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Addressing gender in STEM classrooms: The impact of gender bias on women scientists' experiences in higher education careers in Germany

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Abstract

Gender bias underlying discrimination against women are particularly salient in STEM higher education. Complementing top-down measures to mitigate these issues identified in the extant literature, we aim to highlight a complementary bottom-up approach. First, to elicit gender stereotypes and gender bias in STEM, we conducted a group concept mapping (GCM) study involving women professors, teaching staff, and scientific staff from different STEM disciplines at German universities ($N=70$). We first asked them to provide statements reflecting their experience in response to the following focus prompt: 'In my career as a STEM teacher, I experienced gender issues related to:' Experts were then asked to thematically cluster and rank the statements according to their importance and feasibility with respect to a potential pedagogical intervention that may target these issues. Findings revealed an agreement across STEM disciplines regarding stereotypical beliefs about women, heteronomous gender roles, gender workload, sexism, and structural power relations, in that they remain significant factors for hindering female success in STEM careers in higher education. Based on their experience, however, the women saw potential in working on the awareness of gender bias with pedagogical interventions in online group learning scenarios (CSCL). Statements rated most appropriate were discussed in the light of the aspects of gender bias addressed, with a specific focus on addressing them in collaborative scripts.

Keywords Gender · STEM · Pedagogical intervention · CSCL · Higher education · Group concept mapping · Gender · STEM · Pedagogical intervention · CSCL · Higher education · Group concept mapping

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1 Introduction

1.1 Gender stereotypes & gender bias in STEM education

Gender bias is an ever-present, ubiquitous influence in the daily lives of women working and teaching in science, technology, engineering, and mathematics (STEM) fields. There are many international examples of how gender bias materialises in STEM education from an early age. Gender stereotypes are learned, for instance, through the perpetuation of the portrayal of sexist gender roles in school textbook instructions in computer science education (Papadakis, 2018). It is shown that picturing girls and women as less suited for professional STEM tasks and roles significantly shapes students' perceptions and behaviours towards women and men in STEM environments. Self-identifying as a woman or a man consequently impacts the educational expectations and career choices of students in STEM (Ferreira, 2017; Spencer et al., 2016).

The ramifications of gender bias extend into higher education, where studies reveal disparities in teaching evaluations, where both male and female students favour men over women (Leslie et al., 2015) and widely underestimate women (Carli et al., 2016). Women in STEM receive fewer research grants but more recognition for the social care-taking of their graduate students than men (Bol et al., 2022). Furthermore, gender stereotypes and gender bias in STEM are shown to affect career choices and explain differences in the time spent in academic working positions between women and men (Dasgupta & Stout, 2014; Spencer et al., 2016). Despite some progress made towards gender equity in STEM over the past two decades, a recent literature review suggests that key forms of systemic societal gender bias persists, hindering women's advancement in academic science (Ceci et al., 2023).

Educational scholars advocate for addressing the adverse effects of gender stereotypes on all students' motivation to pursue STEM careers in higher education classrooms with pedagogical interventions (Di Lauro, 2020; Sepúlveda, 2018; Tomai et al., 2014). Rather than solely focusing on individuals and womens' predictors of success, efforts to mitigate gender inequality in STEM should prioritise pedagogical approaches that challenge gender stereotypical perceptions in STEM fields, as Froehlich et al. (2022) posit.

1.2 Theoretical background

According to the American Psychological Association (2020), gender bias is any one of a variety of stereotypical beliefs about individuals on the basis of their sex, particularly as related to the differential treatment of females and males. In general, scholars distinguish between two types of gender bias. Explicit gender bias refers to conscious prejudices or discriminatory behaviour against women, men, or other genders that happen consciously and intentionally and can be measured by self-report (Boysen, 2009; Peterson et al., 2019). In contrast, implicit gender bias happens without conscious intentions (Greenwald & Banaji, 1995). It is an automatic and unaware biased evaluation without an awareness of the causation, but can also lead to discriminatory behaviour (Greenwald et al., 1998). According to Boysen (2009), both implicit and explicit bias exist on the individual, social and societal levels. Sociological investigations of bias invoke the analysis of the different levels associated with individual experience (Bauman, 2001). Implicit and explicit bias are therefore linked with the everyday experiences and segregation of different social groups in society and the media's abundance of gender stereotypical representations, and both are thus equally harmful and exclusionary (Boysen, 2009). When investigating gender bias, researchers often distinguish between three types of category-based reactions of people: gender stereotypes, prejudice and discrimination. Gender stereotypes are the de- or pre-scribed ways how men or women are or should be, with a strong cognitive component. Prejudice—such as the biased presumption that women are not capable of being leaders—operate more on the affective level. The wrongful and harmful differential treatment due to gender, i.e. discrimination, is a largely behavioural gender-related reaction (cf. Fiske, 1998). According to these definitions, we will use the exact term that means the social phenomenon being described in this study.

1.3 Pedagogical intervention

According to scholars from education, psychology and social work, one approach to address gender bias in higher education (HE) may be to develop gender-conscious pedagogies (Norman & Wheeler, 1996; Witt & Cuesta, 2014). If gender bias is directly addressed within pedagogical methods and awareness training in the classrooms of HEI, it can create awareness, which can benefit all genders in their learning in the classroom and later careers (Witt & Cuesta, 2014). A study by Viswambaran and Diwakar (2021) showed how critical pedagogy in the classroom can raise awareness of gender, social class and religion by working with case studies and media deconstruction and Socratic group discussions. They posit that gender equality should be addressed with both top-down policies in HEI and bottom-up approaches. In education, a bottom-up approach refers to an instructional method that tailors the learning experience to the individual needs and experiences of the students, besides student-centred learning one characteristic of it is collaboration (Setiawan, 2020). Computer-supported collaborative learning (CSCL) is a bottom-up method that has become increasingly employed in STEM education in the past two decades, as higher education has become more digitised (Cress et al., 2021).

1.4 Computer-Supported Collaborative Learning (CSCL)

In group learning, small groups of students collectively work on a joint task to achieve learning outcomes that benefit all members (Johnson & Johnson, 2018). In this paper, group learning is both cooperative learning (Slavin, 1990) and collaborative learning (Dillenbourg, 1999), as the differences between these approaches to group learning (Veldman & Kostons, 2019) are not central to the argument presented here. In cases where computers further support group learning, the general term is computer-supported collaborative learning (CSCL). CSCL refers to both a pedagogical practice and a field of research, and while the latter has been an established research community for decades, CSCL as a pedagogical practice has attracted ample attention in recent years (Cress et al., 2021). The interest is due to the many learning benefits, such as critical thinking and problem-solving, which are considered important 21st-century skills (González-Pérez & Ramírez-Montoya, 2022).

Gender-conscious pedagogy challenges the myth of objectivity by interrogating what is commonly perceived as common sense and 'normal' through teaching. This involves actively questioning and reflecting on societal norms, including how gender codes impact various aspects of everyday life and the professional experiences of both women and men (Witt & Cuesta, 2014). Viswambaran and Diwakar (2021) showed that it is highly effective to promote social norms of gender equity and inclusion among students by discussing everyday examples in group discussions. In light of this, a systematic literature review by Kube et al. (2022) showed that CSCL, as a has the potential to create more gender-inclusive learning environments in STEM. However, they found more research is needed to explore the social and psychological mechanisms of inclusion in a CSCL-based intervention regarding gender bias. In order to address the pedagogical goal of raising awareness of gender issues in the classroom, CSCL scholars propose two pathways. The first pathway to foster gender awareness through CSCL tasks involves integrating gender-conscious content into the learning activities (Di Lauro, 2020; Sepúlveda, 2018). For instance, organising, feminist edit-athons, where students critically evaluate Wikipedia articles for gender bias and become authors of women's stories in STEM science, as well as, encouraging computer science students to design games that aim at increasing the self-identification and efficacy of school girls (Richard & Hoadle, 2015), has shown several benefits. These measures helped to increase the self-identification of women with the STEM field, to achieve better learning experiences for women and girls and to raise the awareness of gender bias in STEM among a great number of students. A second pathway is the potential of CSCL to raise gender awareness via the interpersonal and socio-cognitive processes elicited by the pedagogical *method* per se. One such mechanism central for CSCL is socio-cognitive conflict. From a socio-cognitive conflict perspective, collaborative learners engage in conflict-oriented consensus building that encompasses criticising, altering, or substituting each other's contribution to the discourse with the objective of productively resolving the disagreement and arriving at a shared conclusion (Weinberger & Fischer, 2006). This is achieved with collaboration scripts in CSCL (Weinberger et al., 2013). Discussing each other's contributions critically can greatly enhance collaborative learning by building on and strengthening shared knowledge among learners (Johnson & Johnson, 2009). Thus, a targeted intervention using collaborative scripts discussing specific topics of gender bias or discriminatory practice in STEM education might benefit the awareness of gender bias for all students in STEM classrooms, as well.

2 Present research

In this mixed-method study, we aim to elaborate the knowledge on developing gender-targeted pedagogical interventions in computer-supported group learning for a great number of students in the context of STEM higher education in Germany. We aim to generate knowledge on the different aspects of gender bias in STEM higher education in Germany, where gender bias against women working and teaching in STEM is still very prevalent (Froehlich et al., 2022; Rosenthal, 2021; Selent et al., 2011). Furthermore, we seek to provide insights into how a gender-targeted CSCL could look like and what aspects of gender bias in STEM could be addressed to raise the awareness of gender stereotypes and gender bias in STEM among learners in higher education (cf. Johnson & Johnson, 2009).

We use a collective cognition approach, i.e. a group concept mapping method, with women scientists and professors from German STEM departments at higher education institutions. This target group was chosen due to possessing expertise not only in describing and identifying gender bias but also in formulating strategies to mitigate it.

Our guiding research questions are thus:

RQ1) How does gender bias manifest in STEM higher education at German HEI in the experience of women teaching there?

RQ2) Which aspects of gender bias in STEM HE can be addressed with computer-supported collaborative group work (CSCL) to raise the awareness of gender stereotypes and gender bias among learners?

The study makes two main contributions. First, it provides a detailed account of the aspects of gender bias encountered by women in German STEM HE. This knowledge is needed to comprehensively understand gender bias in the German case. It also serves as a starting point to compare gender bias in STEM with other STEM contexts to develop internationally applicable pathways on how to intervene pedagogically. Generally, addressing gender bias in research has the social impact of contributing to broader discussions about equity and fairness in STEM.

Second, the study evaluates the estimations of the women experts on how to address gender bias in STEM with computer-based group work. This knowledge is needed to develop evidence-based pedagogical interventions tailored to the specific STEM environment and allow for effective targeting of these issues in group discussions with students. It further serves as a validation and complement of existing literature on gender-sensitive pedagogies by transferring it to CSCL environments (cf. Kube et al., 2022). Lastly, involving women teachers in the development of gender-sensitive pedagogies with the goal of promoting inclusivity and diversity in STEM education is a source of empowerment and agency for women working, teaching and studying in STEM that stimulates further commitment.

3 Method

Group Concept Mapping (GCM) is a structured methodology to elicit ideas, opinions, and outcome believes (collectively referred to as statements) in a group by means of a focus prompt presented to the group; it is a mixed-method approach to capturing the results of collaborative decision-making processes (Rosas & Kane, 2012; Trochim, 1989). GCM's goal is for a group to arrive at shared visions, through a group cognition process, about specific topics such as gender bias in STEM education. GCMs have already been successfully used to investigate sensitive topics of social stigmatisation or taboo, such as implicit bias, in medical and educational studies (Adams et al., 2021; Cook & Bergeron, 2019).

Unlike other methods of collecting and analysing opinions, GCM requests the participants to generate structures and statements around the topic (Rosas, 2017). The approach includes quantitative and qualitative measures to create a participant-driven visual representation of the group's statements. The method offers several advantages over existing word-based and code-based methods in terms of reliability (i.e., stability, reproducibility, and accuracy) and validity (i.e., construct validity, sampling validity) also since the structuring of the data is done solely by the participants here the experts, not by the researcher (Rosas & Kane, 2012; Schophuizen et al., 2018). Participants work independently and anonymously when brainstorming or rating statements, thus avoiding biasing results via social effects of peer pressure, privacy concerns, or groupthink (Park, 1990). This appears particularly relevant in situations where opinions and experiences may be sensitive, as in the case of experiences of gender bias. In GCM, the researcher uses only the original participants' statements as an observational unit and then quantitatively aggregates these data through multidimensional scaling (MDS) and hierarchical cluster analysis (Rosas & Kane, 2012). Consensus develops objectively through the multivariate statistical analysis that identifies patterns of meaning allocation in the data. The GCM data collection procedure consists of five distinctive phases: (1) Preparation, (2) Generation of statements, (3) Structuring of statements, (4) Data analysis, and (5) Data interpretation. A schematic overview is shown in Fig. 1.

3.1 Participants

We recruited 70 women participants for this study. They were doctoral students ($n=23$), postdocs ($n=31$), or professors ($n=16$) at STEM faculties in German Universities. 53 women had a scientific background in mathematics and natural science (including physics, biochemistry, biomedical neuroscience, chemistry, pharmacology, medicine), information science (informatics, computational and data science, robotics) and technical science (chemical engineering, environmental engineering, material science, electronics, civil structural engineering). 17 women were gender mainstreaming experts at their HE and came from social science (sociology, psychology, political science, and pedagogical science), humanities (linguistics, cultural studies, and literature studies), law and economics. 51 women had been teaching and working in STEM for less than six years. 19 women, the professors and three postdocs, had more than ten years of teaching experience. Most of the participants' experience with teaching online was up to three years ($n=52$), fewer had more experience ($n=8$) and some none ($n=3$) with educational technologies in HEIs. Table 1 presents the demographic data of the participants.

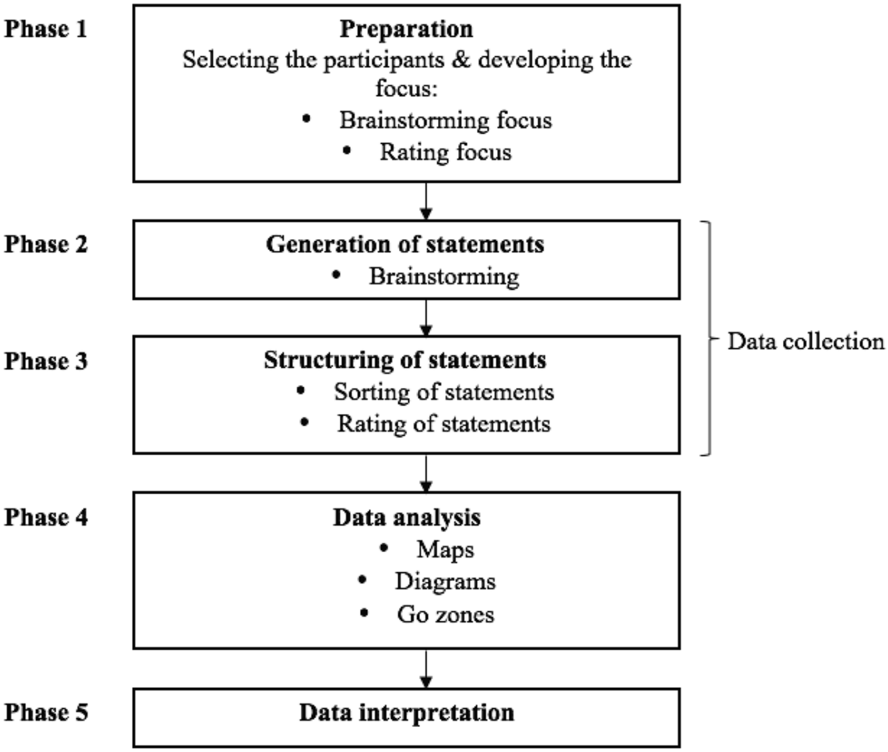

Fig. 1 Flow diagram indicating the process for group concept mapping (adapted from Trochim, 1989)

Within the sample, we specifically recruited 24 women experts in gender and gender mainstreaming from different departments (non-STEM $n = 17$; STEM $n = 6$) at German universities. They were contacted either due to working as (senior) equal opportunities officers, being a researcher in gender studies, or representing women's interests in academic networks in STEM, i.e., being a spokesperson. We targeted women scientists aware of the matter from different STEM departments at German universities. In interviews and e-mail communication prior to participating in the study, we learned that they had personally reflected on their situation as women in STEM before participating in the study and would be able to contextualise it in education and categorise it. Furthermore, we made sure to check with them whether they have knowledge of and, at best, experience with CSCL in order to be able to estimate the potential of CSCL to address gender bias in class.

The other 46 participants were recruited through several channels, such as women networks in academia, faculty emailing channels, and social media, asking women in STEM HE to contribute with their perspectives on experiences and prospects for women in STEM. We gave our most important definitions of gender bias and CSCL and how we want to address gender bias in this study. All participants were

Table 1 The Demographical Data of the Women Participants

Participant question	Answer option	Frequency	%
discipline	mathematics	8	11,43
	information science	12	17,14
	natural science	30	42,86
	engineering (tech.)	3	4,29
	social science	6	8,57
	humanities	6	8,57
	economics	1	1,43
	law	4	5,71
working/teaching experience	0–3 years	34	48,57
	4–6 years	17	24,29
	7–9 years	6	8,57
	10–15 years	7	10,00
	more than 15 years	1	1,43
	more than 20 years	4	5,71
	none	1	1,43
online teaching experience	0–3 years	52	82,54
	4–6 years	4	6,35
	7–9 years	1	1,59
	10–15 years	3	4,76
	more than 15 years	0	0
	none	3	4,76

self-selected. They answered our call to shed light on the challenges and opportunities for women in learning and working in STEM in Germany by sharing their experiences. Since the sorting and rating steps in the GCM were conducted by the experts, it was enough to look for general working and teaching experience in STEM in the other participants. It was an observation that a lot of younger teachers participated in the brainstorming who had less working experience but already rich experiences with gender bias.

The women experts participated in all four steps of the GCM study (see Table 2). The sorting was only carried out by the experts, which ensured that the selection and clustering of the generated statements would be a valid representation of the complete conceptual domain of STEM. Also, their prior experience ensured the validity of the rating of the potential of CSCL to address gender bias in STEM classes. In contrast, the other women participants ensured the reliability of the statements because of their personal experience working and teaching in STEM HEIs in Germany. Interestingly, very few women in our sample had more experience with teaching, and CSCL also took part in the rating steps (please see Table 2). It can be stated that the ideal number of individuals for the sorting and rating, i.e. 20–25 individuals (Trochim, 1989), was reached to ensure the validity of the measurement method. Table 2 shows the number of participants in each step of the GCM process.

Table 2 The Overview of Participant Numbers in the GCM Process

GCM Phase	Number of participants started	Number of participants finished
Brainstorming	70	44
Sorting	24	24
Rating: Importance	44	35
Rating: Feasibility	44	25

3.2 Procedure

The study's data acquisition took place remotely at several German universities during the summer semester of April–October 2021. The GCM was divided into three phases. All of them were online, and the contributors had several days to edit them. Initially, all women participants were informed about the purpose of the study, central conceptual definitions, the procedure and the time needed to complete the specific steps and asked to give informed consent. The first phase was 15–20 min long and consisted of demographic questions and a brainstorming session where participants individually had to complete the following focus prompt:

"In my career as a STEM teacher, I experienced gender issues related to:"

A total of 70 statements were produced, and the researchers reduced this set to 58 by excluding repetitions and misleading statements (see Appendix A). The sorting of the statements with the 24 experts was accomplished in a second separate phase of approximately 60 min. For this task, the 58 generated statements from the first phase were as a list. The experts could drag and drop the statements into piles they created and labelled themselves. They sorted and labelled clusters of meaning allocation with the help of their theoretical and practical expertise on the topic. Based on the collected data, the experts determined the number of interpretable clusters represented on the map in the GCM tool and labelled them accordingly. Then they discussed the sorting results interactively in an online meeting of approximately 90 min together with the researchers. The results varied only slightly and were not changed further after the discussion in the GCM tool. However, the experts' comments on the clustering are included in the discussion of the results.

The third phase started after the sorting step of the second phase, where the experts and a few other participants had to rate these remaining statements according to two criteria in a separate session of about 30 to 50 min; the two criteria were their importance and feasibility. Based on their experience, they rated all items on a five-point Likert scale for their importance (1 = not important at all; 5 = very important) and feasibility (1 = not feasible at all; 5 = very feasible).

They first rated the statements according to their importance for women's careers ("In your personal opinion, please rate the statements according to their importance for women's careers."). Then, they rated the feasibility of addressing the described gender stereotype or gender bias in STEM in the statements with a computer-supported group learning (CSCL) intervention with STEM classrooms, ("Please assess the feasibility of successfully reducing the experiential situation/stereotype identified in the statement through CSCL group work with students.").

Participants who failed to complete the assigned steps were excluded from further analyses.

3.3 Instrument and analysis

This study used the GCM online tool from Groupwisdom (Build version 2013.322.11, [Web-based Platform], 2012). The individual contributions of the participants were aggregated to show patterns in the collected data by applying multidimensional scaling (MDS) and hierarchical clustering analysis (HCA). These operators represent the statements as points on a two-dimensional plane that displays it as a point map on which statements are shown as points with distances between them representing the frequency with which the experts sorted them together. This means that frequently co-occurring statements will be displayed closer to those that appear less together. Then, the points were clustered using hierarchical cluster analysis. This means that sets of statements in proximity will be categorised as belonging together, distinguishing them from sets of statements that appear to belong to another cluster. The experts selected the final number of four clusters together with the researcher.

4 Results

In this section, we present the analysis results of the group concept mapping. Firstly, we show the brainstorming statements of the participants (points on the point map, see Fig. 2) included in the process, which the experts sorted into thematic clusters. In Section 4.1, we present the clusters of gender bias in STEM HE and relate them to the theoretical concepts established in the introduction (see Section 1.2). In a further step, in Section 4.2, we then present the assessments of which statements the experts individually considered to be particularly important and feasible to address gender bias in STEM with group work with students to increase their awareness. These results were discussed among the experts, and we lastly show which topics and contents the experts agreed on to be particularly suited to be worked on in a CSCL intervention.

4.1 Clustering gender bias

First, we assessed the sorting results of all the statements. Figure 2 shows all 58 statements of the women participants (see statements Appendix A) visualised in a multi-dimensional point map showing the proximity of the statements after the sorting by the experts.

The location of the points on this map is based on bridging values calculated by the GCM tool. A bridging value between 0 and 1 shows the low or high association with the other statements and their meaning. Low bridging values describe

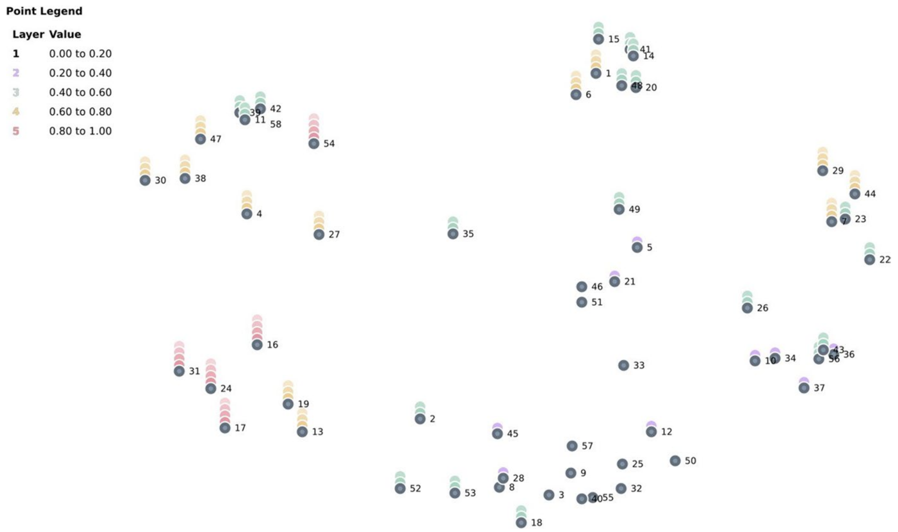

Fig. 2 Point map of the sorted statements

proximity, that is, they have less layers displayed in Fig. 2. Statements close to one another in their location on the map also describe the proximity to one another regarding their meaning and that they have been sorted together more often by the experts. For instance, statements 3, 9, 25, 32, 40, 55 and 57 about unequal perceptions of women and men had low bridging values, i.e., fewer layers showing the high coherence in meaning for the experts. They were also sorted close to one another, which means they were also closely related in meaning to one another. Whereas statements 13, 16, 19, 24 and 31 regarding sexism and power relations had been sorted together but had high bridging values (many layers), and thus less coherent meanings for the experts. To determine whether the point map correctly represents the experts' sorting, we looked at the stress value; these values represent the deviations between the observed values and the predicted values of all observations, to determine the (in-)accuracy of the statistical model, also calculated by the GCM program. Typically, it is found that the stress value for GCM studies should be between 0.205 and 0.365 (Rosas & Kane, 2012). The average stress value for this study was 0.2753 after 16 iterations. This value fell within the accepted range; therefore, we concluded that the point map is a good representation of the original experts' sorting.

Second, we assessed the thematic clusters results of the sorting process of the experts who confirmed four clusters. The multidimensional scaling and hierarchical clustering resulted in a cluster map (see Fig. 3). It helped to interpret the experts' sorting and organise the group cognition of gender bias in STEM HE in Germany out of the 58 statements of women working in STEM. The core themes, i.e., clusters, identified were: (1.) "Gender Role Images," (2.) "Gender Work," (3.) "Unequal Perception of Competence," (4.) "Power Relations." Since lower average bridging values indicate the coherence of clusters, the most coherent clusters were "Unequal

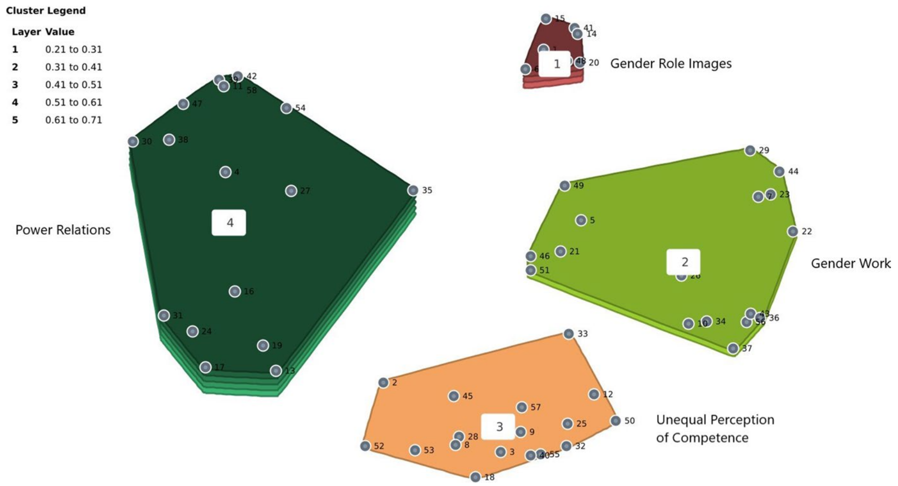

Fig. 3 Cluster map of the sorted statements

Perception of Competence" (0.21) and "Gender Work" (0.40), whereas "Gender Role Images" (0.49) and "Power Relations" (0.71) were less coherent. This means that clusters were partly very coherent, but there was also variance between experts' evaluations, meaning that experts did not consistently associate "Gender Role Images" and "Power Relations" statements.

The cluster (1.) "Gender Role Images " contained seven statements with bridging values ranging from 0.43 to 0.70 ($M=0.49$; $SD=0.10$; $Var=0.01$), which indicated a coherent cluster. Gender role images referred to societal images that depict described or prescribed expectations of gender stereotypical behaviour in the workplace about women. The reconciliation of family and work was the main topic of these statements, as well as discrimination of women at the workplace. Statements described gender stereotypes on the social and even structural level, as well as prejudice and discrimination against women on the social and individual level.

The cluster (2.) "Gender Work " contained seventeen statements with bridging values ranging from 0.11 to 0.67 ($M=0.40$; $SD=0.17$; $Var=0.03$), which indicated that this cluster was somewhat coherent and consists of a mix of statements. The mix of statements mainly described the behaviour resulting from implied prescriptive stereotypes about how women are expected to be caring mentors and socially responsible colleagues. They also described implied social prejudices against women in STEM that resulted in the discrimination of women by their colleagues on the social and also structural level. Women were expected to do more care work than the men, carry out mentoring of students and the maintenance of scientific networks and more preparatory tasks compared to their male counterparts. Structural factors were mentioned regarding the different distribution of resources, the funding and hiring practice, for women and men in STEM.

The cluster (3.) "Unequal Perception of Competence" contained seventeen statements with bridging values ranging from 0.00 to 0.57 ($M=0.15$; $SD=0.18$;

Var = 0.03), which indicated that this cluster was very coherent in the understanding of its meaning by the participants. This cluster was composed of statements that described social prejudice against women, but also resulting discriminatory behaviour against women in social situations and partly also discrimination on the structural level against women working in STEM HE. It described many examples of biased assumptions and judgement about women's competence and professionalism that inform the discriminatory behaviour of co-workers and professors or even students towards women.

The cluster (4.) "Power Relations" contained seventeen statements with bridging values ranging from 0.40 to 1.00 ($M = 0.75$; $SD = 0.19$; $Var = 0.04$), which indicated that this cluster was less coherent in the understanding of the experts than the other clusters. This cluster contained a variety of topics and levels regarding gender bias. The statements described the topics of experienced sexism in the STEM workplace by men, their own self-awareness of gender stereotypes and gender bias among women and *lateral violence* between women. The latter is the term psychologists use to describe the behaviour of people who are discriminated against or subject to oppression and turn on each other as a reaction, thus, women pass the violence they face on to other women (cf. Moane & Campling, 1999). Most statements described discriminatory behaviour and social prejudice against women by men and women. According to the experts, only a few described the results of these social prejudices against women on the structural level (such as missing role models, fewer women professors) and the individual level (lack of self-esteem, high self-criticism of women).

4.2 Clusters and ratings

In order to evaluate the estimation of how CSCL can address gender bias in STEM HE as a pedagogic intervention (RQ2), we assessed all ratings of the gender-related statements by the experts. The ratings visual representation generated by the computer operator showed the following bivariate Go-Zone graph (see Fig. 4). In the Go-Zone map, the x-axis represented the criteria *importance* of the statement regarding gender bias and the y-axis the criteria *feasibility* in a CSCL intervention. The so-called "go-zone" in the graph was where the statements scored high on both importance and feasibility, located in the upper right quadrant. Gender-related statements that fall within the upper green field of the go-zone graph should be highly feasible to successfully address with CSCL in class, with the potential of influencing the gender awareness of involved students and teachers in STEM classrooms.

The statements in the go-zone described a mixture of predominant gender role images, gender workload and unequal perception of competence between the genders. The most feasible and important statements concerned women's gender role at work:

> "*Reconciliation of family and work: It is still mostly women who have to cut back on work or have to justify themselves strongly if they do not do so.*" (41: IM 3.79; FE 3.23).

Fig. 4 Go-Zone graph with individual statements

"*Women do the preparatory work. Men often take over the performance or work presentation.*" (22: IM 3.42; FE 3.68).

"*Women in leadership positions are much more burdened with requests for help/guidance/committee work/seminars/organisation than their male colleagues (at the same level). This reduces their time for independent work and research.*" (7: IM 3.21; FE 3.25).

It was also rated that important inequalities in the (self-) perception of women's competence and professionality can be addressed with a CSCL intervention:

"*Self-awareness: Women are often more self-critical, and men's self-confidence is generally not questioned*" (39: IM 3.85; FE 3.2).

"*…Emphasising gender when a woman has achieved something special.*" (52**:** IM 3.26; FE 3.32).

"I *have already read in job postings that women are considered a minority who need special support, mentioned in the same breath as people with disabilities and people with refugee experience.*" (2: IM 3.14; FE 3.18).

Noteworthy, statements that were rated important but as harder to be alleviated by pedagogic means mainly concerned the structural power & inequality of women (of colour) in STEM and social prejudices against women by men:

"There are fewer female than male role models in academia, especially in higher positions." (27: IM 3.88; FE 2.96).

"*White men are mostly the Profs, while the academic/scientific Faculty workers are mostly female, predominantly female.*" (21: IM 3.26; FE 2.70).

"*Male colleagues overestimate their competencies compared to colleagues who have significantly more experience.*" (50: IM 3.58; FE 2.82).

"*Overall, men are less willing to question their values and worldview and to accept and value pluralistic views.*" (43: IM 3.06; FE 2.83).

"*Women are taken less seriously/and often belittled.*" (3: IM 3.09; 2.91).

"*Promotion towards professor status: Male colleagues doubt women's ability to lead a working group on their own successfully.*" (57: IM 2.94; FE 2.76).

"Male colleagues seem to expect that the few female colleagues who are already there are the solution to all gender problems." (18: IM 3.15; FE 3.14).

The proportion of the four clusters represented in the go-zone can be found in Table 3, and Appendix B lists all statements in the go-zone.

The analysis of the experts' ratings showed that 15 statements concerning gender bias were most important and most feasible to address with CSCL in STEM classrooms.

5 Discussion

In this section, we discuss the results of the experts' group concept mapping. First, we will discuss the specific descriptions and identified constructs of gender bias in German STEM higher education and compare them to empirical findings in the literature in other social STEM contexts in Section 5.1. Second, we will discuss in Section 5.2 how the statements and topics of gender bias rated to be most feasible and important for a targeted CSCL intervention could be best implemented in the

Table 3 The Proportion of Clusters Represented by Single Statements in the Go-Zone

Cluster	Total statement count	Go-Zone statement frequency	Proportion cluster for the go-zone in %
Gender Role Images (1)	7	2	13.33%
Gender Work (2)	17	5	33.33%
Unequal Perception of Competence (3)	17	3	20%
Power Relations (4)	17	5	33.33%
Total count	58	15	100%

light of empirical knowledge on how to design gender-inclusive and awareness-raising pedagogical interventions in CSCL.

5.1 Group concept mapping about gender bias in German STEM HE

Regarding RQ1 about the forms of manifestation of gender bias in German STEM departments, the results of this study yield several answers. We found four clusters representing the shared consensus among the experts about the challenges women face in STEM HE related to their gender. These thematic clusters were: Gender Role Images (1.), Gender Work (2.), Unequal Perception of Competence (3.), and the Power Relations (4) between the genders. The most coherent cluster regarded the unequal perception of competence of women and men (3.), followed by the less coherent clusters of gender work (2.) and gender role images (1.) and, lastly, the power relations between the genders (4.). Generally, our analysis supports the finding of Ceci et al. (2023) and Koudenburg et al. (2021) stating that across many cultural contexts social norms that uphold gender inequality are extraordinarily resilient even when overt sexism and bigotry grow less prevalent in STEM.

What was interesting about all four clusters were the interrelatedness of meanings of statements resulting from the group cognition process in the GCM. All clusters contained statements addressing more than one level and form of gender bias. Even though the experts agreed on the four clusters and sorting of statements into the four categories, they were not free of connections between statements of other clusters or the possibility of multiple allocations of one statement to more clusters. For instance, the described sexism or social prejudice against women (e.g., statement 17, that determination is generally seen as positive but a negative character trait for women) in the power relations cluster (4.) could also be argued to be related to the unequal perception of women and men (3.). Structural level statements in the cluster gender work (2.), such as, statements 46 and 51, that men are favoured over women in funding and hiring practices, can also be related to statements concerning the structural level in power relations (4.). This is always a possible outcome of an activity focussing on group cognition processes (cf. Rosas, 2017). Whereas in the scientific literature, there is a more precise differentiation between different social phenomena and expressions of category-based reactions regarding gender (cf. Fiske, 1998) or the levels addressed (Bauman, 2001), the sorting and labelling of the statements are solely subject to the cognitive group process of the experts.

This shows us two things. First, in practice and the collective and subjective perception of women experts from the field, aspects of gender stereotypes and gender bias that cause discriminatory behaviour were less distinguishable from each other in the evaluation of their own and collective experience. Second, rather than using the scientific distinctions of biases, stereotypes, prejudices, and structural discrimination as a tool for making sense of collective experience, the approach of the experts seemed to stay "close to the matter at hand". They conducted a thematic analysis of the statements of predominant areas of situations women face in their everyday work life. They agreed that there were four main problem areas for hindering women in their STEM careers; the expected reconciliation of family and work

(1.), expected care work at the workplace (2.), the unequal perception of competence of women and men (3.) and predominant gender power relations prevalent in STEM (4.). There is support in the empirical literature that all of these four topics are relevant to focus on when elaborating on gender bias in STEM HE in Germany. For instance, regarding power relations, it is found that women scientists and professors are an underrepresented group and less recognised as experts in German STEM (Rosenthal, 2021). The unequal perception of women in the form of gender stereotypes had a backlash on the motivation and (self-)expectations of women STEM students in Germany (Froehlich et al., 2022). Long-lasting gender roles regarding women and domestic labour and resulting prejudice in Germany hindered the career advancement of women in STEM (Hess & Rusconi, 2010). Lastly, concerning "gender work", the fact that women lacked recognition for their work performance and stayed in insecure work contracts longer compared to men had an impact on their family and career planning in Germany (Selent et al., 2011).

Above all, however, the analysis shows us what women experts in STEM in German STEM HE institutions prioritise and collectively understand about gender bias. It is the strength of the mixed-method approach that contributes to describing gender bias in STEM in German HEIs qualitatively and quantitatively. It complements quantitative findings about the inequality in filling professorships or the remarkable gender pay gap in STEM in Germany (cf. Rosental, 2021) with the women's perception of it. Further, we gain insights into the assessment of gender bias by women experts in the field about how gender stereotypes and biases in STEM are interconnected with their professional and personal experiences in their STEM careers.

5.2 Implications for gender bias and CSCL

With the rating results of this study, we wanted to investigate the potential estimated by the women experts to address gender bias with CSCL in STEM HE (RQ2). They rated the importance and feasibility of addressing different expressions of gender bias with computer-mediated collaborative group learning scenarios aimed at raising awareness. The statements that had high importance and were easy to solve were the ones that should be prioritised in the CSCL interventions in the STEM classroom. The rating resulted in 15 statements across all four thematic clusters describing different aspects relating to gender bias, such as gender stereotypes, prejudice, and discrimination, all on the social and structural level about women in STEM. Based on their teaching experience and knowledge of CSCL, the women estimated that these statements would be best addressed in a CSCL intervention. The question that remained was how exactly?

The findings give some ideas about topics and levels that can be addressed when developing interventions in STEM HE classrooms. Notwithstanding that the field is only starting to grapple with the topic of examining CSCL as an instructional method to decrease gender bias in STEM (Kube et al., 2022), there are two pathways of addressing gender bias with CSCL-based interventions. One is promoting counter-stereotypical team roles, which can also be purposefully shuffled to ensure the outcome of counter-stereotypical gender work divisions in collaboration (Di Lauro, 2020; Richard & Hoadle, 2015) and gender-equal representation of women in educational materials (Berman & White, 2013; Ferreira, 2017). This could be helpful to establish counter-stereotypical learning situations concerning statements regarding women's confidence (statement 39) or the prejudice "that women cannot lead a working group on their own successfully (57)."

Another pathway would be to employ CSCL to induce socio-cognitive conflict. Socio-cognitive conflict can be induced through instructional support in the form of collaboration scripts that specify, sequence, and distribute roles and activities (Johnson & Johnson, 2009; Weinberger et al., 2013). Firstly, the students elaborate on their (assigned) various points of view before contributing comparable amounts of knowledge, which is primarily unique or divergent, to complex assignments. Thereafter they are expected to identify and interact with the identified distinct views in order to resolve socio-cognitive conflicts and reach a joint decision (Weinberger & Fischer, 2006). This method could address gender stereotypes that promote the dualism of maternal or caring personal attributes versus women's abilities and professionality as scientists and leaders (statements 22, 7), prejudice against women (statement 3), and the structural discrimination of women in STEM (statements 2, 18), also concerning the reconciliation of work and family (statement 41).

As an example, statement (7) concerning the gender-stereotypical work division that "*women in leadership positions are much more burdened with requests for help/guidance/committee work than their male colleagues*," which is based on the assumption that all women are better caretakers than men, could be addressed with peer-critique in CSCL (cf. Weinberger et al., 2013). The peer-critique script distributes responsibility for the problem case to the roles of one case analyst and two critics over groups of three. The students would be guided to engage in a series of problem-solving steps, namely the case catalyst would elaborate the relevant problem concerning gender bias against women in STEM, specifically the work division of men and women professors in STEM, and discuss it with the critics, who have more or conflicting information about gender bias in STEM. The case analyst will ensure to jointly come to a proposed solution for the problem and reconcile different viewpoints with the critics through guided discussion rounds. The presentation and discussion of the results with the class and teacher, might further raise the awareness of the students as well as teachers about gender bias (Carnes et al., 2012). Thus, the induced form of argumentative knowledge construction in online discussions could be a way to help counteract gender stereotypes in STEM classrooms as well as raising awareness of gender bias in STEM through targeted collaboration scripts.

In conclusion, the experts found in this study that gender bias can be addressed in certain aspects, as described in the women's statements. The experts' estimations support findings that CSCL has the potential for addressing gender stereotypes and gender bias in the group learning processes through direct intervention. Although gender bias is scarcely researched in the context of STEM CSCL, existing research supported the assumption of the experts that there is a positive interdependence of CSCL and counter-stereotypical and gender-inclusiveness in STEM learning. However, they depended on pedagogical details such as the classroom culture regarding gender, group constellation and work divisions in collaboration scripts, and gender representativeness in the learning materials.

In line with studies attesting to pedagogical bottom-up approaches employing critical pedagogy for the potential to shape social gender norms for the better (Viswambharan & Diwakar, 2021; Witt & Cuesta, 2014), our study contributes to the notion of in-class approaches tackling gender bias by proposing a targeted CSCL intervention in STEM HE. The ways in which computer-supported collaborative learning and gender awareness specifically work together on promoting counter-stereotypical learning in STEM education, and foster awareness of gender bias in STEM beyond the classroom, however, need to be addressed in future research.

6 Limitations

Regarding the sample of women and experts in this study, we were only able to include volunteering women, leaving out the diversity of experience of the women working in STEM HE who did not want to talk about it. However, the statements and the clustering of topics are not representing all women experts and women working in German HE STEM departments, but are one result of a group cognition process concerning gender bias. Nevertheless, it provides a valuable overview of gender-specific problems for women at German HEI. Although we had sufficient participants during the brainstorming phase to generate a good representation of the conceptual domain, a higher number of experts involved in the structuration phase would have been an advantage because that enables research into subgroups. Intersectional experiences of women related to their religion, age or ethnicity could not be looked at in subsets. Lastly, we also could not ask the experts about concrete ideas on how to tackle the identified statements describing gender bias in STEM with CSCL, even if the results allow us to formulate specific topics for an intervention.

7 Conclusion

In this study, we presented the gender-related challenges women scientists face in STEM departments working and teaching in Germany. Gender bias identified in this study included gender stereotypes, prejudice, and discriminatory behaviour in interpersonal situations at the department or society level. It regarded four topics concerning gender role images (1.), gender work (2.), the unequal perception of competence of men and women (3.) and the power relations (4.) in STEM HE.

Our findings support existing research stating that despite some progress in recent years, there are still gender barriers that hinder the full participation of women in German HE in STEM fields and perpetuate gender stereotypes and gender bias. The study results further indicate that addressing gender bias in STEM HE in Germany requires an approach encompassing various societal, institutional, and individual measures. Policymakers, educators, and stakeholders must develop comprehensive strategies that challenge existing gender norms, promote inclusivity, and provide equal opportunities for all genders in STEM HE and beyond.

Moreover, this research highlights the potential of CSCL as a pedagogical intervention to tackle gender bias at the individual and social levels in the classroom. Our results yielded examples of what statements and topics experts found most promising to subject to gender-conscious pedagogical interventions. Also, based on the literature, we discussed how to practically raise awareness of gender bias among students by employing inter alia collaboration scripts that nurture more gender-equal and inclusive learning in STEM.

Lastly, even though we could not develop concrete pedagogical CSCL pedagogies in this study, the unique method to elaborate on the learning context-specific gender bias in STEM higher education in detail enabled the identification of conceptual categories and specific approaches for interventions. Furthermore, our findings demonstrate the prevalence of gender bias and its effects on women in German STEM education. They underscore the need to develop more gender-sensitive pedagogies and methodological tools that challenge gender bias, support gender equality, and encourage the participation of underrepresented genders in STEM education. While the journey to decrease gender bias in Western societies and STEM fields may be lengthy, the study's findings underscore the significance of employing bottom-up approaches like CSCL to initiate positive change in education.

Appendix A

See Table 4

Table 4 Sorting Report (58 Statements after Reduction)

#	Pile Name	Statement Number	Statement
1	(Gender Role Images*) Experience at Work, Career & Family Conflicts	1	The sentence "after all, it is still the women who bear the children" ignores the fact that by far the largest part of the subsequent care work can be taken over by the father completely equally
		6	Shortly after the wedding (with a change of name), people kept asking about pregnancy and the child (in very inappropriate situations)
		14	Another nice sentence on the subject of motherhood & science: "She has just become a mother. There's nothing going on in science for the next 2 years."
		15	In the first 6 weeks after the birth of my daughter, I was expected to write proposals and review doctoral theses because: "The child sleeps all the time anyway", "I did the same with my children back then"
		20	At university: "X can't go to the intermediate test today, she's at the pediatrician's." Exercise instructor, 20, m: "Is she sick?" "No, her son!" "But if she's not sick, I can't sign her out!"

Table 4 (continued)

#	Pile Name	Statement Number	Statement
		41	Reconciliation of family and work: it is still mostly women who have to cut back on work or have to justify themselves strongly if they don't do so
	(7 statements)	48	Children are often still a disadvantage for women when looking for a job, not so for men
2	(Gender Work*) Care Work, Gender Workload & Unequal Treatment	5	The distribution of resources in research alliances often goes by age/gender
		7	Women in leadership positions are much more burdened with requests for help/guidance/committee work/seminars/organization than their male colleagues (at the same level). This reduces their time for independent work and research
		10	Cooperation partners seek contact with male colleagues, although they are not involved in the work or only to a small extent
		21	White men are mostly the profs, while the academic/scientific Faculty workers are mostly female, predominantly female
		22	Women do the preparatory work. Men often take over the performance work/presentation
		23	Committee work: women's quota in committees falls on the few women in the department and leads to excessive demands. Male colleagues are often not on committees, female colleagues are encouraged to actively participate in several committees
		26	Students try to put female teachers under pressure (e.g. to give out solutions, to give more points). Male colleagues are not aware of such incidents
		29	Social care gap: Women spend more time on organizing, preparation, and follow-up, e.g. of their student internships
		34	"Important" men often listen to women's statements only half-heartedly and shortly afterward make the same statement with great emphasis
		36	Men's share of speech is higher in group discussions due to the male-dominated culture
		37	Male colleagues are often poor listeners, especially towards female colleagues
		43	Overall, men are less willing to question their own values and worldview and to accept and value pluralistic views
		44	Greater involvement of women in unofficial positions (running a journal club, initiatives for more job satisfaction, etc.)

Table 4 (continued)

#	Pile Name	Statement Number	Statement
		46	Funding: Men are often favored in the allocation of funds or prize money
		49	Despite the experience, female colleagues working in part-time positions are often not promoted
		51	Discrimination against women is structural in the recruitment process
	(17 statements)	56	It is like the "right" approach to be taken seriously: be loud, rumble, talk a lot…
3	(Unequal Perception of Competence*) Unequal Perception of Competence/Professionality of Women and Men	2	I have already read in job postings that women are considered a minority who need special support, mentioned in the same breath as people with disabilities and people with refugee experience
		3	Women are taken less seriously/and often belittled
		8	Women are seldom perceived as having assertiveness
		9	Students automatically trust male colleagues with more competence; at the same time, in problem cases or critical decisions (failed exams, etc.), they often rely on the 'emotionality' of female staff
		12	Men first look at men when they enter a room, automatically take up more space, and orient themselves towards each other—they are surprised every time they have to listen to a woman and question their claim to leadership more often
		18	Male colleagues seem to expect that the few female colleagues who are already there are the solution to all gender problems
		25	The authority of male colleagues is not (obviously) challenged by male students in front of other students or in dialogue
		28	…Different expectations of the abilities and aptitudes of different genders
		32	The respect of the students seems to be higher for men
		33	Rules of the game are made by men for men
		40	…Less confidence in my professional competence from male students
		45	The work of younger, comparatively inexperienced female staff is often not valued
		50	Male colleagues overestimate their competencies compared to colleagues who have significantly more experience
		52	…Emphasizing gender when a woman has achieved something special
		53	…Generalizations based on (binary) gender

Table 4 (continued)

#	Pile Name	Statement Number	Statement
		55	Male (young) colleagues are automatically attributed to high competence
	(17 statements)	57	Promotion (towards professor status): Male colleagues doubt women's ability to successfully lead a working group on their own
4	(Power Relations*[1]) & Gender Inequalities	4	…Too few role models and therefore less sense of belonging
		11	…Having confidence in oneself
	Experienced Sexism/ Sexist Images of Women	13	When a woman makes a decision that is uncomfortable for others, men often dismiss it as "hormone-driven"
		16	Female lecturers receive negative teaching evaluations because their "voice is too high" or because of their appearance. I assume that men are not penalized for this (but of course I don't know)
		17	If women are determined, it is often not interpreted as a good character trait, but as something negative
		19	Colleagues thank the female colleague after a faculty dinner/lunch because "it is always nice to have something pretty to look at the table while eating"
		24	The unwanted comments about clothes/appearance/make-up; without make-up you are asked if you are ill or not feeling well
	Self-Awareness vs. Lateral Violence between Women	30	…The competitiveness among ambitious women
		31	Women who appear confident are called "bossy"
		38	There is often a big generational difference in the way women think about women-related issues, which means that those women who have been successful in a career path do not always make the best mentors
		39	Self-awareness: Women are often more self-critical and men's self-confidence is generally not questioned
		42	…The insecurity of one's own
		47	Women do not give other women credit for anything
		54	Women are quicker to reject their ideas when (critically) questioned. Men, on the other hand, insist on ideas more often, even in the face of justified criticism
	17	58	Self-assessment: women tend to rate their competence lower than men

[1] Subdivision of the cluster as agreed on with the researchers & experts in the reflection session

Appendix B

see Table 5

Table 5 Go-Zone (List of Statements)

#	Pile Name	Statement Number	Statement	Rating (Importance: Feasibility)
1	4 (Power Relations*)	39	Self-awareness: Women are often more self-critical and men's self-confidence is generally not questioned	IM 3.85; FE 3.23
2	1 (Gender Role Images*) Experience at Work, Career & Family Conflicts	41	Reconciliation of family and work: It is still mostly women who have to cut back on work or have to justify themselves strongly if they don't do so	IM 3.79; FE 3.23
3	2 (Gender Work*) Care Work, Gender Workload & Unequal Treatment	22	Women do the preparatory work. Men often take over the performance or work presentation	IM 3.42; FE 3.68
4	4 (Power Relations & Gender Inequalities*)	11	…To have confidence in oneself	IM 3.56; FE 3.43
5	4 (Power Relations*)	58	Self-assessment: women tend to rate their competence lower than men	IM 3.65; FE 3.24
6	4 (Power Relations*)	54	Women are quicker to reject their ideas when (critically) questioned. Men, on the other hand, insist on ideas more often, even in the face of justified criticism	IM 3.51; FE 3.29
7	1 (Gender Role Images*) Experience at Work, Career & Family Conflicts	1	The sentence "after all, it is still the women who bear the children" ignores the fact that by far the largest part of the subsequent care work can be taken over by the father completely equally	**IM** 3.53; FE 3.19
8	**3** (Unequal Perception of Competence*) Unequal Perception of Competence/Professionality of Women	52	…Emphasizing gender when a woman has achieved something special	IM 3.26; FE 3.32
9	2 (Gender Work*) Care Work, Gender Workload & Unequal Treatment	7	Women in leadership positions are much more burdened with requests for help/guidance/committee work/seminars/organization than their male colleagues (at the same level). This reduces their time for independent work and research	IM 3.21; FE 3.25

Table 5 (continued)

#	Pile Name	Statement Number	Statement	Rating (Importance: Feasibility)
10	**3** (Unequal Perception of Competence*) Unequal Perception of Competence/Professionality of Women	2	I have already read in job postings that women are considered a minority who need special support, mentioned in the same breath as people with disabilities and people with refugee experience	IM 3.14; FE 3.18
11	2 (Gender Work*) Care Work, Gender Workload & Unequal Treatment	23	Committee work: women's quota in committees falls on the few women in the department and leads to excessive demands. Male colleagues are often not on committees, female colleagues are encouraged to actively participate in several committees	IM 3:12; FE 3:19
12	**3** (Unequal Perception of Competence*) Unequal Perception of Competence/Professionality of Women	18	Male colleagues seem to expect that the few female colleagues who are already there are the solution to all gender problems	IM 3.15; FE 3.14
13	2 (Gender Work*) Care Work, Gender Workload & Unequal Treatment	44	…Greater involvement of women in unofficial positions (running a journal club, initiatives for more job satisfaction, etc.)	IM 3.1; FE 3.09
14	2 (Gender Work*) Care Work, Gender Workload & Unequal Treatment	56	The "right" approach to be taken seriously: be loud, rumble, talk a lot…	IM 3:11; FE 3:09
15	4 (Power Relations*)	31	Women who appear confident are called "bossy"	**IM** 3.06; FE 3.10

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