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Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis

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ABSTRACT

Science, Technology, Engineering, and Mathematics (STEM) degrees represent a future employment scenario with low unemployment rates due to the high demand for qualified personnel. However, the STEM sector also represents an educational field marked by horizontal segregation and the gender gap. Different factors play a role in deciding which higher education studies to pursue. From a theoretical and empirical approach, this study aims to identify which factors are associated with the gender gap in the STEM higher education sector. Furthermore, as a research question, it is proposed: are the factors identified at a theoretical and empirical level associated with the gender gap in the STEM higher education sector the same? The empirically validated questionnaire "Questionnaire with university students on STEM studies in Higher Education" (QSTEMHE) was applied to the student community of public and private universities in Spain in 2021, using simple random probability sampling to answer the research question and objective. A final sample of 2101 participants of different genders belonging to different branches of knowledge was obtained. The data analysis was carried out using qualitative methodology and the phenomenological method, following different stages. Firstly, a theoretical conceptual map of the main factors identified in the literature and their authors was composed. Secondly, an empirical conceptual map has been designed with the factors identified in the narratives of the study participants. Finally, these maps were complemented with a SWOT analysis based on the participants' discourses. As a result, it has been observed that there are extrinsic and intrinsic factors and that social constructs and gender stereotypes strongly influence the perception of men, women, and professions and the masculinisation and feminisation of these. Outreach interventions should be proposed from the institutional educational spheres to alleviate existing biases about studies and professions.

1. Introduction

Science, Technology, Engineering and Mathematics (STEM) fields have low unemployment rates worldwide, which means that these are educational and professional fields with potential job prospects [1]. Based on this premise, it is logical to think that there is a high demand for these degrees. However, an analysis of the gender representation of students taking STEM courses shows that there is

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no equal and balanced representation of men and women [2–4]. In some STEM areas, women representation does not reach 25% of the total [5]. This problem, which begins with the choice of higher education, is also projected onto the professional career [6]. In other words, the gender gap in higher education in STEM disciplines is perpetuated in the labour market, resulting in horizontal and vertical segregation [7,8].

Concerning what might be the elements that influence the existence of the gender gap in the STEM education sector, Olmedo-Torre et al. (2018) [9] concluded that girls may be encouraged by their family, school, and friends to pursue studies other than STEM because of the tendency towards the reproduction of gender roles. Likewise, Ceci et al. (2009) [10] highlight that boys and girls are not educated in the same way as girls are educated for motherhood. Consequently, women may opt for non-STEM studies, as they may identify STEM studies as incongruent with future goals of caring for their families [11].

According to other studies, some of the gender roles and stereotypes that occur around STEM studies are based on the belief that it is mainly men who work in the field of computer science [12], as well as in science and mathematics [13]; and the belief that in the social

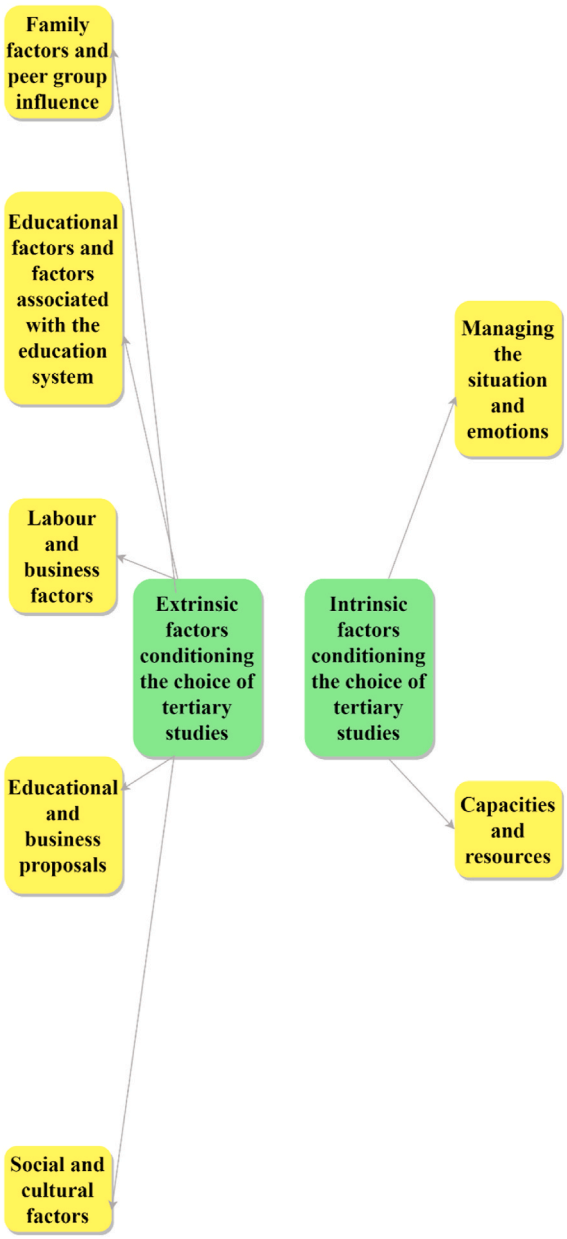

Fig. 1. Intrinsic and extrinsic factors associated with the gender gap identified in the literature. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535473.

and health sciences there should be a women predominance [9]. Along with these false beliefs, another casuistry is revealed, linked to interests. For example, in mathematics, although girls show the same or more interest than boys up until they become adolescents, according to some studies, at the age of fifteen, the situation is reversed, and girls have lower levels of enjoyment and fun than boys [14]. In addition, girls develop more negative attitudes toward science than boys from an early age [15]. Other studies have also concluded that girls are more interested in learning biology and medicine, while boys prefer physics, chemistry, and engineering [16–18].

The lack of visibility and women representation in STEM disciplines must be added to this lack of interest. This lack of visibility results from gender stereotypes, self-perception with negative connotations for girls, and the absence of women role models, among other reasons [19].

In this context, in the international framework, studies have been carried out on professional vocations in primary and secondary education, initiatives have been implemented for the retention of girls and women in the scientific-technical field, and studies have been developed on STEM skills fundamentally from the quantitative methodology. However, the novelty that the research presented here incorporates is the approach and methodology.

Given that the gender gap in STEM has implications for access to STEM degrees in higher education and permanence in the sector, that is, for equal rights and opportunities in access to and permanence in STEM, it is proposed to identify, from a theoretical and empirical approach, the possible factors associated with the existence of this gender gap. Thus, this study aims to identify, from both approaches, the factors associated with the gender gap in the STEM higher education sector. The research question is "Are the factors identified at a theoretical and empirical level associated with the gender gap in the STEM higher education sector the same?".

Two cohesive and different stages were applied to carry out the study. Firstly, a review of the scientific production of impact to find out which factors were identified by authors who publish in international databases. The review of the scientific production was carried out by means of a rigorous procedure of Systematic Literature Review that resulted in the systematisation of the topics of analysis through the construction of a Code Book. The Systematic Literature Review has been implemented through the Scopus and Web of Science databases from 2017 onwards. Secondly, the application of a questionnaire with semi-structured questions to implement a qualitative analysis of the narratives and analyse the units of analysis. As a result of both stages, two conceptual maps were generated, the theoretical and the empirical. The empirical one has been complemented with a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the answers from participants associated with the gender gap in the STEM sector.

This paper is an extension of the work presented initially at the Technological Ecosystems for Enhancing Multiculturality - TEEM 2022. The article is organised under five headings. The introduction is presented in the first, the theoretical framework in the second, the methodology and data analysis in the third, the results in the fourth, and the discussion and conclusions in the fifth.

2. Theoretical framework

For the first stage of the research, a review of the scientific production indexed in the Web of Science and Scopus databases on the gender gap in STEM was carried out [20]. The search strings used were composed of the terms: STEM, education, university, segregation, gender gap, and their synonymous terms, connected through Boolean operators. After reading the results and identifying the factors associated with the gender gap, a theoretical conceptual map was designed, identifying the factors or elements and the authors who refer to them.

According to scientific production, the existing gender gap in the STEM higher education sector is caused by factors both internal and external to the individual. These factors condition the possibility of accessing and remaining in STEM higher education and, consequently, STEM professions. Thus, these factors also determine whether men and women have equal opportunities and rights to enter and remain in the STEM sector.

Consequently, according to the literature, it is necessary to consider the intrinsic and extrinsic factors that intervene when choosing which higher education studies to pursue. In the following lines, the explanation of the theoretical conceptual map, which can be consulted in detail in the link, will be explained in more detail: https://doi.org/10.5281/zenodo.7535473 The image that can be consulted at the following link shows the complete conceptual map generated through the literature. Fig. 1 shows which extrinsic and intrinsic factors are identified in the literature. Each factor contains more categories, which will be commented on in the following two sections.

2.1. Extrinsic factors

The literature identifies the following categories as extrinsic factors: family factors and peer group influence, educational factors and those associated with the education system, work and business factors, educational and business proposals, and social and cultural factors. These factors are linked to other categories, which are discussed below.

Regarding family factors and peer group influence, the connotation of the family has historically been perpetuated as a woman's caring space [9,21]. Also, authors such as Ceci et al. (2009) [10] and Weisgram & Diekman (2015) [11] point out that the connotation above of family leads women to assume family care roles [17,21].

In addition, to educational and education system-associated factors, Lent et al.'s (1994) [22] Social Cognitive Career Theory (SCCT) can be taken as a basis for explaining the gender gap [17,23]. SCCT Theory predicts that an optimistic yet appropriate self-efficacy expectancy promotes a good performance. However, if the ability is underestimated, lower goals are set, and performance achieved is reduced in case of obstacles. SCCT theory could explain why some women perceive themselves as less qualified than men to perform STEM tasks, which leads them to abandon this training and career path.

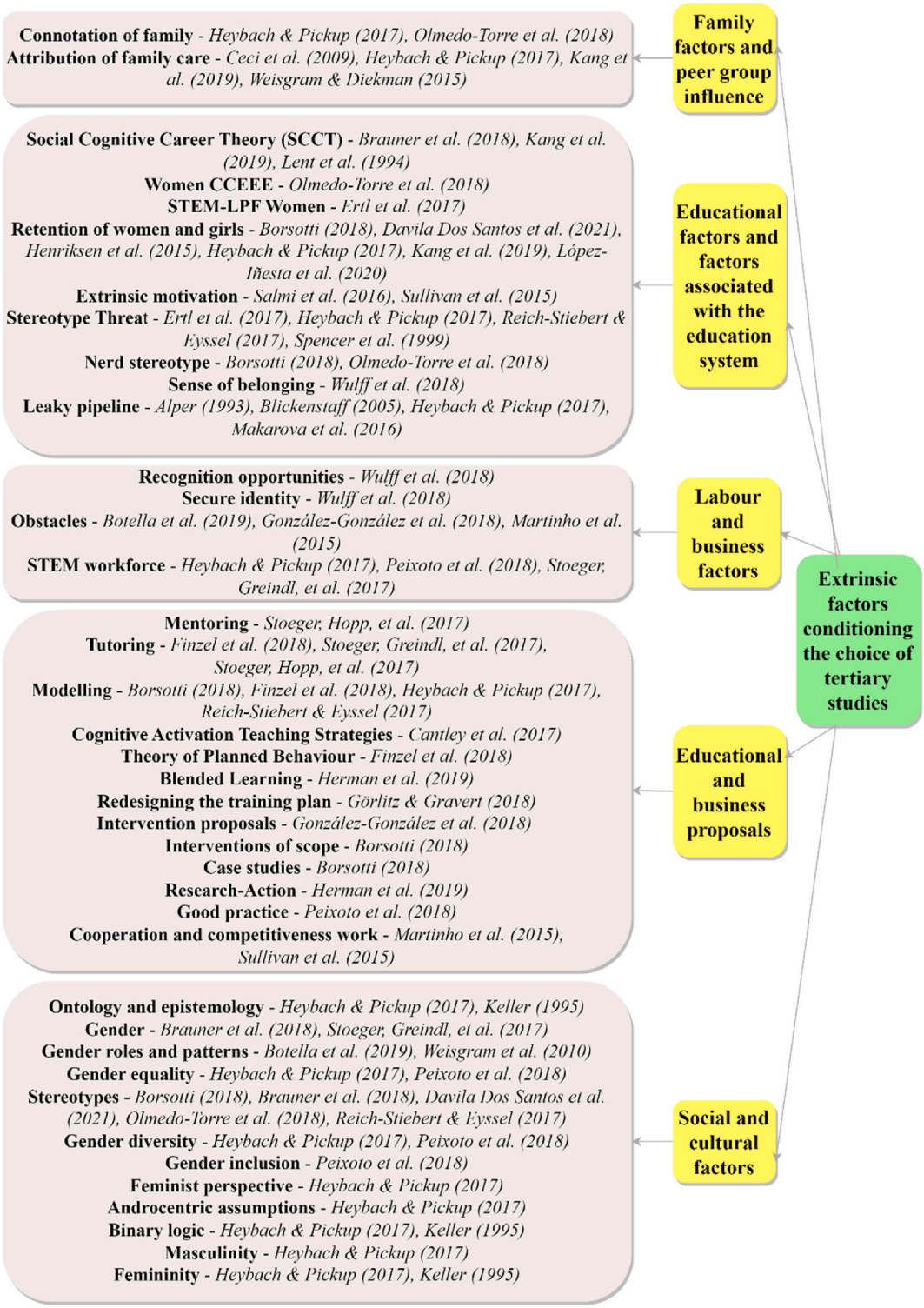

Fig. 2. Extrinsic factors and authors referring to them. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535473.

Regarding the type of women students in STEM, there are the women CCEEE, those studying Computing, Communications, and Electrical and Electronic Engineering [9]. There are also women STEM-LPF, those studying higher STEM studies with a women representation of less than 30% [24]. In both cases, these women represent lower rates than their men counterparts. In response to the figures, retention of women and girls is proposed, which makes it possible for the impact of gender roles and stereotypes to be reduced [17,21,25–28]. It is a measure that is conducive to slowing the loss of women in STEM fields and is made possible through initiatives and measures, for which it is crucial to increase the perception that STEM professions are also aligned with family care roles [11]. Furthermore, extrinsic motivation [29,30], i.e., the motivation that stems from elements external to the individual, is necessary to retain women and girls.

To close the gender gap, it is also necessary to delve deeper into Stereotype Threat [21,24,31], defined as "the experience of being in a situation where one is faced with a judgement based on social stereotypes about one's group" [32]. Another stereotype is the classic nerd stereotype [9,25], attributed to people working in Computer Science, Telecommunications, and Electrical and Electronic Engineering. All this interferes with the feeling of belonging, which allows students to identify with and feel safe in their environment, in this case, women students in the STEM environment [33].

Consequently, if gender stereotypes, patterns, and roles lead to a lack of a sense of belonging and the Stereotype Threat is heightened, the Leaky Pipeline can occur [8,16,21]. This metaphor suggests that women are more likely than men to fall off the STEM career pathway as the pathway in these disciplines becomes more advanced and the culture of science less flexible within the classroom and at work [7].

Regarding work and business, opportunities for recognition [33], i.e., occasions where an employee's achievements are made known, need to be promoted. In particular, recognition opportunities for women in the STEM sector need to be enhanced due to the abovementioned factors. Ensuring opportunities for recognition also positively impacts secure identity [33], which refers to a context in which gender identity, in this case women, is not devalued based on stereotypes [33]. However, it must be considered that throughout the training and employment trajectory in STEM sectors, women encounter barriers to retention and promotion, referred to as perceived barriers [34–36].

Also, in all of the above, one has to consider the STEM workforce [21,37,38], which is the work capacity, made up of physical and mental skills, which can be used to produce. A skilled, equal, and heterogeneous workforce in STEM fields can produce better economic outcomes and reduce the chronic shortage of skilled STEM labour [21].

To support a diverse workforce, educational and entrepreneurial approaches are proposed. Some of the proposals that can be applied in school and work settings to combat gender-based academic and occupational segregation are mentoring [39], tutoring [38–40], modelling [21,25,31,40], working from active methodologies [41], applying the Theory of Planned Behaviour [40], such as the blended learning model [42], the redesign of the training plan [43], intervention proposals [35] and outreach interventions [25], conducting case studies [25], studies based on Action Research [42], working from good practices [37], or cooperation versus competitiveness [30,36].

Finally, to understand social and cultural factors, according to Keller (1995) [44], it is necessary to understand the ontology of the human being, as well as its epistemology [21]. It is the human being who constructs and gives meaning to the diversity and gender equality, and inequality. Gender is understood as the set of culturally ascribed social characteristics and roles according to the sex assigned at birth [23,38]. Thus, gender roles and patterns in family and society regarding appropriate careers for men and women are biases that impact young people's future education and career choices [34,45]. Therefore, there is a need to enhance gender equality [21,37]. However, equality is conditioned by stereotypes, which are erratic social representations based on biases and preconceived ideas about a group of people or a situation [9,23,25,26,31].

Despite stereotypes, it is worth remembering that society is composed of people of different genders, which makes up gender diversity [21,37], and therefore gender inclusion [37] from a feminist perspective [21] is necessary. This requires overcoming androcentric assumptions [21] and rejecting binary logic, defined by Heybach & Pickup (2017) [21] and Keller (1995) [44] as the stereotypical beliefs that professions are divided for men and women. As a result of binary logic, social patterns of masculinity are designed, where men are attributed specific characteristics and professions, such as those related to strength [21]. The same happens with social patterns linked to femininity, such as care and gentleness [21,44].

Fig. 2 shows all the concepts identified as extrinsic factors in a graph, together with the authors who refer to them.

2.2. *Intrinsic factors*

About the intrinsic factors that condition the decision on which higher education studies to pursue, the literature identifies the following: management of the situation and emotions, and abilities and resources.

Concerning situation and emotion management, attitudes towards science, agency, self-concept, self-efficacy, and self-perception play an essential role. Attitudes towards science are defined as the feelings, beliefs, and values held about an object, which may be the science enterprise, school science, the impact of science on society, or scientists themselves [25,27,29,41,46]. Agency is understood as the ability to plan and act intentionally [31,33,47], and self-concept is understood as a person's opinion of him or herself [24]. Along these lines, self-efficacy [23,25,30,47] is the belief that a person has the competence to carry out a desired action. It is argued that self-efficacy is closely related to locus of control, which explains whether people attribute success or failure to their actions or external factors [48,49]. In this direction, self-perception is also defined as the ability to perceive oneself [30,40,50].

Related to self-perception are mental models [48], which are cognitive representations of complex objects, processes, or structures and allow the consequences of actions to be evaluated.

In another sense, expectations [17,50] about an object or a reality, such as higher education, generate a strong interest that

conditions elements such as the choice of studies [22]. Thus, according to Lent et al.'s SCCT Theory (1994) [22] outcome expectancies are beliefs about the effects, consequences and/or outcomes of performing specific actions [17,43,48]. One theory in which the personal and environmental (contextual) approaches converge is scientific identity [33,34].

In terms of interests, it should be noted that the gender gap is likely to start already before upper secondary school entry [17,25,33,37,41,48]. Interest in science is crucial in motivating students to participate in science-related activities, enrol in STEM higher education, and work in the STEM sector [17]. In addition, research has reported high correlations between students' interest in science and their future career prospects. Also, about interest, characteristics of intrinsic motivation are a critical and open attitude toward learning, seeing the connection between isolated facts and the subject area as a whole, the connection between theory and practice, and curiosity, interest, and problem-based learning [29,30,51].

On the other hand, perception, which is how reality is interpreted [17,25], must be considered. Studies such as Sullivan et al. (2015) [30] have studied students' perceptions of the suitability of STEM studies, such as computer science and informatics, for men and women. As a result, misperceptions about STEM careers significantly impede women's ability to pursue STEM career paths [52].

Finally, career aspirations [17,39] are likely to begin around the age of eleven or twelve [53] and develop during the secondary school years through the study and experience of a variety of activities in and out of school settings should be addressed.

In terms of capabilities and resources, cognitive capacity [29], scientific capital [54], learning capital [38], educational capital [39], scientific understanding [55] and school performance [29,33] should be taken into consideration.

Fig. 3 graphically represents all the concepts identified as intrinsic factors and the authors who refer to them.

3. Materials and methods

The study aims to identify, based on a theoretical view and an empirical approach, which factors are associated with the gender gap in the STEM higher education sector. Furthermore, the research question is "are the factors identified at a theoretical and empirical level associated with the gender gap in the STEM higher education sector the same?".

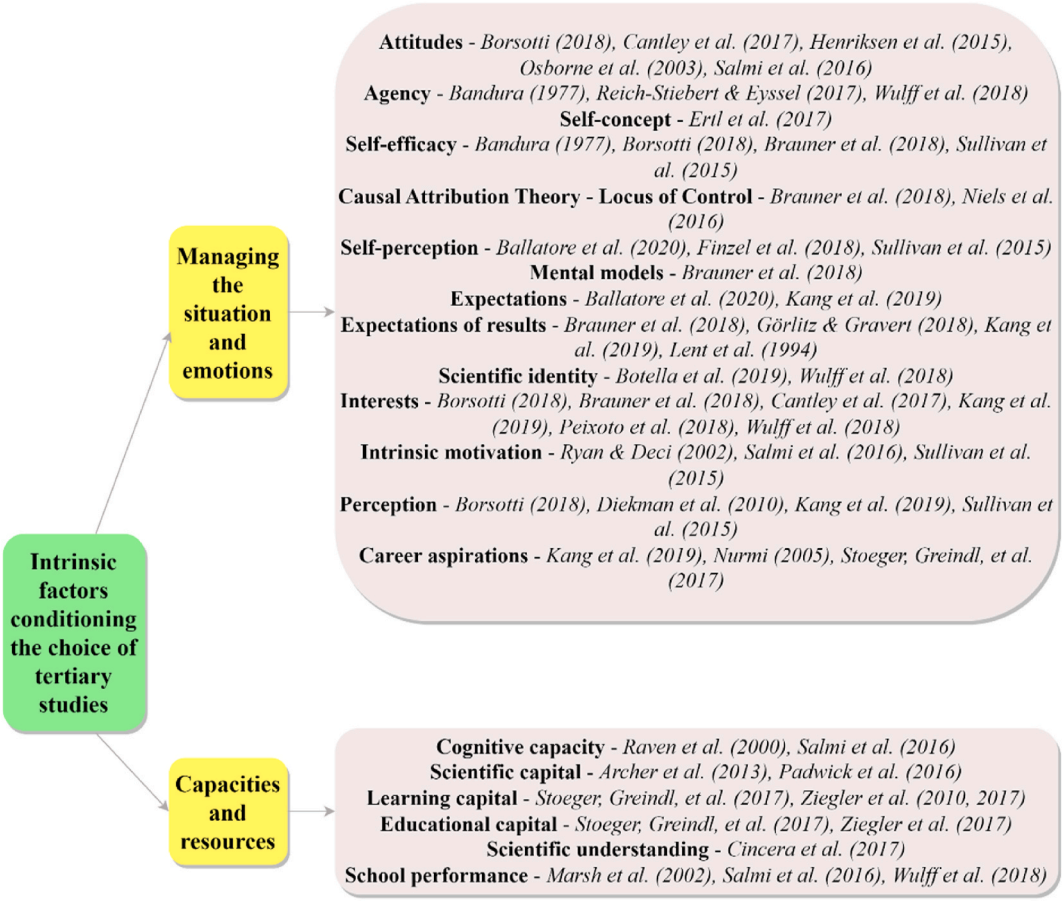

Fig. 3. Intrinsic factors and authors referring to them. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535473.

The empirical study was conducted using qualitative methodology to achieve the objective and answer the research question. This methodology makes it possible to investigate and delve deeper into the reality of the gender gap in the STEM sector through the perspective of the participants [56,57]. The method used was the phenomenological method [58,59]. It is a method that advocates the validity of the research, considering that all contexts and people are potential study subjects [60]. From phenomenology, the study participants have been considered the critical informants from which to extract the data and conclusions through their narratives. These were university students from public and private universities in Spain.

In order to ensure the quality, reliability, validity and credibility and consistency of the research, several measures were taken into consideration. The first measure was to follow an extensive nationwide data collection procedure under the favourable report of the University's Ethics Committee. This favourable report states that the study does not cause harm to third parties and that it follows the ethical principles of research. In order to guarantee quality, reliability and validity, a simple random probability sample was used to obtain a representative sample of the national figures, based on gender and branches of knowledge. On the other hand, the QSTEMHE instrument is empirically validated through statistical processes. Finally, in order to provide credibility to the qualitative analysis procedure, the content analysis process has been followed preserving the textual discourse. The different authors of the article have agreed on the coding process by means of an inter-judge procedure in order to suppress possible interpretation biases.

3.1. Data collection technique

The empirically validated instrument "Questionnaire with university students on STEM studies in Higher Education" (QSTEMHE) [61–63] was used to collect the data. The QSTEMHE questionnaire can be applied to study and analyse the opinion of university students from different branches of knowledge about STEM studies in higher education about the gender of the student.

The QSTEMHE questionnaire analyses the five empirically validated dimensions (Interest, Perception and self-perception, Gender ideology, Attitudes, and Expectations about science) composed of twenty-four quantitative items. In addition, there are also five open-ended qualitative questions. The dimensions are composed of ordinal items. In addition, they are complemented by the open-ended questions, however, these have not undergone a process of empirical validation at the statistical level because the information reported by the open-ended questions is of a qualitative and non-statistical nature.

The study presented in this article has been carried out by analysing the narratives obtained in the answers to these five questions:

- What adjectives or terms do you think to differentiate men and women (physically, psychologically, professionally, socially, etc.)?
- In your opinion, what are the characteristics of a person who studies science, technology, engineering, and mathematics?
- On the other hand, in your opinion, what are the characteristics of a person who studies social sciences/humanities/reading, etc.?
- Do you think there are studies and professions "for men" and "for women"? If so, which ones and why do you think this difference exists?
- Do you think that women have the same rights and equal opportunities as men in studies, on the one hand, and in the workplace, on the other hand, related to science, technology, engineering, and mathematics? Why?

In other words, the data collection technique used was the open-ended questions that are part of the mixed questionnaire QSTEMHE [61–63].

3.2. Population and data collection

The QSTEMHE questionnaire [61–63] is designed to be applied to the university population belonging to any branch of knowledge. Specifically, the study's target population is the student community of public and private universities in Spain, regardless of the branch of knowledge to which they belong and their gender. Concerning the latter, people of different genders could participate in the study. However, more than 98% of the final sample was made solely of men and women.

The questionnaire was applied online using the Limesurvey survey platform. For the study presented, the probability sampling technique was applied. Probability samples are defined as those in which all subjects have the same possibility of being part of the sample, so that they are more reliable than non-probability samples and are more likely to be representative of the population, given that they are random. Furthermore, it is a simple random probability sampling without replacement. Simple random sampling is the sampling method whereby everyone in the population has an equal chance of participating. Non-replenishment means that a person can only participate once in the study.

To calculate the sample size, the infinite population formula has been applied and the values are as follows:

- $z = 1.96$ (because the confidence level is 95%)
- $p = 0.5$ (because the probability is 50%)
- $q = 0.5$ (because the probability is 50%)
- $e = 0.05$ (because the maximum error of estimate is 5%)

Therefore, $n = 384.16$. Thus, the research required at least 385 participants to have a confidence level of 95%. However, the final sample size was 2101 persons. Taking into account that z equals a 95% confidence level (statistical parameter 1.96) and that both p and q equal 0.5, the maximum estimation error equals 0.022.

In other words, the sample size (2101) allows results and conclusions to be obtained at the 95% confidence level with a maximum

estimation error of 2.2%.

In order to obtain a representative sample, the main characteristics of the study have been taken into consideration: gender and STEM studies. Therefore, in order to achieve a representative sample of the population, we have tried to have a representation in the branches of knowledge by gender similar between the sample and the population. To achieve this, we have used the updated characteristics of the university student body in Spain (EDUCAbase, 2022). The questionnaire was disseminated to the university community of public and private universities in Spain. Dissemination was carried out through institutional e-mails among the Departments, Dean's Offices, Vice-rectorates and Equality Units of the universities from 1 March 2021 to 30 April 2021.

The Spanish universities with which the most contacts were established were: Distance University of Madrid, Alfonso X El Sabio University, Antonio of Nebrija University, Autonomous University of Barcelona, Autonomous University of Madrid, Camilo José Cela University, Cardenal Herrera University, Carlos III University of Madrid, Catholic University of Valencia San Vicente Mártir, San Antonio Catholic University, Complutense University of Madrid, University of Alcalá, University of Alicante, University of Almeria, University of Barcelona, University of Burgos, University of Cádiz, University of Cantabria, University of Castilla-La Mancha, University of Cordoba, University of Deusto, University of Extremadura, University of Girona, University of Granada, University of Huelva, University of Jaén, University of La Laguna, University of La Rioja, University of Las Palmas de Gran Canaria, University of León, University of Lleida, University of Malaga, University of Mondragón Unibertsitatea, University of Murcia, University of Navarra, University of Oviedo, University of Salamanca, University of Santiago de Compostela, University of Seville, University of Valladolid, University of Vigo, University of Zaragoza, University of the Basque Country/Euskal Herriko Unibertsitatea, and University of Valencia (Estudi General). A total of 45 universities were contacted, all the main public and private universities in Spain. Subsequently, however, by snowballing, other universities also responded.

Table 1 shows the percentage of the sample coming from the different universities.

The data obtained were stored following the research regulations and ethical guidelines of the University of Salamanca. The study

Table 1
Representation of universities.

University	Percentage	Absolute value
IE University, Distance University of Madrid, Cardenal Herrera-CEU University, University Católica Santa Teresa of Jesús of Ávila, University of Vic-Central University of Catalonia, Francisco of Vitoria University, Miguel Hernández University of Elche, Pablo of Olavide University, Pompeu Fabra University, Public University of Navarra, Ramón Llull University, Rovira i Virgili University, Abat Oliba CEU University, Suffolk University, University of Bologna, Beijing Institute of Technology, Ohio State University, Instituto Tecnológico de Chihuahua (Mexico), Escuela Politécnica Superior of Córdoba, University of Porto, Universitye Federal do Tocantins, Latin American School of Medicine, Oxford, Federal University of Goiás Brazil, Federal University of Ouro Preto, Naval Military School, Salesian University of Bolivia, University of Buenos Aires, UFPel/Uniceub, University of Cuyo (Argentina), Pontifical Bolivarian University, Universitye Federal Rural do Rio de Janeiro, Bucharest University of Economic Studies, Universitye Federal Rural de Pernambuco, University Surcolombiana (Neiva, Huila, Colombia), University of Huelva	0.048%	1
Alfonso X El Sabio University, University of Burgos, Rey Juan Carlos University, University of Havana	0.095%	2
University of Las Palmas de Gran Canaria	0.19%	4
Other university, Carlos III University of Madrid, University of La Rioja	0.238%	5
Polytechnic University of Catalonia, Mondragón Unibertsitatea	0.286%	6
University of Castilla-La Mancha, University of Lleida, University of Cadiz	0.333%	7
European University of Madrid, University of Navarra	0.381%	8
University of Murcia, Pontifical University of Salamanca, University of Girona	0.428%	9
University of Zaragoza	0.476%	10
University of Santiago of Compostela, National University of Distance Education	0.524%	11
University of Córdoba	0.619%	13
University of Vigo	0.666%	14
Universitat de les Illes Balears, University of Jaén	0.762%	16
University of País Vasco/Euskal Herriko Unibertsitatea, University Politécnica of Madrid, University of A Coruña	0.809%	17
University of Extremadura	0.904%	19
Autonomous University of Barcelona	0.952%	20
University of Oviedo	1.000%	21
University of León	1.095%	23
University of Sevilla	1.190%	25
Universitat Politècnica of València	1.238%	26
University of Málaga	1.285%	27
University of Granada	1.380%	29
University of La Laguna	1.618%	34
University of Cantabria	1.761%	37
University Autónoma of Madrid	1.809%	38
University of Alicante	2.570%	54
University Complutense of Madrid	2.761%	58
University of Barcelona	3.189%	67
University of Alcalá	3.522%	74
Universitat of València (Estudi General)	3.950%	83
University of Valladolid	7.996%	168
University of Salamanca	48.406%	1017

was submitted to the evaluation of the Ethics Committee of the University of Salamanca, and a favourable report was obtained (Registration number 557).

3.3. Sample

The final sample used for the analysis of the narratives was made up of 2101 participants (65.30% women and 33.22% men; 0.76% non-binary gender). 61.60% of the sample were under the age of 24, the age set by the UN as the cut-off age for youth. 38.41% were adults, i.e. aged 24 and over. 30.18% of the participants belonged to the Social and Legal Sciences branch of knowledge, 22.18% to the Engineering and Architecture branch, 18.99% to the Sciences branch, 17.51% to the Health Sciences branch, and 11.14% to the Arts and Humanities branch. Thus, 41.17% of the participants were in STEM studies, and 58.83% were in non-STEM studies. Finally, regarding educational level, 65.40% were studying for a Bachelor's Degree or Double Degree, 10.04% a Master's Degree, and 24.56% a Doctorate. 314 persons (22.72%) were in first year, 381 (27.57%) in second year, 306 (22.14%) in third year, 299 (21.64%) in fourth year, 50 (3.62%) in fifth year and 14 (1.01%) in some higher year.

3.4. Data analysis

A brief workflow diagram of the process followed for the data analysis is presented in Fig. 4.

The first stage of the study was carried out, in which the scientific production indexed in the Web of Science and Scopus impact databases on the gender gap in STEM was read. Different chains of terms connected by Boolean operators have been launched, with key concepts on the gender gap in STEM higher education to access the aforementioned scientific production. After an in-depth reading of the literature, we extracted the main factors influencing the decision about which higher education studies to pursue, which are related to the gender gap for access and permanence in the STEM sector.

After identifying these factors, they have been graphically represented in a theoretical conceptual map, where the factors or elements and the authors who refer to them are identified.

Subsequently, in the second stage of the study, different phases were followed to analyse the qualitative data obtained from the answers to the open-ended questions. The narratives of the 2101 study participants were analysed to identify the factors that the university community considers to influence the gender gap in STEM studies and professions.

The data collection was implemented through the QSTEMHE mixed questionnaire in online format to carry out this procedure. The reduction of the data obtained through the open-ended questions was executed to give rise to the arrangement of these and, finally, the

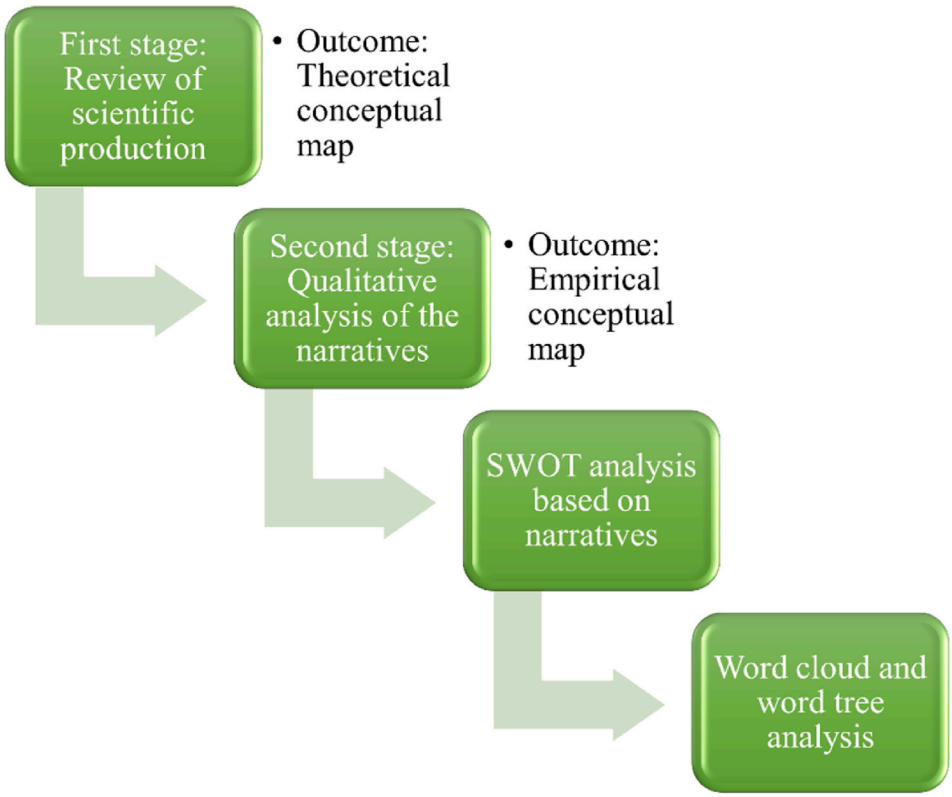

Fig. 4. Workflow diagram of the data analysis process.

drawing of conclusions [64]. After the reduction of the data, the units of analysis were read one by one, in detail, until the different categories to which the participants alluded were identified [65,66]. Identifying the relevant categories through the narratives allows them to be grouped and organised into a theory-generating conceptual map, guaranteeing at all times the quality criteria in qualitative research [59,67]. This phase of the analysis process was supported by the data analysis software Nvivo 12.

The procedure explained above has made it possible to extract a new conceptual map of the factors involved in the gender gap, reflecting the categories to which they allude and which participants mention them. In this way, it is possible to compare the results obtained at a theoretical level with those obtained at an empirical level on the same study reality: the factors involved in the gender gap in the STEM education sector, from the perspective of equal opportunities and rights for access to and permanence in STEM studies and disciplines, according to gender.

In a different phase from the previous ones, four categories have been established regarding internal and external factors, positive and negative, regarding the gender gap in the STEM sector. In other words, a SWOT study was carried out. Based on the narratives of the 2101 participants, the weaknesses, strengths, threats, and opportunities identified concerning the gender gap in STEM have been analysed. The discourses obtained in the five open-ended questions of the questionnaire were analysed to enable coding into these four categories.

Along with interpreting the textual quotations related to the nodes (weaknesses, strengths, threats, and opportunities), word clouds have been extracted from the most frequent word search and word trees. This part of the data analysis process was also supported by Nvivo 12 software.

Through this sequence of qualitative data analysis, the theoretical and empirical conceptual maps of the same reality have been contrasted, and the narratives coded as weaknesses, strengths, threats, and opportunities on the gender gap in STEM have been analysed. All of this has been accompanied by figures.

4. Results

4.1. Empirical conceptual map from narratives

As explained in the previous sections, firstly, a critical analysis of the literature indexed in impact databases was carried out to identify the factors that the authors identify as influencing the decision on which higher education studies to pursue. In this way, it was possible to identify the elements associated with the gender gap in access to and permanence in the STEM sector. Subsequently, the participants' narratives were analysed based on their answers to the open-ended questions of the QSTEMHE questionnaire.

This section presents the conceptual map extracted from the narratives about the elements that participants identify as influencing the gender gap in STEM. The conceptual map is available at this link: https://doi.org/10.5281/zenodo.7535497.

In the following figures, the different elements of the conceptual map will be discussed together with the identifying number of the participant(s) who refer to these elements. First, Fig. 5 shows that participants highlight four main concepts as influencing the gender gap in the STEM sector: the differences between men and women, the differences between STEM versus non-STEM students, the perceived differentiated degrees and careers for men and women, and the perception of whether or not there are equal rights and opportunities in STEM education and employment.

The differentiating elements between women and men are discussed in more detail in Fig. 6. As can be seen, the elements identified are physical, psychological, professional, and social. On the one hand, those involved in gender differentiation, such as the binary conception of gender, are identified. On the other hand, the characteristics attributed to women are identified, such as submissiveness and caring for others. Finally, the characteristics attributed to men, such as leadership, privilege, ambition, and self-confidence, are

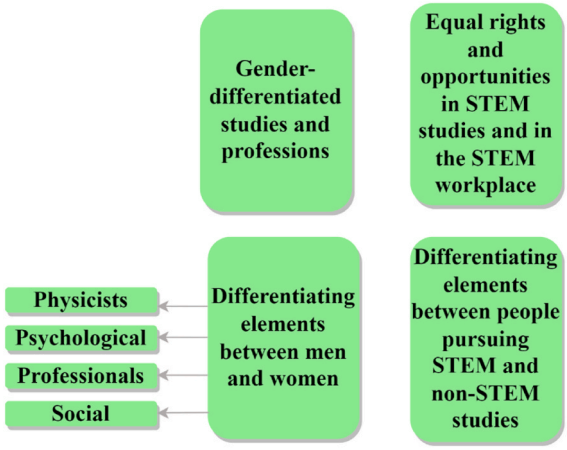

Fig. 5. Main categories associated with the gender gap in STEM as a function of the narratives and their participants. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535497.

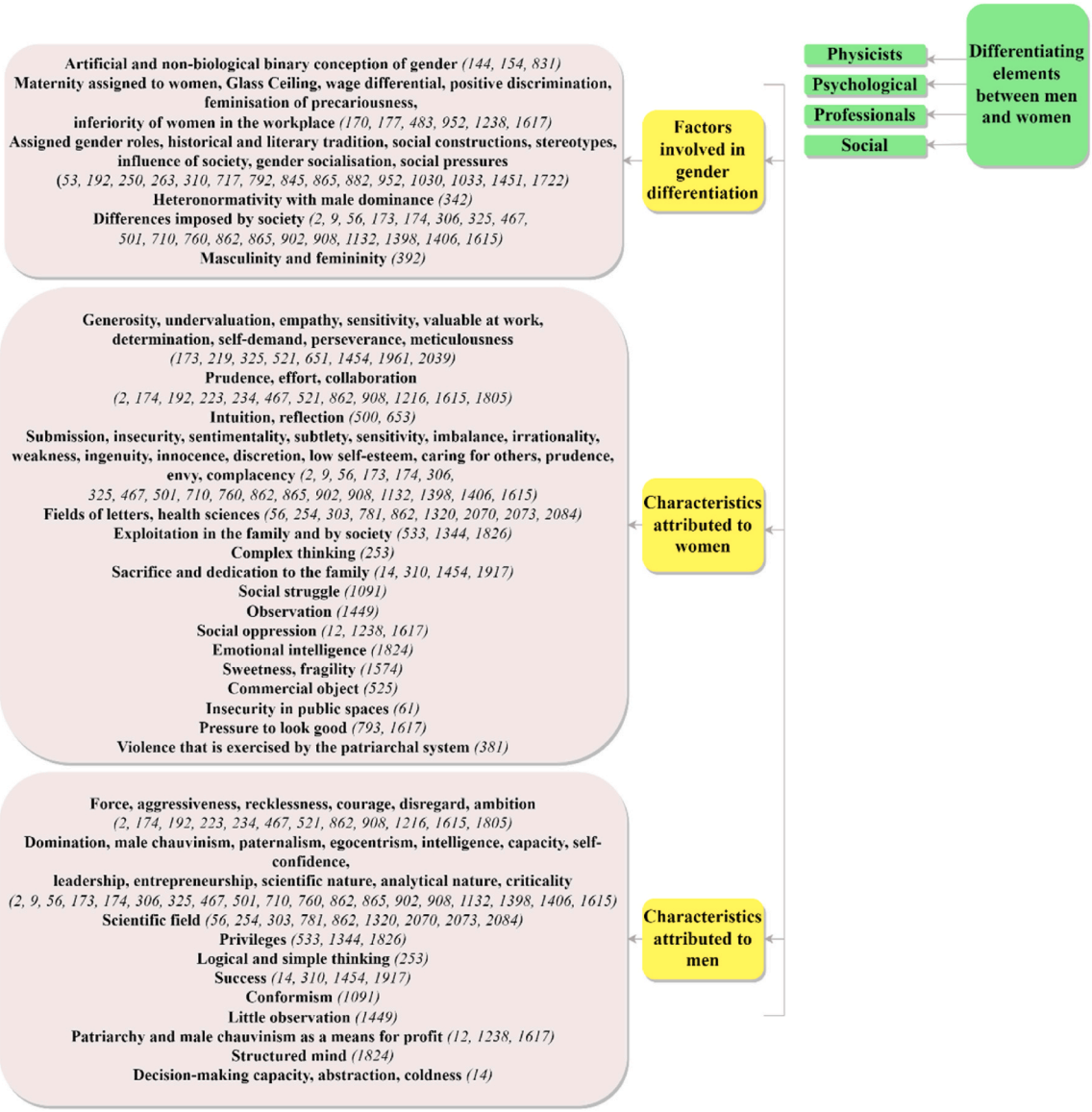

Fig. 6. Differentiating elements between women and men. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535497.

pointed out.

On the other hand, Fig. 7 depicts the elements identified by the study participants as differentiators between STEM and non-STEM students. For STEM students, they attribute intelligence, analytical skills, and interest in problem-solving, among other characteristics. Non-STEM students are attributed with sentimentality, memory, and imagination, among other elements.

Fig. 8 shows which studies and professions the participants identify for men and women. Firstly, they identify influential factors in horizontal segregation, such as gender stereotypes, social prejudices, and sexism. On that basis, men are attributed to engineering and law enforcement, among other disciplines. Meanwhile, among other professions, women are attributed to care, health sciences, and education.

Finally, Fig. 9 identifies the factors that the participants consider to determine whether or not there are equal rights and opportunities in STEM studies and the STEM workplace. Thus, among the factors, they point to men predominance, lack of recognition of women's work, job discrimination for being a mother, and the lack of women role models in the STEM field.

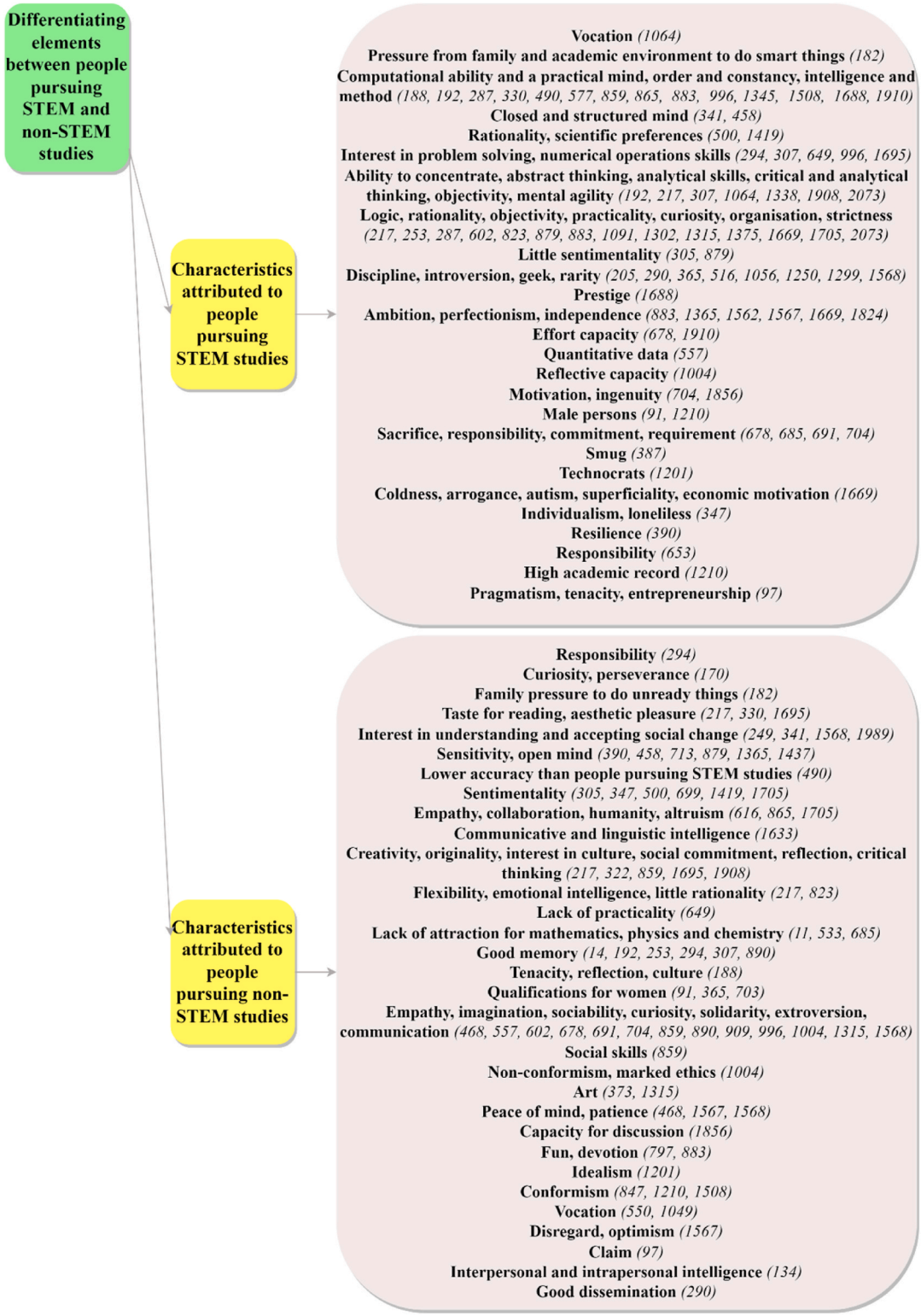

Fig. 7. Differentiating elements between people pursuing STEM and non-STEM studies. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535497.

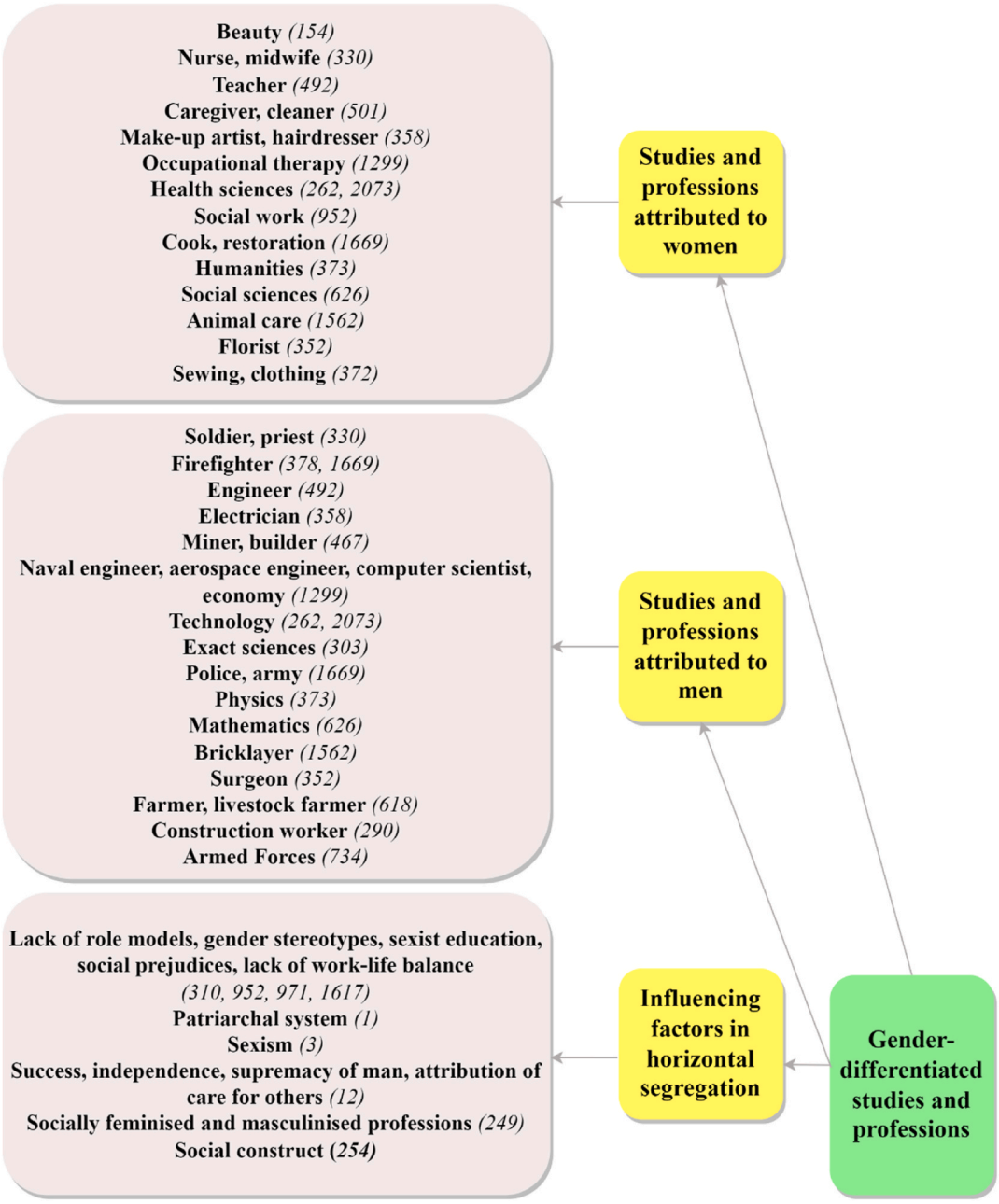

Fig. 8. Gender-differentiated studies and professions. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535497.

4.2. SWOT analysis

Once the empirical conceptual map has been extracted and generated through the participants' narratives, the SWOT analysis has been carried out based on the analysis of weaknesses, threats, strengths, and opportunities. For this analysis, the qualitative data analysis software Nvivo 12 was used, in which four nodes (categories) were generated, and the units of analysis were coded in them.

Finally, 1840 references or units of analysis have been coded in the category of weaknesses, 4090 references in the category of strengths, 4138 references in the category of threats, and 236 units of analysis in the category of opportunities.

4.2.1. Weaknesses: node and word cloud interpretation

It is recalled that weaknesses are those elements intrinsic to the person that represent factors to be improved due to the risks they

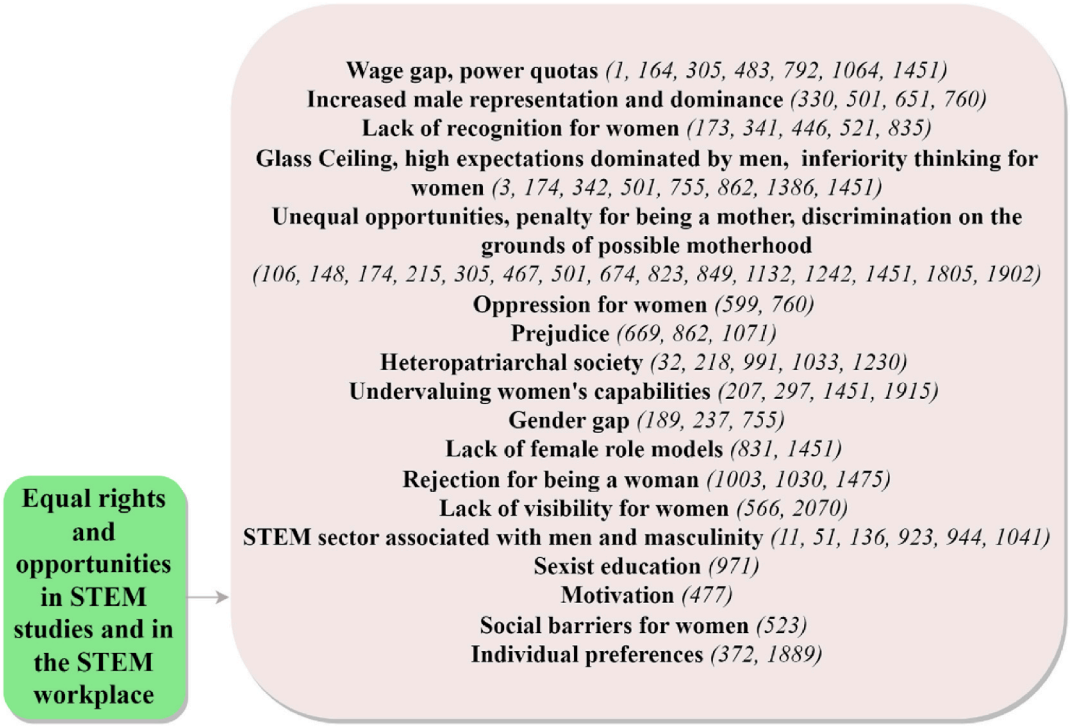

Fig. 9. Equal rights and opportunities in STEM studies and the STEM workplace. High resolution version: Verdugo-Castro, S., Sánchez-Gómez, M. C., & García-Holgado, A. (2023). Factors associated with the gender gap in the STEM sector: Comparison of theoretical and empirical concept maps and qualitative SWOT analysis. Zenodo. https://doi.org/10.5281/zenodo.7535497.

could entail. The weaknesses expressed in the narratives of the study participants are mostly linked to the biology, psychology, and mind of the person, the fact of having family or professional preferences.

Discourses can be detected in which the fundamental cause of gender segregation is attributed to biology, such as: "there are studies in which women tend to be more inclined than men for biological reasons. Hormones shape our feelings and way of perceiving reality; in this respect, men and women are different. Statistically, even if some men and women are out of the average and tend to have different tastes, there will always be something that fits better in a man's biology and something that fits better in a woman's biology.

Fig. 10. Word cloud for the weaknesses node.

Just as all species have assigned gender roles, so do humans because we are animals. We cannot consider biological differences as constructs, for they are real" (participant 1892). In the same line, this thought also stands out, which is repeated by different participants: "physically, and of course, in general terms, I consider that women do not present as much strength or physical capacity" (participant 1238).

On the other hand, in other narratives, justifications are attributed based on physical and psychological characteristics. Thus, quotes such as "physically we are very different, especially biologically, and psychologically we are also different because we think differently, men are simpler and women are more complicated" (participant 378), and "strongly associated with men, psychologically men do show attitudes such as not crying, protecting, appearing "brave". Woman: naïve, innocent, mentally weaker, etc. Professionally, men are associated with terms more related to the scientific field, while women are more associated with the literary field" (participant 862); regarding the psychological component, the belief that "she: geek" (participant 460) should also be emphasised.

Concerning starting a family or professional preferences, speeches such as: "I consider that men tend to be more narcissistic and selfish because being a woman implies being aware that at a certain moment, you have to choose, to a certain extent, between your professional career or starting a family, as the biological clock marks the end to be able to be a mother, which implies many more concerns in the field of work. On the other hand, a man can become a father at 60 if he has children with a younger woman and develop his professional career without any inconvenience. This makes women try to turn their physique into a sculpture, eternally young, and leads to envy and insecurities, which men know how to exploit very well" (participant 1406). Along the same lines, the following narrative is presented: "women, in general, do not tend to prioritise their professional careers. Men, in general, tend to prioritise their professional career" (participant 1158). Finally, about professional preferences: "in general, men tend to choose computer-related careers, while women tend to choose health and/or nature-related careers" (participant 781).

In addition, for the search for the most frequent words among the content coded in the node or category of weaknesses, a search was launched for the two hundred most frequent words, with at least five characters in length. After obtaining the results, empty words were removed from the list. The final results are shown in Fig. 10.

Among the results obtained in the search for the most frequent words, the following words stand out: gender (880 number of repetitions), power (131), sensitivity (125), experience (123), memory (119), culture (118), emotional (118), gap (115), care (115), discrimination (115), access (112) and motherhood (107).

Concerning the term power, the following narratives are collected: "both women and men should be able to do the same job" (participant 2014), and "this is why these social differences are perpetuated, with the cisheteronormative man always at the top of the social hierarchy, occupying positions of great power and with higher salaries than the rest of the gender existence" (participant 32). About the term "gap", narratives such as: "there is a wage gap, and it is always more complicated for a woman to work in a profession traditionally associated with men and above all to achieve relevant quotas of power" (participant 164). On the other hand, the

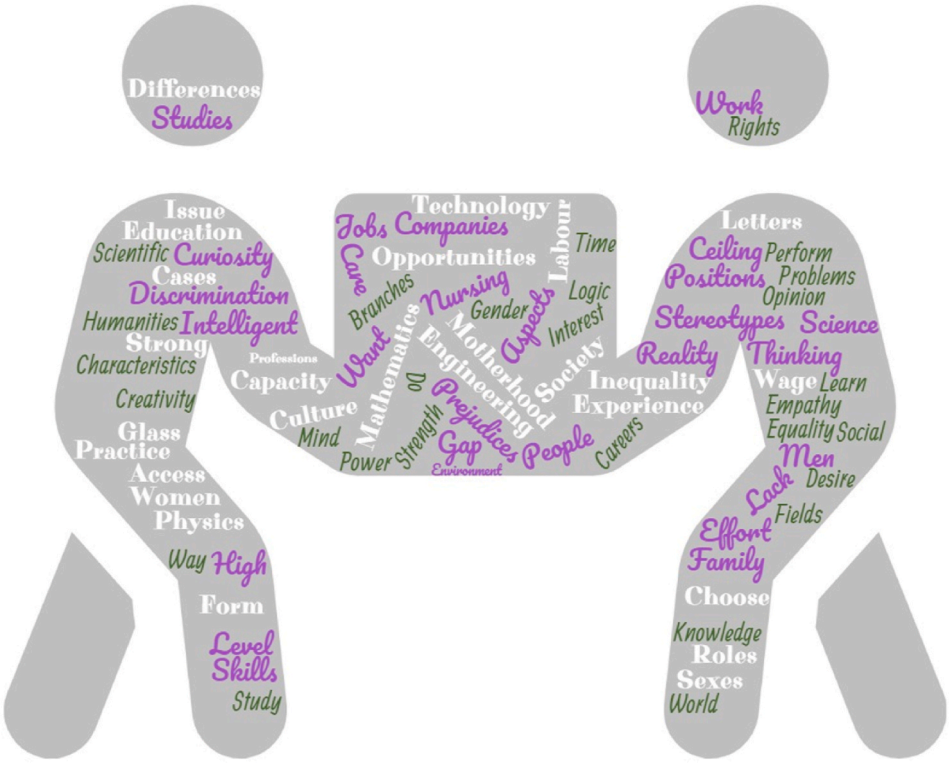

Fig. 11. Word cloud for the strengths node.

following narrative stands out about discrimination: "I think that there tends to be discrimination in general wherever women are, but where it is most noticeable is in the workplace, as there is evidence of the percentage of women working in these areas. This percentage is much lower than that of men, although women's university degrees in this field are 55%" (participant 71).

4.2.2. Strengths: node and word cloud interpretation

About the strengths or intrinsic elements of the person that represent strong points, those attributed to one gender or the other prevail. Thus, discourses such as: "he: successful, intelligent" (participant 460), "men: enterprising, methodical, non-conformist, hard-working, persevering. Women: intelligent, nice, generous, better attention to patients/clients/people, hard-working, patient" (participant 1187), "women more hard-working/responsible, can handle more business at the same time" (participant 349), and "women tend to be more persevering, hard-working and responsible; men tend to be more intelligent" (participant 653).

Some discourses deny that the differences are due to gender but are associated with preferences and personality, such as: "the differences do not depend so much on gender as on the preferences and personality of each person, as well as their qualities. If I had to establish any gender differences (beyond the obvious physical ones), I would point to a greater capacity for empathy and sensitivity in women than in men, which makes them especially valuable for teamwork" (participant 219).

However, in other discourses, gender is assigned as a strength for each discipline, as in the case of: "health sciences are more appropriate for women, they have more empathy towards caring for other people by tradition" (participant 349) and "there may indeed be professions that require more physical strength and are mainly carried out by men (construction, firefighters …) and others that require more manual skills and have a majority of women (sewing and dressmaking …)" (participant 372).

Finally, in other narratives, it is stated as a strength that any profession is potentially eligible regardless of gender: "both sexes have the same intellectual capacities, which are necessary for these professions" (participant 177), and "when it comes to choosing a profession, there are no limits other than those that one wants to impose on oneself and those that one's health imposes on oneself" (participant 480).

In addition, for the search for the most frequent words, the two hundred most frequently mentioned terms in the coded content for the strengths node, with at least five characters in length, were searched. After deleting the empty words, the results were plotted in Fig. 11.

Among the results obtained in the search for the most frequent words, the following terms stand out: capacity (783 number of repetitions), interest (499), study (447), characteristics (421), curiosity (248), knowledge (184), effort (177), skills (160) and empathy (135).

In relation to skills, the following speeches stand out: "in general, women are more emotional and have a greater capacity for the organisation" (participant 710), and "psychologically, women have a greater capacity to solve complex problems than men" (participant 823). On the other hand, about the term skills, the following statement stands out: "I think there are still inequalities. In the field of studies, girls perceive themselves as less capable than their men peers in STEM-related skills from a very young age (4 years old), even though the objective results are equal for both" (participant 1451).

4.2.3. Threats: node and word cloud interpretation

Concerning threats or negative factors extrinsic to the individual, participants' narratives identified threats linked to society and culture, patriarchy and gender roles, stereotypes, social pressures, the glass ceiling, the wage gap and motherhood, dedication to the family, physical appearance, and gender attributions based on studies.

In relation to the threats attributed to society, the following stand out among the narratives or textual quotes from the participants: "I consider that the only thing that differentiates us is something social since women socially are sensitive, caring, organised, compassionate … and men are competent, strong, bosses, busy … So I think these are things society dictates at the end of the day. It is a difficult social line to cross" (participant 9), "woman: from a social and professional point of view, undervalued" (participant 12), "there are profound differences in the way people are socialised according to our gender, and that has consequences at all levels" (participant 144), "socially the situation is evolving, but "faggot", "nancy" are still as offensive for men as "tomboy" or "fresh" are for women. With these adjectives, we see that a certain standard way of behaving and a sexual attitude (hetero-normative with men dominance) is imposed on us, so society determines us" (participant 342), and "I think that gender differentiation is mostly a social issue. I don't know the percentages, but it is clear that women occupy the majority of caregiving professions. I don't believe women have a predisposition or a greater affinity for caregiving. I believe that since we are born, we are taught that women are the ones who do these tasks best because we are assumed to have certain adjectives such as patient, responsible, dedicated, and long etcetera. In addition, the fact that we cannot see other women represented in certain professions unconsciously leads us to think that we are not expected in certain jobs" (participant 1917). To culture, she stresses: "there are only cultural differences based on a binary conception of gender that is artificial and non-biological" (participant 154).

For its part, about patriarchy: "men benefit from patriarchy and women are oppressed. Therefore: On a physical level, there is social pressure on an aesthetic level for both genders, but they suffer more pressure, and the aesthetic canons are different: thinness VS muscles, absence of hair VS hair, etc. At the professional level, there is systematic discrimination in the form of a glass ceiling, feminisation of precariousness, etc." (participant 1617). Also, on gender roles, among the narratives, the following stand out: "it is evident that there are feminised and masculinised professions, so these differences tend to be reproduced socially and academically" (participant 249), "the construction of gender is what establishes the differences due to socially assigned roles" (participant 250), "the reality shows that participation in the branches of knowledge is profoundly unequal. I believe that this is not because these branches are for one or the other gender. Still, a result of gender socialisation" (participant 333), "socially I believe that roles are given to men or women that we adopt without realising it and condition many of our attitudes and even our personality" (participant 533), "we do not

receive the same treatment as them, we are not taken seriously, and our personal life (having a partner, children …) is taken into account much more. In addition to the sexualisation and objectification that we often have to put up with" (participant 849), "gender roles are what differentiate us" (participant 1033), and "society conditions us from an early age through various stimuli and cultural patterns. Moreover, a girl or a boy does not receive the same stimulation or push for the same things. We see this reflected in toys, for example, which are commonly provided according to the biological sex of this person, or that girls do not have the right to be "rough", play and "get dirty" as much as boys, etc." (participant 1663).

Regarding gender stereotypes, the following stands out among the discourses: "society would have us believe this by promoting a stereotypical view of studies, professions, and people's abilities based on their gender. But it should not be like that. We must work to break these stereotypes" (participant 144), "I think that there is less participation of women in studies that culturally have been for men and vice versa, because of the lack of references and because of gender stereotypes and prejudices" (participant 310), "they are all social constructions, stereotypes. Women are less strong than men, men are more scientific, analytical, critical, and women are more sentimental, irrational, etc." (participant 865), and "the problem lies in the stereotypes that society has created. Commonly, certain professions are chosen more by men than women and vice versa" (participant 1877).

Likewise, in their narratives, participants also identify social pressures based on gender as a threat, for example: "socialisation is the part that differentiates men and women the most. Emotional education is different. In the case of men, emotions seem to be hidden as much as possible, while in women, they are accepted to a greater extent. Women are under more pressure to have a particular physical appearance than men. Women live with more insecurity than men because of the violence exercised by the patriarchal system" (participant 381), "women have more social pressure to be submissive, discreet, with low self-esteem and complacent. Men can indulge in childish behaviours, except those related to the expression of emotions ("girls mature earlier"), and men are pressured by society to be self-confident and take on leadership roles. I think the differences are not intrinsic but imposed by society" (participant 501), "women are always asked to show twice as much to be valued equally; they are also expected to work at home as well and take care of others, and at work they are also expected to do caring, listening and empathetic work" (participant 521), "women: Physical - judged, there are double standards for women and men in terms of physical appearance. In reality, an attractive physical appearance can be both a hindrance and a "help" in relationships with colleagues and/or bosses of the same or opposite gender. Social - women are often mistakenly seen as more gossipy than men. Also, women are more obliged to help others than men (and this is taken for granted). Psychological - mistakenly seen as more sensitive or unbalanced than men regarding emotional reactions. Professional - women have to put more effort than a man to "deserve" a job with a high position, especially in typically men domains (e.g., surgeon, judge, president, etc.)" (participant 902), "women have more expectations for everything (they always have to be well dressed, sit correctly, be polite …). If a woman does or says something, everything is seen in a worse light. Socially, for example, women have to deal with the fear of being alone in the street, especially at night" (participant 952), "there is a social pressure (in the form of lack of women references in certain fields, incompatibility with motherhood, etc.) that makes one gender more inclined to certain studies than the other" (participant 1617).

However, culture, society, and gender patterns are not the only threats. Some attributions to motherhood, as well as the Glass Ceiling and the wage gap, are also mentioned as threats in the narratives: "there is the wage gap, and for a woman, it is always more complicated to work in a profession traditionally associated with men and above all to reach relevant quotas of power" (participant 164), "social possibilities, tradition, motherhood assumed only by the mother, the glass ceiling, low salaries for women" (participant 170), "in the field of studies, they have, on paper, the same opportunities, but reality tells us that girls, for social, cultural reasons and lack of referents, abandon the STEM orientation in baccalaureate. I believe that it is motherhood, rather than being a woman, which means that these women-mothers do not have equal opportunities in any field, STEM or otherwise" (participant 215), "I prefer to express myself in terms of labyrinth and glass ceiling. I would even talk about positive discrimination rather than adjectives. Those are the main causes of gender discrimination" (participant 483), "education received, social pressure, the difference in finding jobs/wages, the difference in treatment in general" (participant 882), "I think that women do have the same rights, but not the same opportunities, as men. Women are often discriminated against because of their possible motherhood, instead of helping women who want to become mothers to reconcile it with their jobs. The social valuation of women in science is still much lower than that of men. You only have to listen to people talking about it" (participant 1132), and "professionally, there is a pay gap between men and women. In that sense, there is a (totally unfair) inferiority of women in terms of working conditions. Socially, there is still machismo which means that in areas of freedom, women are also in a situation of inferiority" (participant 1238).

Along the same lines, among the discourses, the identification of women's exclusive dedication to the family as a threat is evident: "I believe that currently there is no equality in the workplace, as many companies prefer to hire men because they do not put the family before their work, whatever the field" (participant 84), "women: exploited in the family and society" (participant 1344), and "women have been educated not to fight so much and to keep quiet and to one side. Also, she has been taught to sacrifice her career for her family, etc." (participant 1454). However, it is not only the dedication to the family that poses a threat but also the connotation of physical appearance: "Women will always be singled out more for their physical appearance" (participant 793).

As far as higher education is concerned, all the elements discussed in this section pose threats that encourage gender segregation in higher education. Moreover, social conceptions legitimise such horizontal segregation. In the narratives of the participants, this is reflected in the following ways: "yes, it is not that they are studies for men or women, but that they are masculinised because of the patriarchal system. Men's" studies refer to those that have logical, scientific, rational or forceful components (engineering, mathematics, physics, sports science, history, philosophy, etc.) and "women's" studies are those that focus on care, empathy, society in general (education and humanities in general). This difference exists because the patriarchal system educates us differently depending on our sex; we are the mothers of our children and our boyfriends and fathers. Our role as women (as women gender, not as sex) is to serve men in the public and private spheres, that is how the patriarchy developed it so that oppression would work" (participant 1),

"socially there is this difference because the subject of technological careers has always been more focused on men, It could simply be seen that when people chose bachelor's degrees, a large majority of men were the ones who chose the technological bachelor's degree" (participant 9), "in general terms, women have always been more related to care tasks, both psychologically, professionally and socially, while men have tended to be linked to care tasks, both psychologically and professionally, as well as socially; while men have tended to be linked to decision-making, with colder sentimental qualities and greater abstraction" (participant 14), "women are associated with adjectives such as tenderness, warmth, empathy and sympathy, and in terms of professional matters they are undervalued, and are associated with humanities careers because they are thought not to have the capacity for careers in science. Conversely, men are seen as a more distant and tougher figure and are always associated with science careers. I think women's work is undervalued in many professions and even more so in the sciences. In our society, if a man and a woman apply for an engineering job, the man is taken first, or if they both work in the same job in the same company, the man is rewarded much more than the woman, doing the same work or even being the woman who does the best work" (participant 56), "socially these studies are not seen in the same way for men and women" (participant 91), "in the world we live in yes, obviously there are more men scientists than women scientists because many girls are taught from a young age to be pretty and slim, not to build buildings or memorise dinosaur names. This is also not good for children with interests related to aesthetics or care, as they are often unable to express these interests freely. Heteropatriarchy is bad for everyone" (participant 154), "physically, men are generally stronger than women. Both socially and professionally, science and technology studies have been more linked to men, so sometimes people are surprised that there are women in fields such as mechanics, industrial engineering, architecture … " (participant 254), "there is a sexual difference when it comes to choosing a career and the women group tends to choose careers associated with a more empathetic side such as biology, medicine or nursing" (participant 303), "the only differences are to a certain extent biological (if we look at cisgender people) and above all social, precisely because of historical and cultural issues, in which women have always been on a lower rung than men. This has meant that we have developed more in the area of care, so it could be said that we are more affectionate, caring, kind … and men have developed more in the fields of knowledge" (participant 310), "I think it still surprises some people to see a boy studying make-up or hairdressing, and a girl studying to be an electrician" (participant 358), "I do think that traditionally some careers have been feminised and masculinised due to the predominant gender studying them, for example, nursing and teaching in the case of women and engineering in the case of men" (participant 492), "they have the same rights, but not the same opportunities. Gender roles make us think that women are not capable of more abstract tasks such as mathematics or logical thinking and, although this is not true, it means that the people in charge of choosing places for scholarships or jobs tend to choose men" (participant 1033), "I think that careers in this field are socially better seen for men because they have been the great scientists and inventors throughout history and that there are certain careers

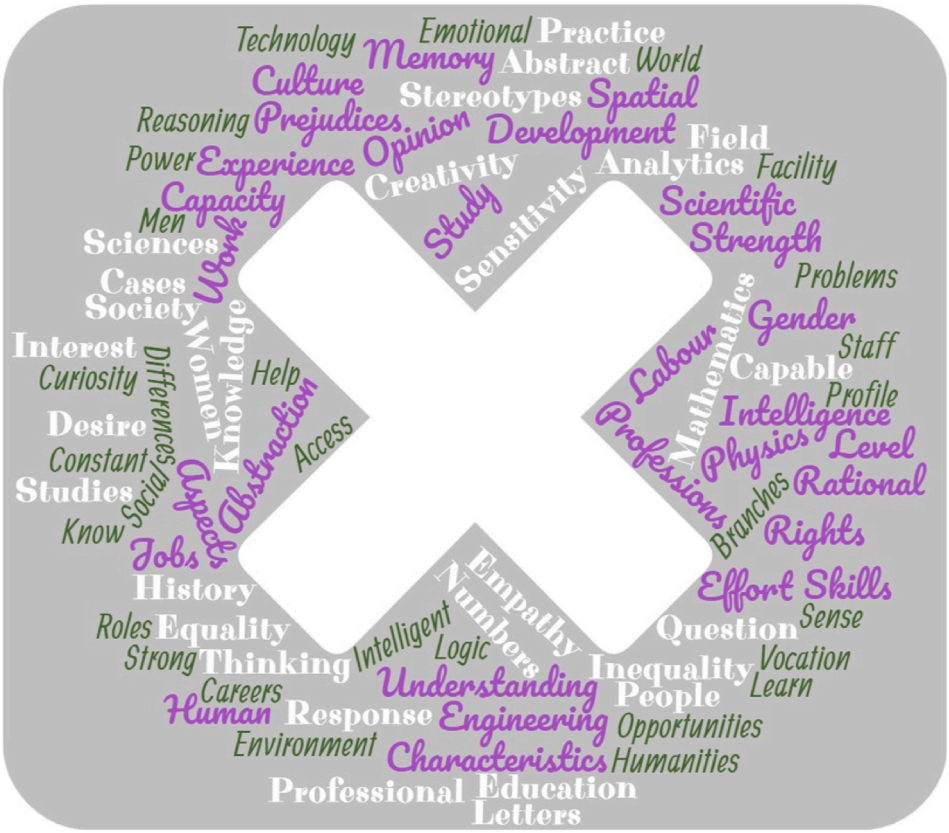

Fig. 12. Word cloud for the threats node.

where it is still rare to see a girl student" (participant 1216), "I think that socially there may be a certain difference between men and women, because culturally and socially women have not been allowed to go into these fields considered for "men". But it is more marked by history than by one's abilities if one trains in these areas" (participant 1475), "we have been taught certain areas in which women are not good (electricity, mechanics …). Although it seems that in other studies linked to women (nursing), men study it without being judged. However, a woman who studies socially directed towards men is more judged and undervalued" (participant 1951), "it is said that men are better with numbers and women with letters" (participant 2070), and "I think that women prefer careers in health sciences because they are more sociable and men, on the other hand, prefer technological careers because they can work on their own" (participant 2073).

Finally, there is a textual quote as an experience about equal rights and opportunities in the STEM field: "No, they don't have equal rights. I have been turned down for science-related job opportunities explicitly and in writing because I am a woman" (participant 639).

In addition, for the search for the most frequent words, the two hundred most frequently mentioned terms in the coded content for the threat node, with at least five characters in length, were searched. After deleting the empty words, the results were plotted in Fig. 12.

Among the results obtained in the search for the most frequent words, the following terms stand out: society (869 number of repetitions), labour (790), differences (675), work (650), problems (330), stereotypes (150), inequality (129), and prejudices (116).

Concerning the term society, the following narratives stand out: "STEM students are people who have stereotypical tastes that are unusual for society" (participant 1299), and "under prejudices and stereotypes, and under a macho society that thinks that STEM studies are a men thing, I think that there are more men because of that fact". The following narrative stands out about the concept of inequality: "women are free to choose whatever studies or profession they want, and therefore they should have the same rights. In terms of studies, I think there is quite a lot of equality. They are chosen equally when it comes to accessing them. But in the field of employment, the choice often involves some inequality. In science, there are usually more men than women in most high-ranking positions, which implies inequality in that sense. In some positions, measures have been put in place to ensure equal numbers of men and women. In conclusion, there are still inequalities" (participant 1386).

4.2.4. Opportunities: node and word cloud interpretation

Concerning the extrinsic factors that represent strengths, those that advocate that all people have the same rights and opportunities regardless of their gender, as well as those attributed to men and those attributed to women, predominate.

In relation to the narratives or textual quotes in which it is defended that both men and women have equal rights and opportunities, some stand out such as: "we all have the right to have the same opportunities and the same duties, as we are all equal before the law" (participant 5), "women have the same rights as men in everything" (participant 210), "obvious, men and women are equal" (participant 268), "of course they have the same rights, because all human beings have the same rights regardless of sex, race, sexual orientation, skin colour, religion … " (participant 273), "exactly the same rights, the law guarantees them. Choice depends only on individual preferences" (participant 372), "rights are not determined by gender considerations. We all have the same academic and work opportunities" (participant 648), "their capacity is not less than that of men and they are subject to the same rules at work" (participant 656), "I don't know women who have had impediments" (participant 664), "I think that, in a country like Spain today and in countries around us, both men and women have the same rights, both men and women have the same rights and equal opportunities in any field of work or studies" (participant 1108), "all studies and professions are currently accessible equally and without difference" (participant 1453), "at present I consider that, regardless of gender, all students have equal rights. Therefore, everyone can choose their academic future" (participant 531), "I don't think there is any difference or difficulty in doing the same studies or jobs as the men gender" (participant 594), "nowadays the opportunities to get a research grant or a job are equal for both men and women" (participant 2082), and "STEM is adapted for both women and men" (participant 847).

Concerning men, narratives such as: "men: from a social point of view, superiority" (participant 12), "men have professional advantages simply because they are men" (participant 533), "men: privileged" (participant 1344), "men have been brought up to seek success and competition" (participant 1454), and "men's opinions are considered more valid and have more prestige" (participant 1826) stand out.

Finally, regarding the opportunities with which women are assimilated, the following narratives stand out: "What I am not in favour of is positive discrimination …. You can't expect equality …. From an inequality … " (participant 151), "they do have the same rights since the Constitution, and the Statutes of Autonomy safeguard the right of all Spanish citizens not to be discriminated against on the grounds of sex; in other words, equality between women and men is contemplated. Likewise, Universities and many companies currently operate quota systems reserved for women, so that, in any case, it is men who are discriminated against" (participant 276), "they do not have equal opportunities. Some scientific seminars specifically ask for women speakers. Soon we will have (if they have not already been approved) measures of discrimination against men for access to these careers" (participant 314), "I think they have the same rights. Even in the jurisdictional and legal sphere, they have more rights than men (for example, the current Organic Law on Gender Violence)" (participant 347), "women have privileges concerning men through quota regulations and with study grants that men do not have. By this, I do not mean to say that there are no valuable women in science. I only mean that there are no equal opportunities because the law privileges women over men" (participant 373), "women have the same rights because there are no longer the barriers as before, now they are even given more support" (participant 378), "for the most part I think that fewer women study certain technological careers because the people who do it tend to be rarer" (participant 703), and "I think that women have more rights than men in making policies that are exclusive to their sex" (participant 1093).

In addition, for the search for the most frequent words, the two hundred most frequently mentioned terms in the coded content for

the opportunity node, with at least five characters in length, were searched. After deleting the empty words, the results were plotted in Fig. 13.

Among the results obtained in the search for the most frequent words, the following terms stand out: opportunities (806 number of repetitions), rights (666), equality (517), careers (440), jobs (216), and companies (99).

Concerning the term opportunities, the following narratives stand out: "in relation to studies, I think that they have the same rights and opportunities" (participant 1902), and "because there is no reason to distinguish between men and women when it comes to rights, opportunities, studies, etc. Maybe it is, on the contrary, the question for me is why should we distinguish between them" (participant 916). Regarding equality, the narrative highlights: "Nowadays, I think that, regardless of gender, all students have equal rights. Therefore, everyone can choose their academic future" (participant 531).

4.3. Word tree

A word search was carried out using the Nvivo 12 software to finalise the qualitative data analysis for the terms: equality, opportunities, rights, gap, gender, and STEM. These concepts have been searched because they are the research keywords presented in the article. After obtaining the results, these have been represented in the word tree. In order not to exceed the space for the article, the links where the word trees can be consulted in detail are indicated: equality (https://doi.org/10.5281/zenodo.7535503), opportunities (https://doi.org/10.5281/zenodo.7535509), rights (https://doi.org/10.5281/zenodo.7535521), gap (https://doi.org/10.5281/zenodo.7535528), gender (https://doi.org/10.5281/zenodo.7535523) and STEM (https://doi.org/10.5281/zenodo.7535532).

There are 494 references to the term equality, 773 references to the concept of opportunities, 623 references to the word rights, 108 references to the word gap in the narratives, 709 references to gender, and 77 references to the term STEM.

These concepts are linked throughout the participants' narratives as two prominent positions on equal opportunities and rights emerge. On the one hand, one position is that equal rights and opportunities exist between people of different genders in the academic and STEM fields of work. Consequently, this position leads to the denial of the actual existing gender gap in STEM. On the other hand, the second position is that inequality does exist in STEM academia and the STEM workplace. In this regard, several possible reasons are identified: weaknesses or threats. Threats are mainly identified in the narratives. All of them are drivers for an increase or a lack of decrease in the gender gap in the STEM sector.

5. Discussion and conclusions

This study has been carried out to find out which elements are associated with the gender gap in the STEM higher education sector.

Fig. 13. Word cloud for the opportunities node.

For this purpose, the literature on scientific production has been contrasted with the data obtained in the qualitative study that has been carried out.

The novelty of the research and its main scientific contribution consisted in studying the phenomenon of the gender gap in STEM studies through a qualitative approach by introducing the contrast between the theoretical and the empirical perspective. In studies by other authors, a theoretical or exclusively empirical approach is taken, usually using quantitative methods. Thus, a different methodological approach has been applied in this study.

Table 2 presents a summary table of the results obtained in the SWOT analysis, which will be commented on in the discussion.

In response to the research question posed in the study, the factors identified at the theoretical and empirical levels concur on some points and differ on others.

According to the results obtained at the empirical level, participants are aware that there are gender roles, patterns and stereotypes that affect the gender gap in STEM. Among the roles they point out that women are attributed with generosity, effort, prudence, social oppression, fragility, insecurity and patriarchal violence. Men, on the other hand, are attributed with strength, aggressiveness, ambition, success and patriarchy, among other ideas. Furthermore, they point out that, at the societal level, systemic violence and the invisibilisation of women are also due to unequal opportunities in relation to motherhood. They point out that this has to do with sexism and carries over into vertical segregation. These two phenomena hinder women's social and occupational advancement and especially in areas socially and culturally understood for men. These findings are in line with authors such as Heybach & Pickup (2017) [21] and Olmedo-Torre et al. (2018) [9], who highlight the connotation of the family and the attribution of its care to women as conditioning factors towards the gender gap. Furthermore, Blickenstaff (2005) [16], Ertl et al. (2017) [24], Makarova et al. (2016) [8], and Reich-Stiebert & Eyssel (2017) [31] point out that the Stereotype Threat and the Leaky Pipeline encourage women representation in the STEM sector to lower than men representation.

In other respects, however, authors and participants disagree. Concerning the research objective, it can be stated that there are different views, depending on the perspective.

While the authors state that there are no typical professions for men or women, it is a question of roles and stereotypes [25,34,37], the narratives of the participants do identify differentiation based on gender. Moreover, some participants deny that there is a gender gap or point to women as privileged figures. This is problematic because it increases the gap at the educational level and, consequently, at the employment level in the STEM field.

In response to this unnatural segregation of studies based on gender, the authors put forward proposals for outreach and intervention to reduce bias and alleviate discrimination, such as mentoring [40] or the use of active methodologies [41], in addition to the work on interests [33] and motivations [30], among other intrinsic elements.

Concerning the limitations found in the study, the main one was that the application was carried out during the global pandemic caused by COVID-19, which made it impossible to attend classrooms in person to collect the data. The online dissemination format required reminders to the university community to obtain responses. As for the strategy followed to avoid obtaining a non-representative sample, the simple random probability sampling technique was scrupulously followed, obtaining a representative sample considering the numbers of university students in the national framework. Finally, regarding the validity of the study, the QSTEMHE questionnaire is empirically validated, which reports internal consistency in its handling. However, the open-ended questions report at a qualitative level and not at a statistical level, which is why they are not empirically validated. In the future, expert validation of these questions is planned.

Finally, as a prospect, the authors of the study set out to design proposals for coeducation through active methodologies to apply outreach interventions, to reduce gender bias in STEM studies, and to raise awareness that professions have no gender and that it is each person who establishes their goals and how to achieve them.

Ethics statement

The data obtained were stored following the research regulations and ethical guidelines of the University of Salamanca. The study was submitted to the evaluation of the Ethics Committee of the University of Salamanca, and a favourable report was obtained (Registration number 557).

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Author contribution statement

Sonia Verdugo-Castro: Conceived and designed the experiments; Performed the experiments; Analysed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

M[a] Cruz Sánchez-Gómez: Conceived and designed the experiments; Analysed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Alicia García-Holgado: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Table 2
SWOT results table.

Positive internal elements: Strengths The narratives are dominated by the skills and abilities highlighted for individuals based on their gender and education.	**Positive external elements: Opportunities** Those that advocate that all people have the same rights and opportunities regardless of their gender, as well as those attributed to men and those attributed to women, predominate.
Negative internal elements: Weaknesses The weaknesses expressed in the narratives of the study participants are mostly linked to the biology, psychology, and mind of the person, the fact of having family or professional preferences.	**Negative external elements: Threats** Threats linked to society and culture, patriarchy and gender roles, stereotypes, social pressures, the glass ceiling, the wage gap and motherhood, dedication to the family, physical appearance, and gender attributions based on studies.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17499.

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