considering the ever-growing diffusion of ICT products in everyday life we can say that in some extent women do use technology. *But who produces it?*

Table 1
Technology-related subgoals of Sustainable Goal 5 ("Achieve gender equality and empower all women and girls") [31]

Subgoal	Objectives
5.5	Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life
5.b	Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women
5.c	Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels

According to official figures related to European Union [7,14], employment in STEM (Science, Technology, Engineering, Mathematics) is definitely male dominated, with women accounting for only 24% of science and engineering professionals and only 15% of science and engineering associate professionals (i.e., technical occupations connected with research and operational methods in science and engineering). Traditionally, the exclusion of women has been particularly severe in engineering [15] and computer science [18] and actually, nowadays, the "gender segregation" problem in STEM has a peak in ICT subjects: for example, a recent study shows that, with current trends, the proportion of female authors in Computer Science is predicted to reach 0.45 around 2124, whereas authorship parity in biomedical literature is projected to be reached within two decades [34].

This unbalanced situation definitely raises some relevant questions pertaining to the relation between gender and technology and to the consequences of including/excluding women on the *producer side* of technology: given the pervasiveness of ICT applications in contemporary society, affecting almost all aspects of daily life, and given the new accelerated pace to this phenomenon imposed by the COVID-19 emergency that is changing our relationships in almost all of our spheres (personal, social, and working) and is moving a variety of ICT tools and applications from discretionary to non-discretionary use, there are some considerations to make: *is it ethical or acceptable that contemporary society is de facto designed by men*? And, from a technical point of view, *which are the consequences in term of product quality, efficiency, and effectiveness?* And furthermore, *is technology designed to really meet men's and women's need or is it rather conformant to the designers' stereotypical configurations of such needs*? [17, 25] And *what happens if the designers' anticipation of users' needs is combined with general cultural norms?* [17]. As Oudshoorns observes, "Due to the norms and values that are inscribed into a technical artifact, objects can attribute and delegate specific roles, actions and responsibilities to their users" [25]. Along this line, an interesting example from a Berg's study on the design of smart houses [4] is reported by [17]: "Berg shows that the designers of the houses, men engineers, imagined themselves as users of the houses ('I- methodology'), and their design of these houses did not include technological solutions to ease household work (considered to be women's work)", which ended up with a smart house characterized as a stereotypical 'masculine' construction.

Design methodologies that explicitly acknowledge the expectations of final users and put them at the center of the design process (e.g., User Centered Design in HCI or Socio-Technical approaches) certainly mitigate these problems. For example, Mumford's (re)definition of the Socio-Technical approach as "one which recognises the interaction of technology and people and produces work systems which are both technically efficient and have social characteristics which lead to high job satisfaction" [20,21] address the necessity of recognizing the needs of people and might be regarded as implicitly anticipating gender issues. Mumford observes that "If a technical system is created at the expense of a social system, the results obtained will be sub-optimal" [23] but *can the simple participation to the design process of women on the final utilizers' side be considered enough to this aim?* Actually, studies already proved that the inclusion of women on the producer side boosts the quality of STEM outcomes as diverse perspectives aggregate creativity, reduce potential biases, and promote more robust knowledge and solutions [30,35] (just to make an example, let's consider machine learning systems and the consequences of training them with biased data).

Anyhow, notwithstanding known results in this direction, and notwithstanding a great volume of literature from the interdisciplinary scholarly field on "gender and technology", including the two strands of research of feminist technology studies and science and technology studies (see, e.g., [6,17,27,37]), we observe with [17] that *"It may be paradoxical that gender and technology have been massively studied, and yet not much has happened to change the paucity of women involved with technology – the generally low and even decreasing share of women who design and study technology, although there remains substantial number of women who uses technologies. Why has it been so difficult to change the gendering of technology?".*

There is actually no simple, direct answer to this question. The ecological framework presented in [30] underlines that there is no single factor that alone can influence girls' and women's participation, achievement and progression in STEM education. Positive outcomes must be the result of interactions among a variety of factors at the *individual*, *family*, *school* and *societal* levels, and demand engagement and explicit actions from stakeholders at each of these levels.

With this position/experience paper, we wish to raise and stimulate the debate within the socio-technical systems community, guided by an approach maintaining two different yet synergistically converging perspectives and objectives: (1) empowering girls and women through the engagement in ICT studies, and (2) addressing issues related to the gendering of technology through refined design principles and methods. More specifically, we aim at outlining a *virtuous chain* in which family and society favor the interest of girls in ICT and their engagement in ICT studies, education professionals prepare girls for ICT careers, and the scientific/technology community not only avoids prejudicial discrimination against women but clearly acknowledges the beneficial role of women in the design process. Explicit actions and initiatives at all these levels are necessary to realize the vision.

With this objective in mind, the remainder of the paper is organized into three sections ideally following the envisioned virtuous chain. In Section 2 we sketch some figures that clarify the overall scenario and present example actions at *societal level*; in Section 3 we briefly present main features and results of the PinKamP program, a consolidated initiative at *educational level* organized by the Department of Information Engineering, Computer Science and Mathematics of the University of L'Aquila since 2018, addressed towards girls of the 3rd and 4th classes of high schools and indirectly impacting on schoolteachers and girls' families; finally, in Section 4 – which stands as a "call for action" at *scientific level* within the socio-technical systems community – we try to lay a basis for a discussion within the STPIS workshop.

2. Framing the problem

Official figures help to grasp the size of the problem and underline the importance and the urgency of interventions. Actually, it has to be observed that the paucity of women in STEM is part of a more general gender independent problem of paucity of professionals in STEM: while the pervasiveness of ICT applications in contemporary society makes labor market seek for more and more professionals and operators in related disciplines, *official reports emphasize persistent skill shortage* (particularly pronounced for technological occupations) *and recruitment difficulties in relation to STEM skill labor*, and observe that without corrective actions the situation is going to get even worse, due to expected retirements [1,14]. There is a forecast of around 7 million job openings in the European Union (EU) only, by 2025 [14]. Studies singled out two key factors among the causes of this situation: (1) *a general and gender independent decline of pupils' interest in STEM subjects*, particularly noticeable already at the secondary school level [28], and (2) the *persisting underrepresentation of women among STEM graduates* as a result of a mix of social, cultural, economic and educational institutional factors [14]: in EU, in 2012 graduates in STEM disciplines account for 12,6% of female graduates in contrast with a share of 37,5% of male graduates (source: Eurostat [14]).

Actually, the consequences of the underrepresentation of women in STEM are not only at cultural and social level but also at economic level (e.g., according to [8], the lack of STEM-skill labor will be a significant obstacle to future economic growth). Interventions aimed at mitigating the issues in the social and cultural domains would have also significant positive impact on the economic growth: according to official reports [13], closing the gender GAP in STEM would contribute to an improvement in EU GDP by 610-820 billion euro in 2050, and a positive impact on EU employment, which would rise - by 2050 - by 850.000 to 1.200.000 job positions, likely to be highly productive and with high wages.

It is certainly appropriate to investigate on how to intervene at education level, where families, education system, teachers and peers appears co-responsible for the early segregation by reinforcing social and cultural stereotypes and giving support to gendered choices with regard to studies and career prospects [29], thus hampering girls' and women's later study and career opportunities. As illustrated in Figure 1, only about 30% of all female students select STEM-related fields in higher education, and, more specifically, only 3% select ICT studies. It is worth noticing that, already among 15-year-old girls intending to pursue science careers, 74% are inclined towards health studies and only 2% towards ICT studies (see Figure 2).

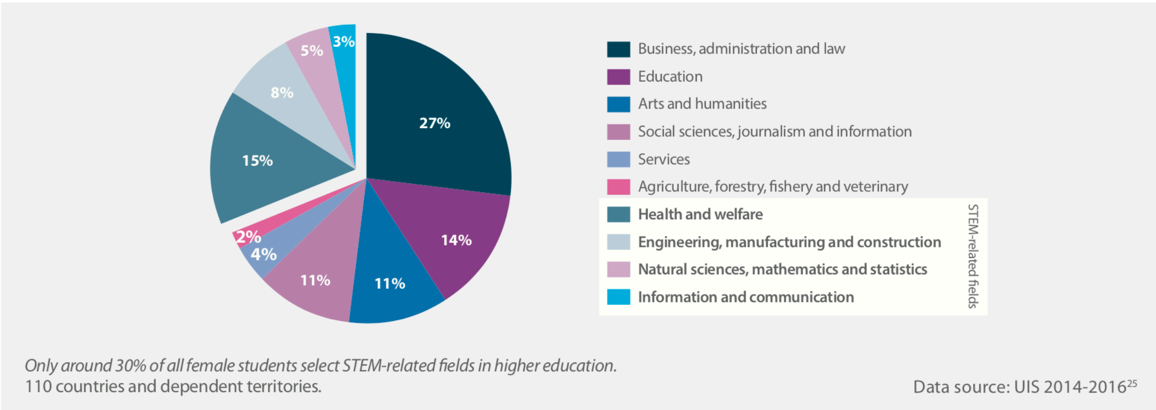

Figure 1: Distribution of female students enrolled in higher education by field of study (from [30])

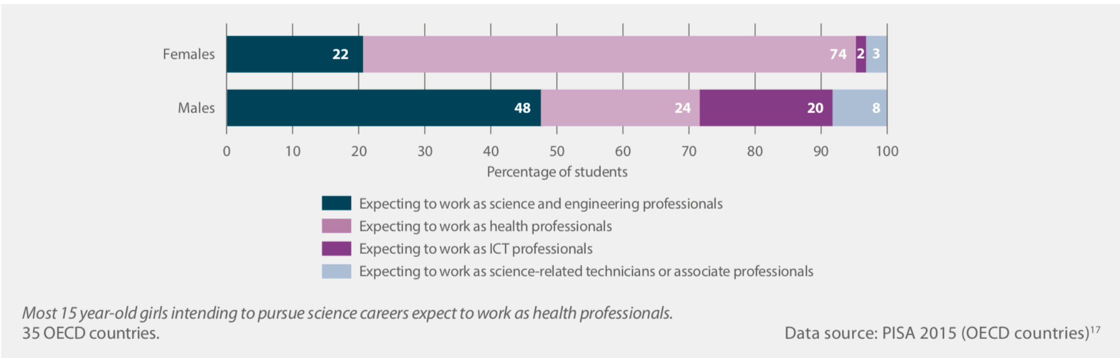

Figure 2: Student expectations on science careers, by sub-field of study, out of those who choose science careers, 15-year-olds (from [30])

These figures acknowledge that policies and initiatives to invert the trend and encourage and guide girls and young women to pursue ICT studies and career are definitely necessary. Studies have shown that stereotyped ideas about gender roles develop early in life, even in families promoting gender equality: girls and boys understand gender stereotypes and want to behave like others of the same sex by as early as age two, and they learn to adjust their behavior according to internalized gender stereotypes by age four [30]. Curricular and teaching methods are therefore only part of a more general scenario focused on the free development of not stereotyped personal vocational interests at family, school, and societal levels.

In this direction, for example, we highly welcome initiatives as the "women of science" special Barbie edition from Mattel (see Figure 3), promoting and making visible the contribution of women working in STEM in an effort to inspire more girls. After the "career dolls" and the "Barbie Inspiring Women™ Series", this recent initiative is part of the more general Dream Gap Project: "*Imagining she can be anything is just the beginning. Actually seeing that she can, makes all the difference*" [19].

Figure 3: Women of Science Mattel special Barbie edition

3. The educational level: the PinKamP initiative

Within this line of interventions on vocational interests, the PinKamP initiative has been designed with the twofold objective of 1) guiding young girls towards STEM careers and 2) developing effective and attractive STEM teaching methods. In particular, PinKamP is structured as a 2-weeks intensive summer camp on Computer Science, Information Engineering and Mathematics, conceived for high schools' girls and built around selected example technological platforms (e.g., virtual reality and drones) and related STEM subjects integrated within a hands-on project-based system. The designed format includes plenary theoretical lectures, team project-based parallel laboratories, soft skills, along with conferences, social debates on women' rights, meetings with successful women in the IT scientific/professional fields, and a final contest. PinKamP aims to bring girls closer to STEM disciplines, beyond gender stereotypes, trying to remove barriers and prejudices, showing and demonstrating how women can contribute to the development and improvement of future technologies, thanks to their creativity, sensitivity and attitude to problem solving. It achieves this goal by implementing a teaching method based on three dimensions (KPS – Knowledge, Processes and Socialization) having as core real projects to conceive, design and implement using girls' creativity and passions.

3.1. The PinKamP experience

PinKamP is conceived for high schools' girls (16-17 years old) who are about to plan their future studies and careers. Designing an educational module with the PinKamP's goals in mind requires a change of paradigm with respect to customary courses where learning objectives are the primary objectives. In our case, we have to address the multi-fold and multi-nature objective of supporting young women in (1) *developing personal vocational interests*, and (2) *acquiring a correct and as much as possible comprehensive concept of technology*. As observed in [28], technology education should develop an understanding of the nature of technology, the relationship between technology and society, and technological design; with emphasis on only few specific aspects of technology there is considerable risk that pupils develop a limited concept of technology. These considerations raised the necessity to harmonize the contrasting challenges of *short time* and *ample overview*. Our solution was to single out a number of selected diverse *example technological platforms* representative of the ICT realm and explore them within a multidisciplinary approach touching diverse related subjects and methods, thus allowing the girls to face a variety of inter-related fields. The presented topics are carefully selected by the organization team and the concepts are presented to the girls using formal definition as well as real-life concrete examples.

The design of the module took into considerations the *universals of technology* that the International Technology Education Association has identified and categorized into three groups [16]. In particular we addressed *Group A – Knowledge* (comprising nature and evolution of technology, linkages, and technological concepts and principles) and *Group B – Processes* (comprising designing and developing, determining and controlling, utilizing, and assessing impacts and consequences), while confining *Group C – Contexts* within the ICT realm. Furthermore, we associated the two dimensions of

Knowledge and *Processes* with the third dimension of *Socialization*, considering that collaborative skills, in secondary schools, were found to have larger effects on pupils' attitudes than more traditional programs [33].

The three *KPS (Knowledge, Processes and Socialization) dimensions* are actually intertwined within a hands-on project-based integrated system, since an approach to learning centered on project work has been linked to greater motivation [2], and studies seem to show that, besides motivating both teachers and students, integrated systems tend to be more favorable to gender and social equality than more customary approaches based on distinct subject areas [32]. Key roles and impacts have the *actors* involved: organizers, teachers, team tutors (young researchers, graduate and under-graduate students, and PhD students), and role models showing that success in STEM fields is possible for girls and women. In summary, the proposed format is structured as shown in Figure 4.

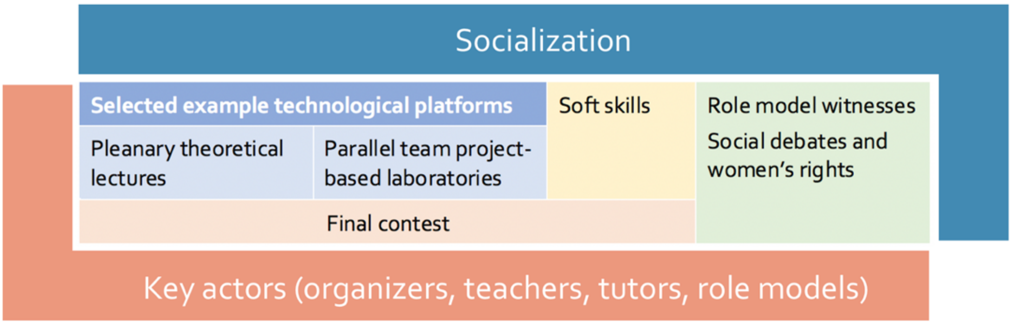

Figure 4: The PinKamP format

To work on vocational aspects and personal appropriation of technology, the activities of PinKamP participants (the "Pinkampers") are focused on *building and telling a story*. Pinkampers are stimulated to use the assigned technological platform to invent and enact a "story" that creatively encompasses and interprets the learned technological contents, working in a team. At the end, each project team is required to produce and make a short presentation illustrating their story and demonstrating the acquired abilities. In a final contest the best projects – selected by a jury – are awarded.

After a pilot simplified edition in 2018, where 20 girls attended 9 lessons of 3 hours each on technical topics on a weekly basis, PinKamP is now a consolidated intensive two-weeks program implementing the conceived format with some variations depending on the social conditions:

- In the 2019 edition, 50 girls, selected from high schools on the whole national territory, attended lessons and laboratories for 7 hours a day from Monday to Friday, at our Department from June 17th to June 28th. A final public contest was organized at the end of the camp on June 29th, 2020. The selected technological platforms were *drones*, *Lego robots* and *virtual reality*.
- In the 2020 edition, due to COVID-19 pandemic emergency, the camp was organized on-line on the MS TEAMS platform, with Pinkampers engaged in synchronous lessons and laboratories from Monday to Friday 4 hours a day from June 22nd to July 3rd, and in asynchronous activities from the end of the camp until the final public contest on September 25th, 2020. Due to the lack of consolidated previous experience on an online camp, for the sake of quality we cautiously reduced the number of Pinkampers (again selected from high schools on the whole national territory) from 50 to 32. The chosen technological platforms were *BioMath*, *drones*, *virtual reality*, and *web sites*.
- In the 2021 edition, given the persistence of the COVID-19 pandemic emergency, the camp was again organized on-line on the MS TEAMS platform, with Pinkampers engaged in synchronous lessons and laboratories from Monday to Friday 4 hours a day from June 21st to July 2nd, and in asynchronous activities from the end of the camp until the final public contest on September 24th, 2021. In light of the successful experience of the on-line 2020 edition, we increased the number of Pinkampers from 32 to 40 (again selected from high schools on the whole national territory). The adopted technological platforms were *BioMath*, *drones*, and *web sites*.

In all editions, Pinkampers were exposed to group dynamics and work organization and had to test themselves in decision making and negotiation. In the final race they tested their ability to communicate in a highly competitive context showing their determination and motivation. During the camp, the girls attended debates on women rights and gender equality issues, as well as interactive meeting with professionals and experts (role models) who reported their experiences not only from the STEM realm but also from art fields (with an eye on the rising interest in the STEAM educational approach using Science, Technology, Engineering, Arts and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking). Furthermore, to stimulate the Pinkampers in becoming active part in the promotion of the work of women in STEM, each team was asked to select a woman (from the present or the past) related to science and/or technology and somehow representative of their project, to study her work and results, and to briefly present her story at the final contest.

3.2. Results

Given the age of the Pinkampers (16-17 years old) and the size of the classes, it is too early to evaluate in a statistically significant way the impact of the three regular PinKamP editions (2019, 2020, 2021) on the number of female students enrolled in University courses related to the three areas involved in the PinKamP program (Computer Science, Information Engineering, and Mathematics). Meanwhile, the success of the initiatives is being assessed in various way, to evaluate both learning achievements and vocational interests.

First of all, it is worth noticing that 95% of the selected Pinkampers completed the three camps (48 out of 50 in the 2019 edition, 31 out of 32 in the 2020 edition, and 37 out of 40 in the 2021 edition). This is an amazing result that demonstrated that the format was attractive to girls and intrigued them in STEM topics. In all editions the level of participation and enthusiasm went well beyond the expectations and the obligations; in the case of 2020 and 2021 editions this is particularly noteworthy for an online campus attended by girls somehow psychologically and intellectually worn out by months of online school activities and by the social restrictions due to the pandemic.

As to *learning achievements*, the final contests were a benchmark through which internal experts (organizers/teachers) and external experts (a jury of five outstanding STEM professionals) could evaluate the level of Pinkampers teams' results and the quality of presentations, which revealed surprising scientific maturity and awareness if compared with the relatively short time spent in the camp. Furthermore, the results of each edition revealed that a key factor was the choice of letting the girls free to conceive their projects according to their personal interests, which made them experience the empowerment provided by technology enhancing their expression capability and serving their intended content and objective. Actually, as observed in [30], curricula that are gender-balanced and take account of girls' interests, for example linking abstract concepts with real-life situations, can help increase girls' interest in STEM. Our results totally confirm it.

As to *vocational interest*, we organized a number of follow-up initiatives where Pinkampers were free to participate, which revealed a constantly high level of interest by the majority of Pinkampers: e.g., 35 out of the 50 2019 Pinkampers attended a second contest held in September 2019 during Univaq Street Science, a University of L'Aquila event co-located with the European Researcher's Night; all the Pinkampers that completed the 2020 and 2021 editions contributed to books reporting the PinKamP experiences [10,40]; 10 of the 2021 Pinkampers chose to be involved in the preparatory activities for realization of a video on gender issues, and 4 of them actually wrote and shot the video.

4. Discussion and Conclusions

The format of the camp proved to be general enough and flexible to adapt to different situations: the three editions of PinKamP differed in the number of Pinkampers, number and typology of example technological platforms, and participation mode (in attendance or online) while maintaining the guiding principles. PinKamP sets itself as a replicable reference model for similar initiatives. A first example in this direction is given by the StemDays (www.stemdays.it), modelled starting from the PinKamP format and running in the same weeks of PinKamP, organized in Torino by "Fondazione Human+" in cooperation with scholars from the University of Verona and the University of Torino, with an initial guidance provided by the PinKamP coordinators,.

Initiatives at individual and school levels like the Dream Gap Project from Mattel and the PinKamP project from the University of L'Aquila should be part of a broader, structured, and organic plan of interventions engaging stakeholders at different levels. For example, to work on the vocational side, after toys and education the chain must continue: as Barbie "science dolls" help girls to *see* that they can be anything and initiative like PinKamP help them to *prove* that they can effectively succeed, design principles, approaches, and methodologies explicitly stating the crucial role of women in the production of technology could make an even bigger difference, making girls *feel "waited for"*.

The sociotechnical design field appears to be an ideal ally in this direction, because of its philosophical approach, its association with the idea of change, its primary objective of ensuring that both technical and human factors are given equal weight in the design process, and the consequent implicitly inclusive nature [3,9,22,36,39]. The gender issue is somehow included in the root of the socio-technical design within Cherns' first principle: "The process of design must be compatible with its objectives. This means that if the aim is to create democratic work structures then democratic processes must be used to create these" [39], as well as, for example, in Clegg's metaprinciples 5 and 6; "Design is an extended social process", and "Design is socially shaped" [9]. Clegg's considerations about the utilization and the appropriation of technology ("Most obviously, users may choose to use a technology in a certain way. They may tailor the technology to meet their particular needs.") are somehow related to Lagesen's consideration about the "domestication" of technology and the co-construction of gender and technology [17]. Besides, Clegg's content principle 9 ("Design entails multiple task allocations between and amongst humans and machines"), along with his related considerations, implicitly entail design decisions about the organization of work, possibly associated with a gendered division of labor.

Anyhow, steps forward must be embraced since it is recognized that inequalities are not dismantled if they are not *explicitly* addressed. We already experienced it for other design-related issues, such as multi-disciplinarity, that is now explicitly recognized and advocated by Clegg's process principle 17 ("Design involves multidisciplinary education") and by user-centered design methods. The same should hold for gender issues.

We like to close this discussion by quoting Clegg's considerations about multi-disciplinarity, inviting the reader to look at them (and rephrase them) with a multi-gender issue in mind in place of the multi-disciplinarity issue:

"A key feature of sociotechnical design involves bringing together people from different roles and disciplinary backgrounds who have different skills, experience and expertise to offer the design process. Pluralism is the norm, and this implies that they share their views and expertise. They need to educate one another in the opportunities that may exist for the design of a new system and what they have to offer the design process. The intent here is not to argue that the holders of one perspective should try to educate others in the correctness of one view (and thereby the inappropriateness of others). Rather, views of the kind articulated in these principles need to be incorporated into design thinking and design practice as worthy of debate. The goal is to educate one another in the complexities of design, and in the need for a more multi-disciplinary understanding. A further potential benefit exists: a multidisciplinary approach to design is more likely to foster creative and innovative solutions. Whilst this may seem obvious, a sociotechnical approach explicitly assumes that design needs to draw upon the expertise of both social and technical domains. This requires considerable resources and support."

Rephrasing Clegg: *A further potential benefit exists: a multi-gender approach to design is more likely to foster creative and innovative solutions. Whilst this may seem obvious, an approach based on gender equality explicitly assumes that design needs to draw upon the expertise of all genders. This requires considerable resources and support.*

What does the scientific community plan to do?

Actually, we observe that the moment for action has definitely come, recalling the strong stand of the European Union for gender equality in research and innovation policy, with three primary objectives underpinned by the European Commission's strategy: (1) fostering equality in scientific careers, (2) ensuring gender balance in decision-making processes and bodies, and (3) integrating the gender dimension in research and innovation content [38]. The EU position is so firm that a new eligibility criterion was introduced for Horizon Europe: applicants will need to have in place a Gender Equality Plan (GEP) to be eligible for EU funding. Time has definitely come for making gender equality issues explicit points in our agendas.

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