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The impact of Neuroeducation on Teacher Training Programs: Reimagining Gender in Education

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This study analyses the challenges faced by future teachers in understanding the complex concepts of gender and gender identity. Given the multidimensional nature of these categories, the research examined students' prior knowledge and conceptions of gender, gender identity, and the role of education in promoting equality. To this end, an educational intervention based on neuroeducation principles was implemented. Initial findings revealed persistent confusion between the concepts of gender, gender identity, and sexual identity, as well as limited knowledge regarding the role of teachers in promoting equality. Using a mixed methodological approach, the effectiveness of the intervention was evaluated. The results highlight the potential of neuroeducation to promote a more solid conceptual understanding and encourage critical reflection. It is concluded that incorporating specific educational programmes in teacher training is essential for integrating gender equality and moving towards more equitable and inclusive school environments. The study suggests that teacher professional development should include pedagogical strategies based on neuroeducation to effectively address gender diversity in the classroom.

Keywords: gender equality, initial teacher training, Higher Education, neuroeducation, gender identity

INTRODUCTION

Persistent inequalities and inequities significantly contribute to gender-based violence, affecting not only individuals but society at large by obstructing social progress (Freude et al., 2024; Peng et al., 2024). While traditional justifications for gender disparities often rely on essentialist, biologically determinist views, social explanations—though less common—highlight the influence of cultural expectations and roles (Rippon, 2023). Human development results from the dynamic interaction between biology and the environment (Quintana & Pfaus, 2024). Gender identity, therefore, arises from both

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innate elements, such as chromosomes and hormones, and acquired factors, including socialization, culture, and lived experience. Education, socioeconomic status, and occupation also play crucial roles in shaping identity (Rippon, 2020). Brain plasticity (Figure 1) enables individuals to adapt to their surroundings by selecting and internalizing meaningful stimuli (Bjorklund, 2020; Choudhury & Wannyn, 2022; Fragkaki et al., 2022; Dehaene, 2020). This capacity allows students to navigate academic and social environments, form peer relationships, assess risks, and express their gender identity (Butnor & MacKenzie, 2022).

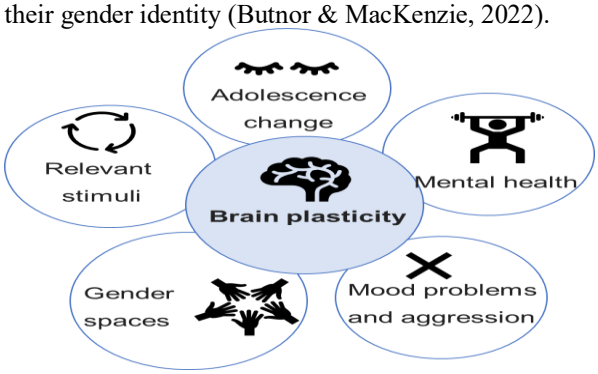

Figure 1
Brain plasticity

The growing visibility of non-normative gender identities has been accompanied by a notable rise in psychological disorders among transgender university students in recent decades (Henriques & Pereira, 2024; Price-Feeney et al., 2020). This phenomenon is a global problem, as reflected by various international organisations. UNESCO (2016) has warned about the negative impact of discrimination and violence based on gender identity within education systems. Specifically, it highlights how bullying, exclusion and the lack of inclusive policies affect the psychological well-being and academic performance of LGBTQI+ students. It therefore recommends implementing inclusive curricula and teacher training in diversity.

Along the same lines, recent research (Suárez et al., 2024) has highlighted the vulnerability of the trans population to disorders such as depression, anxiety, self-harm and suicidal thoughts resulting from social stigma, structural violence and lack of access to adequate health services and psychoeducational support tailored to their needs. People who experience gender incongruence (GI) may face cognitive and emotional challenges that hinder their overall development. Early intervention is essential, with early childhood and primary school teachers playing a key role in creating inclusive, safe and equitable learning environments. However, despite the evidence linking learning, well-being, GI, brain development and the educational environment, teacher training programmes in Spain show a notable lack of neuroeducational content (Beroíza-Valenzuela, 2023; Coch, 2018).

Existing research has mainly addressed this issue from social or psychological perspectives, with little incorporation of neuroscience-based perspectives. In this regard, there is a need to promote studies that analyse how neuroscientific knowledge—such as

brain plasticity and emotional regulation processes—can enrich gender equality training for future teachers (Tan & Leininger, 2024). Ultimately, a deeper understanding of GI's neurobiological basis, social context's role, and emotional regulation's relevance in learning processes (Ruiz, 2024) could better prepare teachers to implement truly inclusive pedagogical practices. In this context, the present study investigates the perceptions and knowledge of prospective primary school teachers regarding gender, GI, and the educational role in promoting equality. An educational intervention (EI) grounded in neuroeducational principles was designed to address this gap. The study's objectives were: (1) to explore prospective teachers' perceptions and knowledge of gender; (2) to analyse their understanding of GI; and (3) to examine their views on the educational role in advancing gender equality. Correspondingly, the research questions formulated were: What are prospective teachers' perceptions and knowledge regarding gender? How do they understand and what knowledge do they have about GI? What is their view on the role of education in promoting gender equality?

Gender and Gender Stereotypes

The definition of gender has become increasingly debated within the scientific community (Quintana & Pfaus, 2024). Indeed, it is now widely acknowledged as a complex and multidimensional construct shaped by biological, psychological, and socio-cultural influences, all of which significantly impact individual development and learning. According to this perspective, neuroeducation posits that gender is not solely biologically determined but is also deeply influenced by cultural and social dynamics, thereby forming the basis for understanding related constructs such as sexual identity, gender incongruence (GI), gender roles, and sexual orientation.

Empirical evidence challenges the existence of substantial brain-based differences between men and women. For example, Eliot et al. (2021) found negligible structural or functional differences in brain activity across cognitive and emotional tasks. Similarly, Sutherland and Young (2022) concluded that men and women exhibit more similarities than differences in cognitive and temperamental traits. Taken together, these findings highlight the significant role of socio-cultural expectations in shaping gender-related behaviors and life choices (Jaoul-Grammare, 2024).

Research in higher education has uncovered the persistent presence of gender stereotypes among university students (Breda et al., 2020; Löffler & Greitemeyer, 2023), particularly future teachers. Gender stereotypes are based on preconceived notions of traditionally masculine and feminine traits, reinforcing conformity and penalizing deviation (Meeussen et al., 2022). On an individual level, such stereotypes influence self-perception and interpersonal evaluations (Li et al., 2022; Ruiz, 2024), while at a societal level, they perpetuate inequality through embedded norms, values, and institutional practices across sectors such as education, health, and politics (Milic & Simeunović, 2023).

The brain, functioning as a 'stereotype maker,' rapidly interprets environmental and experiential cues (Appel & Weber, 2021; Jolles & Jolles, 2021; Thomas et al., 2019). In contexts where sexism, racism, or violence, these biases are internalized and reflected in behavior and identity (Neoh et al., 2023). Therefore, education must play a central role in dismantling stereotypes and fostering equality.

Gender Identity and Narrative Identity

Gender identity (GI), as highlighted by the European Institute for Gender Equality (2024), is a deeply personal construct shaped by the interaction of brain development, hormonal influences, and social dynamics. Moreover, it is closely tied to cognitive and emotional capacities such as self-esteem, empathy, and the ability to understand others' perspectives (Cherrier et al., 2020; Gribovedova & Feldman, 2021), all of which begin to form early in life. A sense of belonging is essential for emotional and cognitive development, prompting individuals to adjust their behaviour to align with societal expectations (Griffiths & Dickinson, 2024). This need for social inclusion is supported by the Cyberball experiment, which demonstrated that social exclusion could cause emotional pain similar to physical discomfort (Lieberman & Eisenberg, 2006).

Furthermore, human beings are inherently narrative-driven, engaging in storytelling from an early age as a means of connecting with others and making sense of the world (McAdams, 2018; Melzi et al., 2023; Tilley, 2024). These narratives often go beyond physical or logical explanations, encompassing beliefs and interpretations. Reflecting on difficult experiences through storytelling can promote emotional well-being and deeper self-understanding (Mitchell & Reese, 2022; Vine et al., 2020), yet educational spaces rarely provide opportunities for this kind of narrative expression, despite its benefits and the negative consequences of emotional inhibition (Duijndam et al., 2020).

Narrative identity—the internalized story one tells about oneself—shapes how individuals perceive their past, present, and future (McAdams et al., 2021). This includes how gender is experienced and expressed. For individuals whose GI diverges from social norms, their life narrative may reflect a journey of self-discovery and affirmation. Thus, GI and narrative identity are closely interlinked, as both contribute to how individuals understand and express who they are. Gender, in this sense, becomes a central thread in the personal narrative of identity.

Gender Equality Training from Neuroeducation

In Spain, recent teacher training initiatives have incorporated educational neuroscience (Peregrina & Gallardo, 2023), though its potential in promoting gender equality remains underexplored. Nevertheless, Neuroeducation can contribute significantly to preventing gender-based violence by enhancing understanding of brain development, learning processes, and emotional regulation (Thomas et al., 2019; Choudhury & Wannyn, 2022; Coumans & Wark, 2024; Miller & Maricle, 2022). Applying this knowledge, teachers can foster inclusive and equitable classrooms (Fletcher et al., 2023; Niemi, 2021).

Recognizing brain plasticity, educators can design activities that challenge gender stereotypes and promote critical thinking (Warsah et al., 2021), particularly through reflection on micromachisms. Inclusive learning environments, essential for healthy brain development, should also support diversity and equity (Reverter-Bañón, 2020). Thus, teacher training spaces must evolve into interdisciplinary, gender-conscious contexts that enable transformative teaching (Gavilán-Martín, 2021).

These environments should encourage storytelling, critical reflection, and speculative exercises that envision gender-equitable educational futures. Moreover, they must be

inclusive of non-binary identities and promote intersectionality as a core principle—ultimately preparing educators as agents of social and educational change.

METHOD

A mixed approach (qualitative and quantitative, emphasising the former) was used to achieve the study's objectives. In the case of the qualitative method (Denzin and Lincoln, 2011; Flick, 2004), the design was based on Grounded Theory (Charmaz, 2006; Glaser, 2004) to understand the perceptions of future Spanish primary school teachers on gender and GI and their perspective on the role of education in advancing gender equality.

Grounded Theory was key to understanding the experiences and meanings constructed by the participants. This methodology is particularly relevant when exploring phenomena that have been little researched, are laden with subjective dimensions and are influenced by social, emotional and cultural factors, as is the case with perceptions and knowledge about gender and GI and teacher training. One of the main strengths of Grounded Theory is its inductive nature (Glaser, 2004). Unlike other approaches that rely on previous theories to interpret data, this methodology allowed the codes and relationships between them to emerge directly from the empirical material, that is, from the voices and experiences of the students themselves. This approach proved valuable in capturing the complexity and transformation of their representations throughout EI without imposing predefined conceptual frameworks that could limit or distort understanding of the phenomenon.

The approach also facilitated the articulation between the individual and the collective, allowing for analysis of how personal experiences fit into broader social, cultural and educational frameworks. This strategy was beneficial for understanding how students reframed gender, GI and education for equality based on their own stories and reflections and for identifying common patterns and divergences. Finally, the use of Grounded Theory in this study made it possible to recognise the participants' tensions, resistance, progress and learning, constructing situated knowledge that was sensitive to the context and had transformative potential. In parallel, to test whether there were changes before and after the educational intervention in the perceptions and knowledge of prospective primary school teachers about gender equality, Chi-square tests and Cramer's V coefficient were used.

Context and participants

The research was conducted at the University of Alicante (Spain) from September 2021 to July 2022 (academic year 2021-22). This institution trains around 5,500 future teachers in early childhood education, primary education, and secondary education every year.

Measures were taken to ensure meticulous sample selection, ensuring that the sample size exceeds commonly accepted standards in qualitative research (Hennink & Kaiser, 2022). The sample was selected using the non-probability, purposive sampling technique. The conditions for the selection of the participants were threefold: (1) to be studying for a degree in Primary Education, (2) to be enrolled in the subject Theory and

History of Education, and (3) to have chosen to teach in Spanish. One thousand three hundred and fifteen students met these requirements.

The representativeness of the sample was verified using the saturation method for purposive samples (Saunders et al., 2018). Additionally, the use of Grounded Theory (Morse, 1994) in the research process further ensured the credibility of the findings. This theory suggests that a representative sample should range between 30 and 50 interviews. In line with this, the sample consisted of 132 students, with 69% reporting as female, 31% identifying as cisgender heterosexual males, and none reporting as bisexual. The age distribution was as follows: 61% were between 17 and 18 years old, 21% between 19 and 20 years old, and 18% were over 21 years old.

Instruments

The study adopted a semi-structured interview approach, in line with the research objectives (Denzin and Lincoln, 2011). It focused on key dimensions such as gender, gender identity (GI), and the role of schools in promoting gender equality. To guide the research process, each dimension was operationalised using a set of specific indicators (Table 1).

Table 1
Dimensions and indicators or the research instrument

Dimension	Indicators
1. Understanding gender	o Ability to differentiate between sex, gender, sexual orientation and gender identity. o Recognition of gender as a social and historical construct. o Identification of stereotypes or personal beliefs about gender. o Level of critical reflection on the influence of gender in everyday life and in the classroom.
2. Understanding gener identity	o Recognition of the process of constructing GI. o Attitude towards diversity within the school context. o Ability to identify factors influencing well-being (self-esteem, body image, social recognition).
3. Rol of the school in promoting gender equality	o Perception of the role of future teachers in preventing gender discrimination. o Appreciation of co-education and active methodologies as strategies for promoting equality. o Knowledge of inclusive tools and approaches (neuroeducation, emotional education, integration of SDG 5). o Personal commitment to inclusive and transformative practices in the classroom.

Key questions explored participants' understandings of gender and GI, and their views on education's role in fostering equality. The instrument underwent expert validation involving six specialists across educational research, neuroeducation, and gender studies. To minimize social desirability bias, question wording was carefully reviewed, and a pilot test was conducted with 25 trainee teachers (67% female).

The instrument was distributed via Google Forms, and each participant took between 30 and 40 minutes to respond. Subsequently, data analysis combined qualitative software (AQUAD 7) and quantitative tests (Chi-square, Cramer's V). Throughout the research process, the ethical standards established in the Declaration of Helsinki were respected, ensuring the confidentiality and anonymity of the participants.

Procedure and design of the educational intervention

The educational intervention (EI) sought to enhance future primary school teachers' understanding of gender and gender identity (GI), while fostering competencies for integrating gender equality into their professional practice. Conducted within the Theory and History of Education course, the intervention spanned 18 cross-cutting sessions over four months (Table 2). A 60-minute focus group involving the research team and five course instructors was held to determine where to integrate the topics of gender, GI, and education's role in promoting equality. The consensus was to incorporate these themes into all six course modules due to their relevance and complexity.

To evaluate the EI's impact, participants completed both an initial questionnaire (IQ) and a final questionnaire (FQ), administered before and after the intervention. The process was designed to ensure the reliability and validity of the findings.

Table 2
Curriculum coherence matrix

Module	Contents	Principles Neuroeducation	Methodology
1. The school	1.1 The educable nature of the human being. 1.2 Comparison between schools in different countries. Education for Sustainable Development.	Natural spatial memory. Learning is enhanced by challenge and inhibited by fear.	Guided reading and class discussion: issues in education today. Case study: Analysis of different education systems worldwide.
2 & 3. History of education	2.1 Classical Greece and Rome. 2.3 Medieval education. 2.4 Humanist Education. 2.5 Education in the 17th and 18th centuries. 2.6 Education in the 19th and 20th centuries.	The search for meaning is innate. Each brain simultaneously creates and perceives parts and whole.	Research of female referents from different periods. Gender roles.
4. Culture, values, people and education	4.1. They know, analyse and reflect on culture and education. 4.2. Socialisation as a learning process. Enculturation, educational personalisation. 4.3. Conflict versus violence: bullying and types of violence. 4.4. School coexistence and non-coexistence factors: addictions, cyber-violence.	The search for meaning happens through learning patterns. Emotions linked to learning patterns	Culture-related constructs (enculturation, socialisation, ethnocentrism, intercultural education). Constructs of gender, identity, sexual identity, GI, and school violence. SDGs relationship.
5. The learner, human educability, and the purpose of education	5.1. Specific educational projects and actions about: Identities, the structure of subjectivity, personality versus identity, individual identity, self-esteem and self-concept. Collective identities. Sex and sexual identity; gender and GI.	The search for meaning happens through learning patterns. Each brain simultaneously creates and perceives the parts and the whole. Promotion of spatial memory.	Introduction: how neurons work, how memories work and how stress occurs. We start with the students' conceptions to identity false beliefs. Key concepts (gender, identity, sexual identity, GI, sexual orientation).
6. The new teaching profession	6.1. The teaching identity. 6.2. The 20th century teacher. 6.3 Metaphorical models of the teacher.	The search for meaning happens through learning patterns. Each brain creates and perceives simultaneously the parts and the whole.	Analysis of teacher identity and thinking to establish the characteristics of an effective teacher. Self-concept, self-regulation and self-esteem.

The basic principles of neuroeducation that can be applied to integrate gender equality in any subject or area of knowledge (Figure, 2): natural spatial memory, meaning-making, learning patterns and perception of parts.

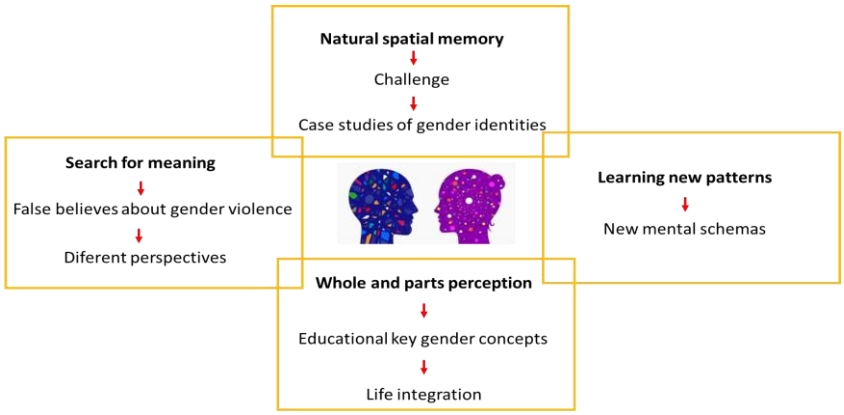

Figure 2
Neuroeducation principles to promote gender equality and equity

FINDINGS

Three themes emerged from the coding process of the participants' voices: gender, GI and gender equality education. These units of meaning are made up of 10 categories, 27 codes and 11 sub-codes. The findings are explained, comparatively, where:

- AF is the absolute frequency of each code or subcode and refers to the number of times participants mentioned a meaningful unit.

- %AF is the percentage absolute frequency of each code or subcode and is obtained by calculating Fax100/total.

Theme 1. Knowledge and perceptions of gender

In this theme, the participants' voices were analysed about 'gender.' Students related gender to 'gender roles.' Five sub-codes emerged from the participants' narratives in this category (Table 3). In the IC, women emphasise that gender assigns roles that differentiate people: 'Gender is the roles that differentiate people from each other' (Prealu34-F, p. 101). At the same time, the men say that 'gender is being a man or a woman' (Prealu-66-M, p. 141).

Table 3
Comparison of IQ and CF: Category 'gender'

		PRETEST				POSTEST			
Category	Codes	AF		%AF		AF		%AF	
		F	M	F	M	F	M	F	M
1.1 Gender	1.1.1 Roles								
	1.1.1.1 Social role	6	2	7.9	7.7	42	13	59.2	46.4
	1.1.1.2 Being male or female	8	4	10,5	15.4	3	3	4.2	10.7
	1.1.1.3 Male or female	6	1	7.9	3.8	2	3	2.8	10.7
	1.1.1.4 Male	0	2	0,0	7.7	0	0	0.0	0.0
	1.1.1.5 Differentiation	11	1	14.5	3.8	2	0	2.8	0.0
	1.1.2 Identity								0.0
	1.1.2.1 Biological sex	22	8	28.9	30.8	12	4	1.9	14.3
	1.1.2.2 Personal identity	2	2	2.6	7.7	1	0	1.4	0.0
	1.1.2.3 Sexual identity	4	1	5.3	3.8	1	1	1.4	3.6
	1.1.2.4 Gender identity	9	2	11.8	7.7	5	3	7.0	10.7
	1.1.2.5 Gender diversity	0	0	0.0	0.0	2	1	2.8	3.6
	1.1.2.6 Sexual orientation	2	0	2.6	0.0	0	0	0.0	0.0
	1.1.3 Does not know	6	3	7.9	11.5	1	0	1.4	0.0
	Total	76	26	100.0	100.0	71	28	100.0	100.0

AF: Absolute Frequency, % AF: Percentage Absolute Frequency

Initially, students had vague and general conceptions of gender: 'It seems that it refers to the way of classifying people' (Prealu23-M, p. 174). After the educational intervention, their understanding deepened, recognizing gender as a historical and socio-cultural construct: 'It refers to the social, but also a historical construction. Gender inequalities have been produced throughout history' (Posalu44-M, p. 188).

Under the code 'roles', sub-codes such as 'being a man or a woman', 'masculine and feminine', and 'differentiation' appeared, with women more frequently highlighting the role-based distinctions: 'People are different because of their gender and the gender roles they play.' (Prealu54-F, p. 176).

In addition, many participants initially confused gender with identity, biological sex, or GI: 'Gender is the identity of the person' (Prealu18-M, p. 142); 'There is a male or female, and that would be gender' (Prealu110-F, p. 143); 'Gender refers to the fact that each person chooses' (Prealu10-F, p. 144).

By the end of the intervention, students connected gender to socio-emotional and educational aspects: 'It is something social and cultural that can influence how children feel and learn' (Posalu02-F, p. 206). Notably, although some initially claimed not to understand gender, no such responses appeared in the final questionnaire.

Theme 2. Knowledge and perceptions of gender identity

The analysis of gender identity (GI) revealed four categories and eight codes (Table 4). The category 'self' included the codes 'self-esteem,' 'self-knowledge,' and 'self-concept,' linked to personal reflection. Women, in particular, frequently connected GI with these constructs. At first, their understanding centred on the body: 'GI is how you feel about your body.' (Prealu05-F, p. 135). After the intervention, students expressed a broader view: 'It is how a person feels about their gender, so they should feel accepted

and loved' (Posalu42-F, p. 283). Nevertheless, bodily perception remained significant post-intervention, especially among women. 'I still think that something fundamental in GI is the body; if you feel good about your physical appearance, you will have positive self-esteem. The opposite can also be true' (Posalu53-F, p. 288).

In addition, Self-knowledge appeared in both the initial and final questionnaires. Whereas initial responses were superficial: 'It is important to know oneself' (Prealu09-F, p. 360), final responses reflected deeper insights, emphasizing self-awareness and resistance to societal stereotypes: 'Knowing one's GI allows one to live without being conditioned by stereotypes' (Posalu29-F, p. 262). Self-concept, initially described in terms of physical traits: 'what the person thinks of their physical characteristics' (Prealu103-M) was more nuanced in final responses. Women showed increased reflection, linking self-concept to identity development and emotional well-being: 'First one has to know oneself to live as one is' (Posalu13-M, p. 383).

Table 4
Comparison of IQ and FQ: Category 'identity'

		PRETEST				POSTEST			
Category	Codes	AF		%AF		AF		%AF	
		F	M	F	M	F	M	F	M
3.1 Self	3.1.1 Self-esteem	16	2	21.3	7.7	15	5	17.4	16.1
	3.1.2 Self-knowledge	11	2	14.7	7.7	10	4	11.6	12.9
	3.1.3 Self-concept	10	3	13.3	11.5	27	9	31.4	29.0
3.2 Person	3.2.1 Personal freedom	6	6	8.0	23.1	7	5	8.1	16.1
	3.2.2 Personality and character	2	1	2.7	3.8	11	1	12.8	3.2
	3.2.3 Personal development	5	1	6.7	3.8	6	3	7.0	9.7
3.3 Others	3.3.1 Irrelevance of GI	2	1	2.7	3.8	0	1	0.0	3.2
	3.3.2 Mental health	1	1	1.3	3.8	2	0	2.3	0.0
3.4 Does not know		22	9	29.3	34.6	8	3	9.3	9.7
	Total	75	26	100.0	100.0	86	31	100.0	100.0

AF: Absolute Frequency, %AF: Percentage Absolute Frequency

Initially, future teachers superficially associated GI with personal freedom: 'I think GI simply refers to the possibility for each person to choose what they want to be' (Prealu63-M, p. 200). After the intervention, some linked it to personality, character, and emotional regulation. One student noted: 'I think GI refers to what a person is like; that is, how they are and how they act in certain situations, what their impulses and reactions are like taking into account their gender' (Posalu48-F, p. 285), although these perspectives were limited. Few participants mentioned the irrelevance of gender: 'Currently, especially in education, GI is not important' (Posalu50-F, p. 212) or its impact on mental health, especially when GI is repressed: 'GI does not influence people's mood or how they feel' (Posalu69-F, p. 236). Some students admitted to not knowing the meaning of GI: 'I could not tell you what GI is, as it has not been studied or addressed in any subject' (Prealu06-F, p. 230).

Theme 3. Gender equality education

Five categories and 18 codes were identified (Table 5), with 'active methodologies' being the most prominent. Initially, the students did not perceive any relationship between these methods and gender equality: 'I think gender equality is one thing, and

active methods are another. In other words, there is no connection between them '(Prealu89-M, p. 218), but after the intervention, the women highlighted their potential to promote equality through awareness-raising projects:' The school can promote gender equality by designing projects that raise children's awareness through active methods' (Postalu01-F, p. 195). The concept of 'gender equality mainstreaming' was absent from the initial responses but was later recognised, especially by women, as essential for teacher training. One student emphasised that it should be a compulsory skill in all subjects: 'Now that I know what gender equality mainstreaming means, I think it should always be included in all subjects for future teachers as a compulsory skill' (Postalu88-M, p. 196).

Table 5
Comparison of IQ and FQ: Category gender equality education

		PRETEST				POSTEST			
Category	Codes	AF		%AF		AF		%AF	
		F	M	F	M	F	M	F	M
2.1 Teaching-learning methodologies	2.1.1 Active	14	4	20.3	15.4	21	11	18.9	23.4
	2.1.2 Lectures	10	2	14.5	7.7	8	1	7.2	2.1
	2.1.3 Audiovisual	2	0	2.9	0.0	0	1	0.0	2.1
	2.1.4 Collaborative work	0	0	0.0	0.0	10	5	9.0	10.6
	2.1.5 Positive vision	0	0	0.0	0.0	1	1	0.9	2.1
2.2 Incorporation into the curriculum	2.2.1 General treatment	1	1	1.4	3.8	8	1	7.2	2.1
	2.2.2 Mainstreaming	0	0	0.0	0.0	11	3	9.9	6.4
	3.2.3 Didactic material	0	0	0.0	0.0	2	1	1.8	2.1
2.3 Gender spaces	2.3.1 Emotional education	2	0	2.9	0.0	4	1	3.6	2.1
	3.3.2 Values education	9	3	13.0	11.5	4	5	3.6	10.6
	2.3.3 Education against discriminations	8	3	11.6	11.5	8	2	7.2	4.3
	2.3.4 Traditional estereotypes	8	3	11.6	11.5	2	4	1.8	8.5
	2.3.5 Diversity education	2	2	2.9	7.7	3	0	2.7	0.0
	2.3.6 Coeducation	3	2	4.3	7.7	16	7	14.4	14.9
	3.3.7 Sport	1	2	1.4	7.7	1	1	0.9	2.1
	2.3.8 Lenguaje	1	0	1.4	0.0	4	0	3.6	0.0
2.4 Teachers	2.4.1 Teachers' role	6	2	8.7	7.7	6	2	5.4	4.3
	2.4.2 Teacher training	0	0	0.0	0.0	2	1	1.8	2.1
2.5 Does not know		2	2	2.9	7.7	0	0	0.0	0.0
Total		69	26	100.0	100.0	111	47	100.0	100.0

AF: Absolute Frequency, %AF: Percentage Absolute Frequency

In the category' gender spaces', the codes' values education', 'anti-discrimination education' and 'traditional stereotypes' featured prominently in the initial questionnaire (CI). While some students advocated for the elimination of stereotypes through play: 'We have to eliminate stereotypes with games between boys and girls to teach them equality' (Prealu14-F, p. 199), others, particularly men, questioned the existence of gender inequality: "There is much talk about gender inequalities and stereotypes, but I do not think there is as much inequality as they say" (Prealu89-M, p. 205). After the intervention, there was greater awareness of the persistence of inequality and the educational role of values-based teaching: "I think we need to work on many values with children, especially freedom, respect and tolerance, but to do so, the classroom must be a pleasant place" (Postalu111-F, p. 260), as well as a recognition of the need to

challenge gender norms and stereotypes in schools: 'We have analysed the reality of education and the problems related to inequalities, and my opinion has changed. I believe that schools should not differentiate by gender. Clichés related to objects directly associated with a particular sex (e.g., dolls and the colour pink for girls) should be destroyed, and children should be taught values of respect and equality (Posalu89-M, p. 218).

Although initially marginal, emotional education became more relevant in the FQ, especially among women, who highlighted its role in fostering empathy, respect and emotional management: "Emotional education consists, above all, of teaching children to recognise and understand their own emotions, to manage them and to develop skills for relating to others" (Postalu33-F, p. 226). Coeducation evolved significantly; although initially considered traditional, it later came to represent holistic development and freedom of choice for both boys and girls: 'Teachers should carry out mixed activities, but this is not coeducation. It is more important that both boys and girls are free to choose their interests and vocations; that is, they can do what they like, always in an orderly manner (Postalu101-F, 262).

At the same time, the codes "teacher role" and "teacher training" appeared more frequently in the teacher training questionnaire, where students recognised the need for educators to model equality and promote mutual and peer understanding: 'Firstly, it would be important for teachers to demonstrate gender equality in their behaviour. Secondly, it is important to educate for equality by teaching in a way that does not undervalue other genders. It is essential to recognise that children and young people know and understand themselves and their peers' (Postalu71-F, 226). Although some students initially felt unable to express their opinions and discuss gender equality, after EI, there was greater critical reflection, understanding of GI and recognition of the role of teachers in promoting gender equality and developing socio-emotional skills.

Statistical Analysis: Significance Tests and Effect Sizes

Significance and effect size tests were applied to assess outcome changes after the intervention. The former is used to determine whether an observed difference between groups or variables is statistically significant or simply the result of chance, and the latter indicates the magnitude of the effect of the intervention.

The results obtained in the Chi-square tests for the category gender (Table 6) show statistically significant associations across the three analysed groups (men, women, and total sample).

Table 6
Chi-Square tests – Gender

Sex		Value	gl	Asymptotic Significance (Bilateral)
Men	Pearson's Chi-square	18.789	3	0.0
	Likelihood ratio	22.547	3	0.0
	Linear by linear association	6.263	1	0.0
	N of valid cases	41		
Women	Pearson's Chi-square	37.578	3	0.0
	Likelihood ratio	43.215	3	0.0
	Linear by linear association	12.526	1	0.0
	N of valid cases	91		
Total	Pearson's Chi-square	31.315	3	0.0
	Likelihood ratio	37.578	3	0.0
	Linear by linear association	10.438	1	0.0
	N of valid cases	132		

The analysis revealed a statistically significant association between pre- and post-intervention responses. Among male participants, Pearson's Chi-square test indicated a significant effect, $\chi^2(3) = 18.79$, $p < .001$. The association was even stronger among female participants, $\chi^2(3) = 37.58$, $p < .001$. In the total sample ($N = 132$), the association remained significant, $\chi^2(3) = 31.32$, $p < .001$. These results suggest that the intervention effectively improved participants' understanding of gender as a socio-cultural construct, with a greater impact observed among women.

The symmetric measures corresponding to the analysis of the gender category reflect a statistically significant association between the variables analysed before and after the educational intervention.

Accordingly, the results obtained in the Chi-square tests for the category gender identity (Table 7) show statistically moderate associations across the three analysed groups (men, women, and total sample).

Table 7
Chi-Square tests – Gender identity

	Sex	Value	gl	Asymptotic Significance (Bilateral)
Men	Pearson's Chi-square	10.844	3	0.001
	Likelihood ratio	13.013	3	0.001
	Linear by linear association	3.615	1	0.001
	N of valid cases	41		
Women	Pearson's Chi-square	21.689	3	0.0
	Likelihood ratio	24.942	3	0.0
	Linear by linear association	7.23		0.0
	N of valid cases	91		
Total	Pearson's Chi-square	18.074	3	0.0
	Likelihood ratio	21.689	3	0.0
	Linear by linear association	6.025	1	0.0
	N of valid cases	132		

Among male participants, Pearson's Chi-square test indicated a significant association between pre- and post-intervention responses, $\chi^2(3) = 10.84$, $p = .001$, suggesting a moderate improvement following the educational intervention. By contrast, this

association was stronger among female participants, $\chi^2(3) = 21.69$, $p < .001$, reflecting a more pronounced change in responses. In the total sample, the association remained significant, $\chi^2(3) = 18.07$, $p < .001$. These findings highlight the positive impact of the intervention on students' understanding of gender identity, with a greater effect observed among women.

Regarding the analysis of the gender identity dimension, the results also show statistically significant associations, although of lesser magnitude compared to the previous category.

Furthermore, the results obtained in the Chi-square tests for the category gender equality education (Table 8) show statistically significant associations across the three analysed groups (men, women, and total sample).

Table 8
Chi-Square tests – Gender equality education

	Sex	Value	gl	Asymptotic Significance (Bilateral)
Men	Pearson's Chi-square	22.787	3	0.0
	Likelihood ratio	27.344	3	0.0
	Linear by linear association	7.596	1	0.0
	N of valid cases	41		
Women	Pearson's Chi-square	45.574	3	0.0
	Likelihood ratio	52.41	3	0.0
	Linear by linear association	15.191	1	0.0
	N of valid cases	91		
Total	Pearson's Chi-square	37.978	3	0.0
	Likelihood ratio	45.574	3	0.0
	Linear by linear association	12.659	1	0.0
	N of valid cases	132		

Among male participants, Pearson's Chi-square test revealed a significant association between pre- and post-intervention responses, $\chi^2(3) = 22.79$, $p < .001$, indicating a marked shift in perceptions following the educational intervention. This association was even stronger among female participants, $\chi^2(3) = 45.57$, $p < .001$, reflecting a more substantial change in attitudes. In the total sample ($N = 132$), the association remained statistically significant, $\chi^2(3) = 37.98$, $p < .001$. These results highlight the effectiveness of the neuroeducation-based intervention in fostering awareness of gender equality, with a greater impact observed among female participants.

In fact, the results of the analysis on education for gender equality reveal the highest statistical association among all the dimensions analysed.

DISCUSSION

This study examined future teachers' perceptions and knowledge of gender, GI, and the role of education in promoting gender equality. Based on these findings, an IE was designed to incorporate gender equality across the board in teaching, integrating contributions from neuroscience. Statistical analysis confirmed the interpretative results of the qualitative information, revealing a significant improvement in the understanding of gender as a sociocultural construct, with a particularly notable impact among women.

In the first topic, "Knowledge and perception of gender", there was initial confusion, as many participants equated gender with biological sex, sexual identity or equality, reflecting the persistence of traditional inherited models, as pointed out by Meeussen et al. (2022). However, after the EI, the students could define gender as a sociocultural and historical construct and link it to socio-emotional development and learning processes. They were also able to differentiate it from other categories, such as biological sex or sexual orientation.

The findings highlight the key role that sociocultural expectations play in shaping gender-related behaviours (Jaoul-Grammare, 2024). One of the most relevant results is increased subcode 1.1.1.1 "Social role". After EI, students could shift their view of gender from approaches focused on the body or binary thinking to a perspective that recognises the social construction of gender roles. At the same time, a significant decrease was observed in subcodes 1.1.2.1 "Biological sex" and 1.1.1.5 "Differentiation", suggesting that there was a profound revision of previous mental frameworks that reduced gender to merely biological.

According to the theory of gender performativity, formulated by Judith Butler and taken up by Butnor and MacKenzie (2022), gender is understood as a set of repeated social acts rather than an innate identity. This theoretical framework allows us to interpret the resistance some male participants expressed to gender-related content, probably influenced by social norms discouraging emotional expression and critical reflection. Male adolescents often show greater interest in topics such as technology, leisure, or appearance, which can limit the perceived relevance of the gender approach in educational contexts unless it is explicitly linked to their interests and experiences.

Regarding the second theme focused on GI, after EI, significant transformations are revealed in how both male and female students understand, verbalise and re-signify this identity dimension. This progress is not only relevant from a pedagogical perspective. However, it can also be analysed considering the principles of neuroeducation, understood as the bridge between neuroscience, psychology and education (Pradeep et al., 2024). One of the study's most notable findings was the increase in self-concept as a central axis in the representation of GI after the intervention, which suggests a deeper activation of processes of reflection, self-regulation and metacognition. From a neuroeducational perspective, this phenomenon can be linked to activating the Default Mode Network, associated with introspective thinking, autobiography, and identity construction (Menon, 2023). When learning experiences allow students to stop and think about themselves, narrate their stories and reframe their experiences, neural circuits linked to the self are stimulated, promoting more meaningful and lasting learning (McAdams et al., 2021).

In addition, the significant decrease in the "Do not know" code after the intervention suggests strengthening students' ability to identify and verbalise complex aspects of GI. The fact that they felt emotionally secure during the intervention, in a judgement-free space oriented towards self-knowledge, facilitated the consolidation of synaptic networks linked to identity language and personal reflection. In this sense, the shift from a reductionist view of GI (associated in the pretest with body image in the case of

women) to a more profound view (linked to personality and character in the post-test) can be interpreted as the result of a process of neuroplasticity favoured by EI. Likewise, the intervention has favoured emotional and cognitive self-regulation, key competencies for meaningful learning. Students changed vague and undefined language ("I do not know") to a more precise and personalised expression of their identity, indicating that they could establish connections between what they felt, thought and expressed. In this regard, Fragkaki et al. (2022) and Funa et al. (2024) state that the most lasting and profound learning is that which mobilises both the cognitive and emotional structures of the brain. Therefore, equality training should include components of emotional education, as it strengthens executive functions such as self-control and flexible thinking, which are key processes in brain plasticity (Choudhury & Wannyn, 2022; Dehaene, 2020).

The third theme, referring to gender equality education, showed that, beyond the quantitative increase in various codes, there was a qualitative change in the understanding, appropriation and expression of equality-related discourse. This change is not only pedagogical but also from the perspective of neuroeducation. Among the most notable aspects was the students' preference for active and collaborative methodologies. The findings suggest that spaces were created in which students not only learned about gender but also experienced equality as a relational and reflective experience.

Particularly relevant is the disappearance of the "Do not know" category, which accounted for a significant proportion of responses in the pretest. Its absence in the post-test can be interpreted as an indicator of the consolidation of cognitive structures that enable students to identify, conceptualise and express ideas about gender and equality. Likewise, the increase in their perceptions of coeducation, the cross-cutting treatment of gender in the curriculum and the use of inclusive language — although still in its infancy — reflects a conceptual change: gender equality is beginning to be understood as a structural axis of the education system and not as isolated content. This change requires reorganising previous frameworks, which involves high-level cognitive processes such as revising beliefs, integrating new meanings and critical reflection. In neuroeducational terms, this type of deep learning occurs when emotional, social and executive processes are activated simultaneously, which EI seems to have fostered.

Another noteworthy aspect is the reconfiguration of the value attributed to traditional stereotypes, diversity, and values education. While in the pretest, some students associated these elements with more traditional or superficial views; the post-test revealed more nuanced responses that reflected increasingly complex and flexible thinking. Among male participants, the sustained or even increased mention of values education can be interpreted as progress in their ability to integrate emotional dimensions into their educational experience. These outcomes align with the idea that ethics-based teaching activates brain regions associated with empathy and emotional self-regulation (Cherrier et al., 2020; Gribovedova & Feldman, 2021).

Female students identified the mainstreaming of a gender perspective following the intervention as a key factor in transforming attitudes (Rosa & Clavero, 2022). Likewise,

students understanding of coeducation evolved—from an initial view centred on mere mixed-gender grouping to one oriented toward personal and social development, as proposed by Martín et al. (2024). In this context, an educational intervention (EI) grounded in neuroeducation proved essential not only for acquiring conceptual knowledge related to gender and equality but also for transforming the classroom into a safe, inclusive space that encourages critical reflection (Griffiths & Dickinson, 2024; Rippon, 2020).

Overall, the findings indicate that students acquired new knowledge and shifted their thinking and feelings about gender equality. Such change is only possible when learning is meaningful—when content is connected to emotions and personal experiences. From this perspective, it can be argued that the EI functioned as a conducive environment for neuroplasticity, self-reflection, and meaningful learning, demonstrating that a gender-focused education is both ethically and socially necessary and cognitively effective.

The EI's emphasis on spatial memory development, the search for meaning and female role models throughout history, and especially the connection between emotions and learning patterns played a decisive role in the outcomes observed. As Ruiz (2024) points out, increased awareness of gender equality, social context, and emotional regulation in learning can better prepare teachers to adopt inclusive practices in their professional work. In short, neuroeducation can enhance learning and emotional regulation—key components in preventing gender-based violence (Coumans & Wark, 2024; Miller & Maricle, 2022).

Differences in the opinions of male and female participants on the topics addressed can be explained by a combination of social, cultural, emotional, and neuroeducational factors. First, gendered socialisation plays a crucial role. In the pretest, many male participants conflated the concepts of gender, biological sex, sexual identity, and gender equality, reflecting the internalisation of inherited traditional models (Meeussen et al., 2022). Female participants, in contrast, displayed greater openness and sensitivity toward a gender-based perspective, possibly because they are more frequently exposed to discriminatory experiences and discourses. From a neuroeducational standpoint, it is also possible that male students face greater barriers to engaging reflectively with gender-related topics, as traditional social norms discourage emotional expression and critical self-reflection among men, limiting their willingness to participate actively in these discussions (Butnor & MacKenzie, 2022). Moreover, the understanding of gender as a sociocultural construct was especially pronounced among female students, which may be linked to a greater emotional and linguistic (narrative) capacity to articulate relational identity processes (Choudhury & Wannyn, 2022).

Finally, the neuroeducational approach applied in this EI may be replicable and relevant beyond the Spanish context, as it is based on universal principles that transcend specific cultural frameworks. Neuroplasticity, emotional regulation, empathy, and meaningful learning depend not on geography but on educational conditions that foster students' emotional, cognitive, and social development (Dehaene, 2020; Fragkaki et al., 2022). Thus, the findings of this study provide a solid foundation for extrapolating similar

pedagogical proposals to other contexts where the integration of gender equality into teacher training is pursued from a critical perspective.

CONCLUSION

Prospective teachers in Spain often report feeling insufficiently prepared to engage with topics related to gender, gender identity (GI), or sexual identity. This lack of preparation frequently leads to avoiding these issues or treating them as private matters rather than as pedagogical concerns. This situation highlights the urgent need for more in-depth, critical, and pedagogically updated training—one that recognizes the impact of gender and GI on students' emotional well-being and learning processes.

The study revealed that, at the outset, a significant portion of pre-service teachers held reductionist conceptions of gender, frequently conflating it with biological sex, sexual identity, or even gender equality. These representations reflect the persistence of inherited traditional models and the absence of systematic training in this area. However, following the educational intervention (EI), a substantial transformation was observed: students developed a more robust understanding of gender as a sociocultural and historical construct. This conceptual shift was accompanied by a critical reassessment of previously held beliefs and a greater openness to new ways of interpreting and giving meaning to gender through both personal and collective experience.

Regarding gender identity, the intervention fostered a profound redefinition of the concept. Participants moved away from a perspective centred on bodily appearance or binary thinking toward a more complex understanding tied to self-concept, personality, and character. From a neuroeducational standpoint, these developments may be associated with self-reflection, emotional regulation, and metacognition—particularly when learning is emotionally resonant and takes place in a safe, nonjudgmental environment.

Students also demonstrated a more critical and engaged appreciation of the transformative potential of education in promoting gender equality. Their understanding of the gender perspective expanded, recognizing it not merely as a specific topic but as a transversal curricular axis, an ethical framework for teaching practice, and a key tool for fostering empathy, social justice, and inclusion. The revaluation of active methodologies, coeducation, inclusive language, and ethical values education reinforced this renewed perspective. Ultimately, the conviction was strengthened that gender-focused education contributes to social equity and the cognitive, emotional, and ethical development of future educators.

Based on the study's findings, there is a clear need to profoundly transform teacher education around gender equality by coherently integrating insights from neuroeducation. Specifically, personal and collective reflection can be encouraged through reflective journals, autobiographical narratives, or identity maps—activities linking academic content with lived experience. These practices stimulate the activation of the Default Mode Network (DMN), associated with self-construction, thereby fostering more enduring and meaningful learning.

It is also essential to adopt active and collaborative methodologies that enable prospective teachers to analyse real-life situations of inequality critically. Strategies such as gender-focused project-based learning, simulations, or case studies promote the development of competencies for transformative pedagogical action. These approaches also cultivate empathy, active listening, and teamwork—core competencies for inclusive teaching. Another key dimension of teacher training is the transversal integration of emotional education. This aspect should focus on developing skills such as emotional self-regulation, the recognition of gender biases, and awareness of both one's own and others' emotions. Neuroeducation research has shown that these processes enhance executive functions such as flexible thinking, ethical decision-making, and the capacity to foster respectful and empathetic relationships in the classroom.

Moreover, it is imperative to transform the classroom into a safe space where students feel free to express their ideas, emotions, and uncertainties without fear of judgment. Only in such environments is it possible to challenge deeply rooted beliefs, reconfigure prior cognitive frameworks, and become open to new ways of understanding diversity. Finally, training in gender equality must not be approached as an isolated topic or a supplementary subject. Its continuous and transversal integration across the entire teacher education curriculum is essential to fostering critical consciousness and a pedagogical practice committed to equity, social justice, and respect for diversity.

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