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Towards a gendered STEAM education approach: building a comprehensive model to strengthen girls' and students with non-conforming gender identities' STEAM trajectories in Chilean public schools

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Abstract

There is worldwide recognition of the gender gap in STEAM careers. Throughout the world, women are under-represented in STEAM jobs. The explanation for this lies much earlier in girls' educational trajectories. The characteristics traditionally attributed to the feminine and the masculine are reproduced through the preservation of stereotypes in textbooks and teaching practices, which question the meaning of education for girls and students with non-conforming gender identities. By theoretically assuming gender not as a binary but as a mobile category that includes non-conforming gender identities, we sought in this study to construct a comprehensive model to strengthen the trajectories in STEAM areas of girls and those with non-conforming and socially marginalised gender identities in public schools in a semi-rural zone in Chile. We introduce the theoretical foundations of the model and its relevant dimensions and key indicators of development. As a result, this model (in construction) considers the following dimensions: a strategy of collective awareness-raising for the local communities; teacher education in STEAM education; implementation and use of FabLabs and a community centre; and an institutional strategy of accompaniment for schools and students. These are addressed in four moments of participatory research: diagnosis, design, implementation and validation. We discuss the challenges of developing a culturally responsive STEAM education by building a comprehensive model of the above-mentioned groups using a gendered approach that places the binary reproduction of the sex/gender system in tension with the principles of participation and democracy.

Keywords culturally responsive STEAM education; girls and non-conforming gender identities; comprehensive model; participation and democracy

Introduction

There is worldwide recognition of the gender gap in STEAM (science, technology, engineering, arts and mathematics) careers (Rahman and Halim, 2022). Women are under-represented in STEAM jobs. The explanation for this lies much earlier in girls' educational trajectories. Although initially girls and boys perform similarly in STEAM-related assessments, girls tend to show underperformance as early as the second half of primary education. The characteristics traditionally attributed to the feminine and the masculine are reproduced through the preservation of stereotypes (Abett de la Torre, 2016). Women who are assumed to be sensitive, submissive, maternal and feminine are linked to the arts and humanities, while men who are supposedly powerful, overly assertive, immature and intelligent, are oriented towards mathematics and sciences (Abett de la Torre, 2016). These characteristics associated with gender have been identified in school texts and have resulted in a lack of formal strategies to promote gender equality within schools (Baeza Reyes and Lamadrid Alvarez, 2018). Research in Chile has shown that in primary mathematics lessons, teachers interact and give less feedback to female students, while female students participate less than their peers (Espinoza and Taut, 2016). Something similar occurs in science lessons, where teachers attribute innate characteristics that limit female students' participation possibilities (Melo-Letelier et al., 2020). Research has also shown how this situation, transferred from the K–12 school context, affects women in adulthood, and their quality of life (González-Badilla, 2016). Valdés (2013) points out that there is a high segregation both in areas and in careers in higher education,

which strongly impacts women's salaries. Similarly, there is a predominance of men entering careers in science and mathematics (CNED, 2015).

The tensions in the sex/gender system oblige countries to question the meaning of education not only for girls, but also for students with non-conforming gender identities, and to consider this factor when addressing inclusive and democratic education (Arancibia et al., 2019). This question, in turn, forces us to ask if educational institutions consider this factor when addressing inclusive and democratic education. For this reason, this study does not consider gender as a binary (male/female with male/female sex) but as a mobile category that includes non-conforming gender identities. Besides, we assume an intersectional approach, recognising that those intersections between different identity markers – gender, social class, disabilities and so on – are complex phenomena that must consider the social contexts of oppressed and privileged groups. Thus, our article aims to present the initial findings of an ongoing design of a comprehensive model of accompaniment that includes: (1) an implemented and validated dissemination, and an awareness-raising strategy of the local communities in gender and STEAM matters; (2) a training and support strategy for teachers to design and implement a STEAM education; (3) the construction and installation of FabLabs and a Community Research Centre; and (4) an institutional accompaniment strategy for students and schools.

Elements to consider in the creation of a comprehensive model: an international overview

A culturally responsive STEAM education, incorporating the arts into STEM (science, technology, engineering and mathematics), which promotes the inclusion of women and under-represented groups in the STEM field, is based on education for social justice, with different proposals in the literature. From a more institutional perspective, such a programme should involve a strong commitment from all participants, as well as partnerships and institutional links between the school community, stakeholders and institutions associated with STEM, as well as evaluation and research to provide evidence of the programme's success (Leggon and Gaines, 2017).

At the teacher training level, a transformative pedagogy (Leggon and Gaines, 2017) needs to be deployed, where teachers have content knowledge related to equity and justice, as well as the ability to critically analyse the construction of such knowledge (Sondel et al., 2017). Dewsbury (2020), for his part, proposes as a starting point the teacher's self-awareness, in order to generate empathy with students, improve the classroom climate and apply a diversity of pedagogies. In their model of inclusive transformation, Johnson and Elliott (2020) integrate elements such as cultural competence, generating in students a sense of belonging and confidence in their abilities through, for example, combating stereotypes in STEM.

Additionally, the development of critical teacher awareness is proposed, where situations of disadvantaged under-represented groups in STEM are explicitly recognised, generating a sense of advocacy and alliance with students, parents, colleagues and communities towards justice-oriented practices through methods that engage all students in meaningful learning (Sondel et al., 2017). In this regard, Madden et al. (2017) emphasise the possibility of employing a STEM-based curriculum as a means of problematising inequities and, thereby, generating meaningful learning in these areas. Meanwhile, Mildenhall et al. (2019) show that the development of design-based learning strategies facilitates intellectual and emotional involvement by allowing students to solve socially relevant problems.

In relation to practices that specifically strengthen the inclusion of women in STEM, a study with Latina high-school students showed that a greater identification with scientists, either a scientist with a similar life story to the students or a panel of Latina scientists, was correlated with greater confidence, belonging and interest in STEM (Pietri et al., 2019). In another study with Latina high-school students who aspired to pursue a STEM career, while they valued the existence of Latina scientists or science teachers as role models, they also valued those teachers who, having a different profile from them, supported and made them feel that they shared the same struggle against inequalities (Sparks et al., 2023).

In summary, the construction of a comprehensive model that strengthens the inclusion of girls and students with non-conforming and socially marginalised gender identities must consider a holistic vision that articulates diverse institutions, as well as teacher training and the inclusion of specific activities in the classroom that help students identify with those involved in STEM.

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The local school system: gender and STEAM in Chilean public policy

In Chile the education system faces the challenge of advancing gender equality and equity. National and international indicators show that gender gaps in primary education increase in tertiary education and are perpetuated in the labour market (Baeza Reyes and Lamadrid Alvarez, 2018). Schools must generate strategies to advance in the accompaniment of educational trajectories with a gendered approach, in which the structural inequalities accompanying them are addressed to ensure equal opportunities in each classroom.

At the level of public governance, the Gender Equity Unit was established in 2014 within the Ministry of Education (MINEDUC) as a permanent and transversal structure in charge of promoting gender mainstreaming in education policies and programmes. This was accompanied by a plan called Education for Gender Equality (2015–2018). The work of the Gender Equity Unit, together with the setting-up of key events such as Feminist May in 2018 and the visible demands for greater gender equality from civil society, has contributed to improving the knowledge of the effects of gender gaps in the daily lives of women and their children. Indeed, this inequality has increased due to the Covid-19 pandemic. In this context, educational communities have a key role to play in eradicating the transmission of gender biases, which are expressed in schools, for example, when students are assigned differential skills according to their gender status, undermining participation in STEAM areas. Regarding ministerial orientations towards a gender approach, in 2022, MINEDUC introduced the Gender and Inclusion Action Plan for Technical Vocational Training, without distinguishing specifically between secondary and tertiary education. In 2020, the National Strategy for Technical Vocational Training had recognised the need to generate a vocational and employment guidance system through a mentoring programme for female students and workers in male-dominated occupations and industries.

The strengthening of the policy in this area has also been reflected in the Ministry of Science, Technology and Innovation, through the creation of research funds that consider the gender perspective as an axis of research in the educational sphere. Moreover, the National Policy for Gender Equality and its action plan, called 50/50 by 2030, seek to resolve the impacts of the gender gap that exists in the areas of science, technology, knowledge and innovation in the country. It is within this framework that the STEAM Gender Lab team, composed of a transdisciplinary research team (professionals from the areas of biology education, psychology, philosophy and design), has been commissioned to develop a comprehensive model to support and strengthen STEM trajectories of women and those with non-conforming gender identities in technical-vocational high schools (TVHS), incorporating art as a work strategy (STEAM).

STEAM, gender and technical-vocational high schools

Our interest in developing an accompaniment model for TVHS education has been considered in several critical aspects. The first one is that this type of education in Chile represents 44.7 per cent of total secondary education enrolment, primarily managed by public providers, and its students belong to the lowest quintiles of the population in terms of family income. In addition, the National Socio-Economic Characterisation Survey (CASEN, 2020) reveal that the trajectories of young women who attend TVHS, based on data on non-attendance and students lagging behind, show greater fragility. Average non-attendance rates show significant differences according to the type of provider, with students enrolled in the public sector being the most affected (38.1 per cent), with subsidised private school students less affected (22.6 per cent) and private school students even less (7.7 per cent). Moreover, the school lag indicator is mainly found in households belonging to the lowest two quintiles (2.4 per cent and 2.1 per cent, for quintiles 1 and 2 respectively). It is practically non-existent in the highest income quintile. The schooling indicator refers to the percentage of incomplete schooling in each sector, affecting 39.8 per cent in the lowest income quintiles. Another critical aspect accompanying the trajectories of TVHS students is access to up-to-date technology that keeps them in line with contemporary requirements. The CASEN (2020: 13) survey indicates that '42.7% of children and adolescents aged 6 to 18 live in households without adequate technological tools for educational purposes, which represents a barrier to connectivity and, therefore, to participation in virtual classes', as well as to accessing online learning and to strengthening cyber skills.

In the educational context of the TVHS, gender inequality is more complex. It requires a review of other challenges, such as the disparity in school completion rates, which varies by gender, income level and territorial location (Canales Sánchez, 2020). This last point makes it possible to affirm that it is

not enough to generate better access conditions, but that it is also necessary to generate support that allows these groups to complete their educational processes, to opt for the entire existing educational offer and to not be marginalised by gender bias in STEM areas.

A gendered STEAM education approach in technical-vocational high schools

It is necessary to consider that the sex/gender system (Arancibia et al., 2019) is a system of dialectical relations, of struggles and confrontations, in permanent conflict, tacit or explicit for those who live it. For this reason, it is not only women who encounter difficulties in the reproduction of gender stereotypes, but also all those identities that question the limits of the binary construction of gender. This is why, in this article, we assume a gender perspective that does not consider gender as a binary category (male/female), but as a mobile category that includes non-conforming gender identities – including, but not restricted to, LGBTQIA+ (lesbian, gay, bisexual, transgender, queer [or sometimes questioning], intersex, asexual and others) students.

Furthermore, we assume an intersectional approach (Recio et al., 2022), which recognises that the intersections between different identity markers, such as gender, social class and disabilities, are complex phenomena that must take into account the social contexts of oppressed and privileged groups (Rouhani, 2014). We know that, in tertiary education, women represent a lower proportion in STEM areas, with differences by region and country (Canales Sánchez, 2020). This impacts the under-representation of women in high-level and leadership positions in both internationally and locally productive sectors. This problem has been present in international discussions, in the UNESCO International Colloquium and Policy Forum 'Cracking the code: Girls' education in science, technology, engineering and mathematics' in Bangkok in 2017, a milestone that marks the need to consider cross-sectoral and comprehensive responses to enable the full participation of girls, women and dissident identities in STEM disciplines.

The data on TVHS students indicate that the gender variable acts as a double exclusion for these lower quintiles, and make explicit the need for a comprehensive model of educational trajectories accompaniment in which gender and STEM variables intersect. In doing so, it is possible to dismantle the transmission of biases and stereotypes, and the determination of differential skills by gender in educational communities.

One of the advantages of incorporating the arts into STEM is that it helps to combine convergent thinking (characteristic of STEM disciplines) with divergent thinking (common in the arts), also helping to generate a more personal sense of self and promoting self-motivation (Land, 2013). In the particular case of women, a study carried out by Wajngurt and Sloan (2019) with university students in the USA showed that women's interest in pursuing STEM studies increased if they had previously attended courses that included the arts component (STEAM courses, compared to traditional STEM courses). These results support the positive relationship between female students attending a STEAM course and the desire to pursue a STEM degree, while highlighting the importance of incorporating the arts into STEM to attract more women. We cannot forget that increasing the representation of women in STEM generates greater diversity in how problems are approached and solved, enhancing innovation and enriching research.

We propose that integrating a gender approach in supporting educational trajectories in STEM areas in TVHS also represents an opportunity to expand the capacity of science, technology, knowledge and innovation to have a more significant impact on other areas of society. For this reason, the creation of a comprehensive accompaniment model that considers the STEM/STEAM and gender axes is a contribution to the field. Learning experiences that integrate different areas of knowledge are implemented, as are challenges that integrate the students into the local and global context, as well as the use of technologies and application of science, based on design thinking and problem-based learning. Moreover, the inclusion of the gender component in the STEM/STEAM area, in addition to the promotion of an inclusive and diverse classroom space that strengthens the accompaniment of the educational trajectories of groups that have been excluded, allows them to recognise, identify and correct the gender limitations that remain in the school system. This is clearly illustrated by the high percentage of women in secondary technical training who opt for training linked to the logic of care, which perpetuates a hegemonic and patriarchal interpretation of the role of women in society. Furthermore, this selection expresses a double exclusion, precisely because these specialisations have a lower economic return in the labour market, keeping these groups marginalised socio-economically.

Although Chile has made progress in terms of public policies that promote gender equity, to date, there is no model to support trajectories that would reduce the gender gap that accompanies the

educational life of women, particularly in STEM areas in the technical-vocational secondary education system. Hence, this proposal would design, implement and package a comprehensive development model with a gender approach. This approach strengthens the presence, learning, participation and continuity of women and LGBTQIA+ communities in these areas, and it can also have an impact on the productive sector. The design of the model considers three dimensions: an implemented and validated strategy for both dissemination of and awareness-raising of local communities on gender and STEAM issues; a strategy for training and supporting teachers for the design and implementation of STEAM education through the use of mobile FabLabs; and a strategy of institutional support for educational trajectories from schools and local institutions.

Method

Design

The methodology proposed to implement and validate a model of comprehensive support for the educational trajectories of women and LGBTQIA+ communities in STEAM areas uses a participatory design. It is based on a social-ecological perspective, which postulates that students' experiences are integrated, intertwined and interrelated with different micro, meso and macro environments (Bronfenbrenner, 1976). Because educational decisions and trajectories are determined by the way students are treated and by the expectations generated by these relationships, we consider that a STEAM strategy must develop an ecosystem that fosters, in these different environments, students' experiences, motivation and engagement. This entails working with school education administrators, school leadership teams, teachers, parents and, of course, the students themselves. Educational trajectories are strongly determined by the type of relationships established with the education system at all levels, and with all its actors/actresses that can contribute to its improvement.

Furthermore, the study used a participatory research design aimed at change and improvement considering the protagonists' vision (Tójar, 2006). This participatory process during the diagnosis and design stages has been implemented through collaborative activities between the actors of the local education system and the project researchers, raising awareness of the objectives and stages of the project, as well as generating relationships between the participants. We have called this process democratic, as it privileges horizontal relationships between teams.

Participants

The meso-context is the Education Area of a Municipal Social Development Corporation of a medium-sized commune located in the region of Valparaíso, Chile. As a public holder, the local district administers, through the Municipal Corporation, 14 secondary and primary schools, with an enrolment of 4,933 students by 2022. Since 2021, the Annual Municipal Education Plan (PADEM in Spanish) of the participating local district has implemented a gender approach as the focus of work for its schools. In doing so, the local district corporation assumes that the problem should not be 'how many women study but rather what is the quality of the education they receive and in what environment' (PADEM, 2021: 67).

This local district includes a secondary school that provides technical vocational education in which we have worked directly in the diagnosis and design process, as well as two primary schools, as the leading tuition providers for the TVHS. The project assumes the gender approach for developing STEAM competencies from this TVHS and the two primary schools, which have a school vulnerability index of 93 per cent. The index is an indicator of the socio-economic level of schools in Chile. In this case, 93 per cent of the students belong to the first four deciles of the lowest socio-economic level.

The local district is located east of the Valparaíso region and has an estimated population of 126,548 people as of 2017 (PLADECO-Villa Alemana, 2020). If we analyse the data by gender, we identify that more than 50 per cent of women are within the 40 per cent of the local population with the lowest income and highest vulnerability, according to information from the social register of households. In addition, half of this group assume the role of leading provider or sole breadwinner for home maintenance. This characterisation expresses the need for educational proposals that modify these indicators through educational opportunities that allow women to have higher economic income for themselves and their families.

The project has been implemented in three schools under municipal administration, which account for 15.5 per cent of the total enrolment of the commune. The data have been provided by the Municipal Corporation, through institutional documents such as the Annual Plan for Municipal Educational Development (PADEM) and the General Student Information System (SIGE) of the Ministry of Education. The second phase of implementation compares the data provided by the Municipal Corporation with the data from the schools, with the purpose of monitoring the educational trajectories from both levels of the education system in parallel. This adjustment work will be carried out through participatory roundtables between the two levels during the second semester of implementation (March 2024).

Data collection and analysis

We use the timeline interviewing methodology (Adriansen, 2012), and the preliminary results of these interviews made it possible to identify common obstacles and facilitators within the trajectories. A main facilitator was the role of teachers as the main predictors of motivation and continuity of educational trajectories. In contrast, the main obstacles referred to the macho treatment of male peers. These results were discussed with the students belonging to the STEAM discipline, and together, they began the construction of strategies for dissemination, support and motivation for gender equality in these areas within the school and the community, which are still under development. Finally, a participatory evaluation of what had been done was carried out through a group interview, in which the actions performed were discussed, and proposals for improvement of the interventions were suggested. At the same time, other actions to support and accompany educational trajectories were visualised.

Ethical considerations

To carry out this research, participants signed a consent form validated by the Bioethics and Biosafety Committee at the university. These documents were drawn up specifically for each of the participating educational institutions, and they were signed individually. The documents consider the objectives of the project and the activities to be developed with each of the groups, in addition to indicating that the data collected would be strictly anonymous and private, confidential, and only for scientific use. Thus, participation was free and voluntary, meaning that participants could suspend or end their participation in the project.

Findings

The results have been grouped into three main areas. First, the conceptualisation of educational trajectories from a gender perspective will be described. Second, reference is made to the proposal of the axes encompassed by the integral model. The third result is related to the key development indicators that will make it possible to evaluate the socio-educational and social impact of the implementation of this model.

Conceptualising education trajectories from a gender perspective

During the diagnosis and design process, and based on the literature review and territorial information, the work team developed the proposal for a comprehensive model for the accompaniment of trajectories, distinguishing two work axes. The first axis is linked to the monitoring of trajectories in the education system, and considers two components, one quantitative and the other qualitative (see Figure 1). The quantitative components are organised into two types: participation and access, which account for the incorporation, attendance and permanence of students; and progress and promotion, which involve data that account for student learning through the grades and scores received in their evaluations and standardised tests. This latter factor makes it possible to verify the progress and difficulties of the trajectories in the education system, becoming a barrier for transitions from one educational level to another. The qualitative information is reported based on instruments and techniques for producing qualitative data that allow the identification of the barriers that prevent or hinder the progress of educational trajectories in STEAM areas.

A second axis addresses the accompaniment of educational trajectories, building on the three dimensions proposed by Booth and Ainscow (2011) interrelated in the national experiences of moving

towards inclusive education: policies, practices and culture (see Figure 2). The policy dimension articulates the regulations at the national, local and school levels, allowing the comprehensive model to be part of the school's management instruments to guarantee the permanent allocation of time and resources for its implementation. The practical dimension considers the incorporation of the gender perspective in pedagogical and relational practices in the school, which allows incorporating a gender approach to STEAM teaching into the dynamics of everyday relationships, incorporating strategies such as design thinking and project-based learning. This implies assuming that gender gaps consider epistemological and curricular elements that must be addressed. The cultural dimension addresses the biases, gaps and stereotypes in the actors who are part of the school, both inside and outside, considering in this process the practice centres where students make their first professional approach.

Figure 1. Gender and STEAM trajectories in the education system

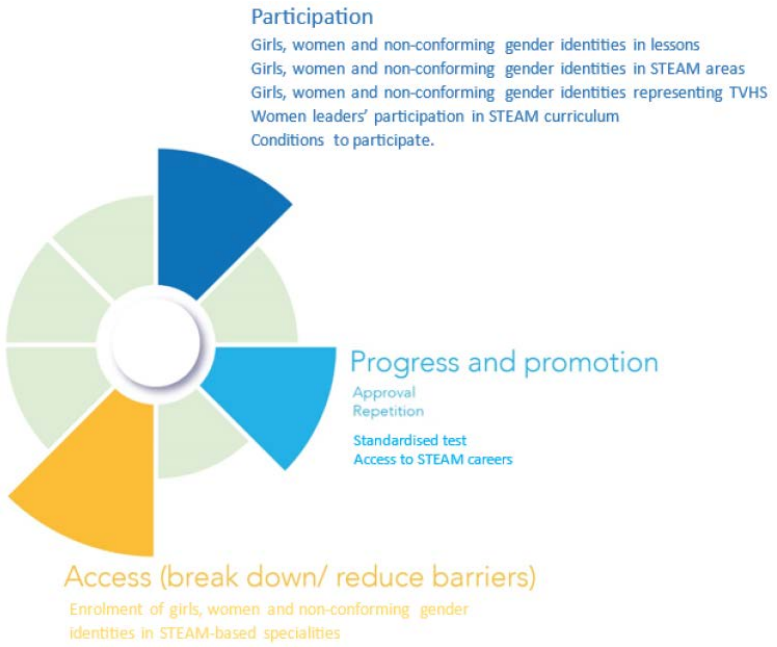

Figure 2. Articulation of the three dimensions proposed by Booth and Ainscow (2011)

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Co-creating a local proposal for the accompaniment of STEAM trajectories

The proposal for a model to support educational trajectories has two differentiating aspects: the area of arts (STEM + Arts) and a gender approach. These aim to develop actions to reduce gender gaps in these areas of knowledge, because although several proposals address the problem in Chile, none of them are offered as a solution in which all the variables intersect: gender, educational trajectories and STEM/STEAM in TVHS teaching.

According to INJUV (2017) studies, women who drop out of the Chilean formal education system do so in response to gender factors such as romantic relationships, pregnancy and childrearing or caregiving, among others, which are often associated with the female role in society (Dussaillant, 2015). However, as a team, we consider that these care tasks are also accompanied by epistemological biases that must be identified. The gender perspective in the project is approached as an analytical tool for the accompaniment of educational trajectories to address the discrimination against, and injustices experienced by, girls and students with non-conforming gender identities in the education system. This approach considers enabling opportunities to stimulate and enrich education from transdisciplinary perspectives that address a complex teaching framework. In addition to the social-ecological approach to the design of the proposal, STEAM experiences can be lived in the classroom with schoolteachers, among peers, with their families and with other members of their local communities.

Axes of the comprehensive model

In the early stages of the design and development of the comprehensive model, the team encountered some obstacles regarding the participation of all stakeholders in the educational community for the implementation of the project with respect to the original approach. One of these obstacles was the significant resistance on the part of parents and guardians regarding gender issues. This was illustrated in difficulties associated with the authorisation of their students to participate in spaces for reflection and research on gender, because they identified a possible contradiction with their religious principles linked to prejudices on the subject. On the one hand, the recognition of this barrier made it possible to reorient the sensitisation and accompaniment strategy, considering a first approach that demystified the notion of gender and its application to the model of strengthening educational trajectories. On the other hand, as part of the process of building the model, the participants reported that families and guardians hindered the deployment and development of STEAM skills on a daily level, as they do not trust the competencies learned by the students. From this, it was identified that it is key to highlight the presence and participation in the family of women referents in STEAM areas, making them visible as leaders who allow anchoring and promoting changes at the level of beliefs and family culture.

As for the facilitators, it was identified that teachers can encourage students to continue their studies in STEAM areas, appealing to their individual characteristics and bringing students closer to innovative experiences. Students perceive the presence of female referents in STEAM areas as a motivation, which is encouraged during the project.

The above background information was considered to co-construct the 'comprehensive model to the accompaniment of STEM/STEAM educational trajectories for TVHS from a gender perspective', which we present below. This model considers three dimensions: collective awareness-raising and accompaniment, implementation and use of FabLabs, and teacher education, which are addressed in four moments of participatory research: diagnosis, design, implementation and validation.

Collective awareness-raising and accompaniment

Specifically, three strategies have been differentiated. First, familiarisation and contextualisation for the translatability and appropriability of the project. This dimension mainly includes activities related to the dissemination of the project, awareness-raising on the relevance of the gender perspective, and generation of dialogues and participatory observations regarding the importance of the gender perspective to facilitate trajectories of women and the LGBTQIA+ community at TVHS. Second, a diagnostic survey, which involved the construction of baselines with quantitative information regarding the current state of the variables of the project, the development of interviews and focus groups with different educational agents, the application of questionnaires to identify gender biases and self-concept of students in STEAM areas, and a review of relevant policies and documents. Third, co-design strategies

for awareness-raising and support actions (such as work teams, collective brainstorming, analysis of scientific internships, and intergenerational dialogues, among others), which involved collaboration between different actors/actresses to analyse, describe, suggest and contribute to the construction of the comprehensive model for the accompaniment of trajectories in TVHS from a gender perspective.

Implementation and use of FabLabs

From the STEAM perspective, it is proposed to use digital fabrication technologies to materialise ideas within project-based learning under the format of FabLabs, or technological fabrication laboratories, considering the students' ideas in this process. A FabLab is 'a place to play, create, learn, advise, invent: a place for learning and innovation. In this sense, FabLabs provide access to the environment, skills, materials, and advanced technology to allow anyone anywhere to do (almost) anything' (www.fabfoundation.org), creating the necessary environment for the development of cyber skills.

As Blikstein (2013) points out, every so often – decades or even centuries – new kinds of intellectual skills and activities become key to work, entertainment and citizenship, making tasks and skills that were previously reserved for experts more accessible. This has been the role of FabLabs and the maker movement for the past few decades. This process of democratisation of knowledge and technologies, however, is developed to uneven degrees, at different paces, and in different ways around the world. In this sense, FabLabs have the particularity of constituting a global network and at the same time locally situated projects and places (Kohtala, 2018). Even so, the global dissemination of these labs and makerspaces have facilitated universal access to technology and the knowledge that mobilises it. Initiatives such as Teach2Learn, Learn2Teach, which brought together FabLabs and children for the first time, were based on three fundamental pedagogical ideas: experiential education, constructionism and critical pedagogies, such as those developed by Dewey, Seymour Papert and Freire (Blikstein, 2013). From these perspectives, the focus is on learning as a dynamic and creative process, rather than a one-sided understanding of teaching.

Technologies can support creative learning, in the sense that, as Papert (Blikstein, 2013) suggests, mental images, ideas and constructions are strengthened when they become 'public' or externalised and, thus, shared with others. This can be a sandcastle, a cake, a computer program, a text or a constructed object. Designing and making material objects can also play a symbolic role in the imagination, 'conveying a particular vision and animating actors' (Kohtala, 2018: 6). In this context, the purpose is not only to use technologies in educational contexts, optimising or supporting traditional education, but also to become an emancipatory tool that puts robust materials in children's hands (Blikstein, 2013). Student participation in FabLabs in diverse educational contexts has demonstrated that children and adolescents can become users of technologies in complex and creative ways, not only as consumers of technological devices and products (Blikstein and Krannich, 2013).

Transdisciplinary STEM teaching methodologies that emphasise an integrated process of learning knowledge through relating and connecting concepts from different disciplines have been considered for STEM strengthening. This approach uses science, technology, engineering, arts and mathematics as entry points to guide student enquiry, discussion and critique, generating a more multifaceted approach that helps engage students who were not previously interested in STEM (Wajngurt and Sloan, 2019). For this reason, it has been proposed to adopt a more interdisciplinary approach, expanding STEM to STEAM, making these areas of knowledge more attractive to groups that have been marginalised.

In this model, it is also assumed that promoting and developing STEAM competencies from a gender perspective requires students to develop a critical view of society, its relationships and knowledges, which allows them to feel like builders of knowledge. For students to be actively involved in STEAM initiatives, it is necessary to provide them with the conditions to actively participate in the design and selection of the educational opportunities offered to them. Educational opportunities also allow students to develop active and enriched learning strategies through scientific, technological and artistic research methods on productive, social and economic topics that are culturally relevant to local territories. Issues such as the Covid-19 crisis, the water scarcity crisis, anthropogenic contamination by mining extraction, and water privatisation, among others, are social and economic issues of great relevance in the Valparaíso region.

Teacher education

A training perspective is needed that focuses attention on learning as a dynamic and creative process, rather than a one-sided understanding of teaching, and that draws on the use of technology in educational contexts, to turn it into an emancipatory tool that puts powerful materials in children's hands (Blikstein, 2013).

The teacher education process encompasses three strategies: (1) familiarisation and contextualisation for the translatability and appropriability of the project, its objectives and implications; (2) the development of a diagnosis of teachers' perceptions, both of gender and STEAM education; and (3) the generation of an initial teacher education proposal in gender, STEM/STEAM and design thinking with teachers and the educational community of TVHS.

The initial results of the diagnosis (n = 48 responses) indicate a manifest need for training in the area, observing responses that range from the invisibility of the child and adolescent population belonging to non-conforming gender identities in STEAM classrooms, to their recognition, and of the importance of cultural, social, political and biological factors in processes of transformation or perpetuation of historical inequalities. Building on these results, the main aim of this part of the project has been the development of a diploma course for teachers titled 'Rethinking our practices from the link between STEAM education and gender perspective' (see Table 1 for the general structure of the diploma), which started in September 2023.

A distinctive feature of this diploma course is that it positions teachers from a critical perspective of their own practice, which begins with self-awareness (Dewsbury, 2020) and explicit recognition of the inequalities that occur in the classroom (Sondel et al., 2017), in order to empathise with students and deploy a variety of strategies aimed at building students' sense of belonging and confidence in their abilities, for example, by combating stereotypes in STEM (Johnson and Elliott, 2020; Mildenhall et al., 2019).

Key indicators by dimension

The design of the comprehensive model considered three main variables: educational trajectories in STEAM disciplines, gender and TVHS.

The *educational trajectory* variable refers to the journey through the education system at different educational levels, which vary in relation to time, continuity and interruptions, configuring linear and real-school trajectories (Terigi, 2009). Educational trajectories make it possible to identify various factors in the educational environment that could have an impact on it, in addition to recognising and developing alternatives to strengthen education (García Robelo and Barrón Tirado, 2011).

The *gender* variable was transversal to the construction of criteria to identify the barriers that interrupt or hinder the trajectories of women and the LGBTQIA+ community in STEAM areas. This variable is approached considering two axes of theoretical discussion: the theories of care (Harcourt, 2021), based on the review of the barriers of exclusion (Federici, 2018; Segato, 2018) that accompany gender markers (Butler, 1990); and the theory of epistemic injustices (Cely Ávila, 2022; Fricker, 2007), which explains the barriers that knowledge has used to exclude women and feminised bodies from knowledge. Within the critical variables studied in gender, a diagnosis of gender biases was made based on the postulates of Eichler and Burke (2010). Three categories of gender bias were considered: androcentrism; gender insensitivity; and double standards. In doing so, the taxonomy regarding the level of change of gender biases present in the student body was used (Azúa Ríos et al., 2019). This taxonomy classifies the interactions between teachers and students, which has been diagrammed as a pyramid that goes from the base of 'invisibilisation' to the top of 'transformation'.

The *TVHS* variable refers to the level of education aimed at developing aptitudes, competencies, skills and knowledge that allow students to obtain a specialisation in the labour market at the end of secondary education. This variable was approached mainly from two indicators: origin of the students who opt for TVHS education, in order to identify the possibilities of articulation and accompaniment of educational transitions; and analysis with key actors on strategies deployed to accompany the STEAM trajectories of women and the LGBTQIA+ community, identifying promotional, targeted and specialised activities to strengthen this type of trajectory. Table 2 describes the operationalisation of the above-mentioned variables.

Table 1. General structure of the diploma course: 'Rethinking our practices from the link between STEAM education and gender perspective'

Theme		Aim	Content	Question related to the Instant Action Research (IAR) as a transversal strategy	Triggering activities (artefacts/critical incidents that allow us to raise the standard for IAR)	Sessions (dates)
1 Re-understanding our practices	Problematisation of practice around STEAM, gender and inclusion	Agreeing on common language, preliminary visualisation of problems	- Common languages: gender, STEAM, inclusion, among others - Teaching experiences and their encounter with the gender approach - Teaching experiences and their encounter with the STEAM approach	What is my classroom practice like? What positive experiences have I had in relation to gender, STEAM and inclusion? Thinking about STEAM, gender and inclusion, is there anything that makes me uncomfortable about my practice that is in my hands to solve? What do I do about gender/ STEAM/inclusion?	- Analysis of mass cultural producers (current Chilean reality shows, songs and so on)	**25 Sept to 2 Oct**

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2 **Gender, STEAM and inclusion**	Body/ intersectionality/ situated knowledge + gender studies and feminist theories: an overview + inclusion and rights approach	Understand the gender perspective from myself + the relevance/ incidence of the participation of women/dissidents/ diversity in STEAM	- Body, language, and teaching performance (Evidencing our biases, who we are and what crosses us [Proposal-Body Mapping]) - Intersectionality as a category of analysis - Situated knowledge - Diversity, inclusion - National policy and international regulatory framework - Neurodiversity paradigm - Universal learning design (UDA) - Cognitive accessibility - Inclusion and STEAM experiences - Gender perspective - Women and gender diversity in work, education, health and STEAM disciplines - Gender biases and stereotypes at school - Gender violence in the classrooms - Masculinities in the classrooms	What happens to me when I address these topics? How does this background change my understanding of the problem?	- Body mapping 1 - Student stories - Stories from thesis facilitators/participants/texts - Documentary: Women in Science - Testimonies from women leaders/dissidents in STEAM/former students of the school (school representative in charge of the science workshop)	**6 Oct to 30 Oct**
3 **Gender perspective in the classroom**	STEAM education and gender: the gender perspective in the classroom	Analysing one's own practice from a gender perspective	- The national curriculum and the gender approach - Cross-cutting approach to gender equality - National policy and international regulatory framework	How do I address (or not) a gender perspective in my classroom? In relation to gender, STEAM and inclusion, is what I think, feel and do in the classroom consistent?	- Walking through the school with a gender 'lens' - Gather evidence from the students (from their own teachers and the accompaniment team)	**3 Nov to 13 Nov**

https://doi.org/10.14324/LRE.22.1.06

4 **STEAM approach: 'glocal' vision**	STEAM approach	To know the STEAM approach from the global, Latin American, national, regional context, and the own body levels, and articulate it with one's own practice	- Convergent education model - STEAM educational approach in Latin America - Scientific inquiry - Critical scientific literacy - STEAM projects in Latin America	What would a STEAM approach mean for my classes? What needs do my students have that the STEAM approach can contribute to? How can it be translated to a local project?	- Blended Experiment Resource (as an example of STEAM in Latin America) - Provocative texts/phrases in relation to STEAM versus local STEAM experiences to improve quality of life - Walking around Villa Alemana (surroundings of the school and beyond) - Body mapping 2	**17 Nov to 27 Nov**
5 **Teaching to transform (us)**	Sociopolitical dimension of STEAM education; teaching to transgress	Becoming aware of the transformative power of one's own practice	- Positionality in scientific STEAM knowledge – what the data tell us - Decolonising the biological knowledge of the body – who are we? - Power, Science and Knowledge - AI in the moment as a political practice	What will be the implications (for my students and the community) of a project like the one I am considering? How have I transformed myself along the way? (Teachers' own stories regarding their transformation) Metacognitive exercise: analysis of how the IAR question changed	- Testimony of transforming/transformed teachers (in first person: ex-Arequipa teachers, STEAM teachers from subsidised schools in Valparaíso)	**1, 4 and 11 Dec**
6 **Thinking with hands/sensitive doing**	Active methodologies	To learn about different methodologies to carry out the project in the classroom	- Design thinking - Robotics - Computational thinking - Project-based learning	What are the most appropriate tools to carry out the project in the classroom? How do I design a project in my classroom?	- Go to FabLab - Body mapping 3	**12 to 15 Dec**

7 **Design and Implementation of educational projects**	Based on design thinking and/or project-based learning as active methodologies	Design and implementation of the project; Present in front of a peer-review panel to evaluate the design and presentation of educational projects	- Identification and prioritisation of problems/challenges with a territorial stamp - Identification of the product to be achieved - Activity planning and schedule execution - Budgeting - Key stakeholders and alliances - Project implementation - Communication - Sustainability and evaluation of the initiative	How can I guide a process with my students that involves STEAM, gender and inclusion?	**April lessons** **May to July accompaniment**

Table 2. Description of critical variables designing the comprehensive model for the accompaniment of STEAM trajectories from a gender perspective

Variables	Operationalisation development indicators	Theoretical references Key concepts
Educational pathway in STEAM disciplines	- Barriers and enablers of trajectories in STEAM - Self-esteem (intrinsic motivation, self-efficacy, self-determination and degree of motivation) and self-concept (positive or negative self-perception) in STEM/STEAM disciplines - Statistics on school trajectories by gender (enrolment, lag, attendance, passing and choice of professional training speciality) in experimental and control high schools	- Educational trajectory (Terigi, 2009) - Self-esteem in STEAM disciplines (Rojas-Barahona et al., 2009) - Self-efficacy in STEAM disciplines (Hsiao and Su, 2021)
Gender	- Gender biases - Perceptions of gender and implications for STEAM trajectories - Epistemic exclusion barriers by gender in STEAM - Barriers to exclusion from educational trajectory due to care work	- Gender biases (Eichler and Burke, 2010) - Typology on gender biases and stereotypes (Azúa et al., 2019) - Care policy (Harcourt, 2021) - Exclusion barriers (Federici, 2018; Segato, 2018) - Gender (Butler, 1998, 2004) - Epistemic injustice (Fricker, 2007; Cely Ávila, 2022)
TVHS	- Origin of students entering TVHS - Knowledge about gender and its implications for deploying TVHS trajectories in the community system and education system - Perceptions on the relationship between gender and TVHS trajectories in the community system and schools	- PADEM of the local district - 'Gender equity plan action in technical-vocational schools' (Ministerio de Educación de Chile, 2022a) - 'Standards of the teaching profession in technical-professional secondary education' (Ministerio de Educación de Chile, 2022b)

Discussion

One of the main achievements of this project has been the design and initial participatory development of a comprehensive model to strengthen STEM/STEAM educational trajectories in technical high schools from a gender perspective, with a social-ecological perspective that encourages experience, motivation and student engagement. This has involved working collaboratively with educational administrators, school management teams, students, teachers and the educational community as a whole. This is in line with Leggon and Gaines (2017), who propose that generating a teaching model aimed at including under-represented groups in STEM should involve the engagement of diverse stakeholders at different levels. During the design and diagnosis process, some hindering and facilitating factors related to the gender variable were identified, which we are still developing, defining and discussing with the

participants in order to build a model that is situated and embodies the experiences of the participants themselves. It is therefore necessary to analyse these factors for the sustainability and transferability of the model to other local districts and educational contexts, towards establishing the conditions for the model to maintain a situated character, and according to the different contexts and specific conditions of the various educational centres that facilitate its appropriation by the educational communities.

Among the facilitating factors, we have found that, from the point of view of students, women and members of the LGBTQIA+ community, teachers play a facilitating role in the construction of spaces for raising awareness about gender, its expression and rights, making existing biases visible. In this way, recognition and consideration on the part of teachers and some colleagues, especially male colleagues, has been identified. Also, interest and motivation were identified by female students in historically masculinised TVHS specialities – in this case, construction and electricity – to encourage other women to enter STEAM disciplines. The main motivation for starting a STEAM career as a woman was identified as having teachers who particularly encourage students to continue their studies in STEAM areas, appealing to the students' individual characteristics, and bringing them closer to innovative experiences and teamwork. The presence of female references in STEAM areas is perceived as a motivation to continue in STEAM educational trajectories. This coincides with the literature, both in relation to the relevance of the teaching role (Pietri et al., 2019) and in the use of female referents or profiles similar to those of the students (Sparks et al., 2023). Female students who do not have female role models close to STEAM are more likely to be demotivated to continue their studies or to practice in STEAM areas.

Among the obstacles identified is the reluctance of some families to allow their children to participate in spaces for reflection and research on gender, because they identify a possible contradiction with their religious principles, linked to prejudices regarding gender issues. From the point of view of teachers, we have found that many have a diminished perception of their abilities to influence their students' vocational choices in STEAM areas.

The unequal presence of men and women in these specialities is perceived as an obstacle to the continuity of STEAM educational trajectories. Women point out that their male peers limit the practical experiences of their female peers. In other words, it is men who carry out activities that are socially associated with a masculine role, such as handling heavy objects or designing projects. In addition, they point out that men rarely take women's opinions into consideration when giving feedback to students on their work.

Families are seen as hindering, when no female referents are close to the STEAM area. When there are women referents in the STEAM area in a nuclear family, they have the perception that their family believes in them regarding their abilities in the chosen speciality.

With regard to conclusions, we can realise that a good indicator regarding the educational trajectories of women in STEAM careers is the presence of other women in STEAM areas, especially in leadership roles, since they can model and promote individual and collective empowerment and agency. This makes it possible to enhance empowered subjectivities and agency capacities when the ways in which other women have been empowered become visible. The presence of female role models in the daily lives of female students generates greater motivation to stay in STEAM careers, and promotes the capacity for future projection (Pietri et al., 2019; Sparks et al., 2023).

All of the above converge in the identification of possible strategies that could be incorporated into the model, and which are being evaluated by both the research team and the participants, including the possibility of having women leaders who encourage participation in STEAM areas, incorporating specific experiences derived from the context itself in teacher training in education with a gender perspective, and devising spaces for dialogue with families, among others.

The road ahead

The ongoing configuration of the comprehensive model that attempts to strengthen the trajectories of women and LGBTQIA+ communities in STEAM areas has been a great challenge and has some limitations, especially due to the multiple edges of the problem, and practical and epistemic inequity related to gender in our society. In particular, the limitations derive from the need to have more members of the educational community who have participated in the participatory dialogues for the analysis of the information gathered and the construction of strategies to be incorporated into the model. In this sense, the time that still remains for the final development of the model makes it possible to identify that these actions are fundamental to develop.

Although we have already participatively identified some enablers and barriers, we still need to delve deeper into each of them, articulating a model that makes visible the practices, cultures and policies that could sustain a more inclusive system that is free of gender biases for TVHS in Chile. In doing so, we must keep working with different agents in the system, especially families and male students.

In the same way, we must continue working to find the best way to articulate the different systems (micro, meso, macro), the different agents and existing devices (and those that can be created) for the configuration of the comprehensive model that can be scaled and transferred to other high schools, making it understandable and practicable, and a promoter of the necessary transformations for the participatory and pertinent construction of an education free of gender exclusion.

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Declarations and conflicts of interest

Research ethics statement

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Conflicts of interest statement

The authors declare no conflicts of interest with this work. All efforts to sufficiently anonymise the authors during peer review of this article have been made. The authors declare no further conflicts with this article.

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