Beyond the Classroom: Attitudes Toward Science and Gender Perception Among Schoolchildren Based on the Microworlds Exhibition Experience

Author information

Danae Barría-Subiabre [1], Colomba Sánchez-Pérez [2], Pía Magaña [3], Valentina Marroquín-Pinochet [3], Carolina Parra [1]*

1 Laboratorio de Nanobiomateriales, Departamento de Ingeniería Mecánica, Universidad Técnica Federico Santa María, Valparaíso, Chile
2 Socióloga, Universidad de Chile, Santiago, Chile
3 Profesora de Biología y Ciencias Naturales, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile
*To whom correspondence should be addressed: carolina.parra@usm.cl

ABSTRACT

Gender disparities in science access and persistent stereotypes can hinder girls' aspirations in STEM fields. While formal education may suppress scientific interest, informal learning experiences—such as museum visits—can foster positive attitudes and help reduce gender gaps. This study examines science-related attitudes and gender stereotypes among 4th to 7th grade students in Valparaíso, Chile, comparing their perceptions in formal education and during the exhibition Microworlds: Science and Art in Your Hands (MSA), a museographic installation at the Natural History Museum of Valparaíso. Using a quasi-experimental quantitative design, a structured questionnaire was administered to 235 students from seven public schools. Results revealed positive attitudes toward science, teachers, the MSA exhibition, and the role of women scientists. Girls reported higher-than-expected self-assessments in science, and the notion that science is gender-exclusive was broadly rejected. A significant association was found between perceived science performance and gender, but no significant differences emerged in motivation when comparing formal and informal education settings. These findings underscore the pivotal role of teachers in shaping scientific attitudes and suggest a potential sociocultural shift in how girls perceive their place in science. The MSA exhibition is validated as an effective science communication experience that promotes inclusive and positive engagement with scientific work.

Keywords: gender stereotypes, attitudes toward science, formal education, informal education, science communication

Statements and Declarations

The authors declare no conflicts of interest. This study and particularly the questionnaire and methodology were approved by the Ethics committee of the University of Santiago de Chile (Ethics approval number: 419/2024).

INTRODUCTION

Access to scientific knowledge remains a global and national challenge. Standardized assessments such as PISA reveal significant disparities among students from different countries (OECD, 2020). In Chile, this gap is particularly pronounced in science and mathematics, especially among students from socioeconomically vulnerable backgrounds (Ministry of Education, 2021). Gender inequality further exacerbates this gap, disproportionately affecting women in STEM fields. Globally, women represent only 30% of the scientific workforce (UNESCO, 2022), while in Chile they account for 34% of researchers, of whom only 16% lead centers of scientific and technological excellence (Ministry of Science, Technology, Knowledge and Innovation, 2021).

Gender stereotypes—defined as socially and culturally constructed beliefs about attributes, skills, and behaviors considered appropriate for expected roles based on biological sex—are established early in childhood (5-7 years old), when children internalize notions about abilities and professions, consequently shaping their academic choices (Steele, 2018; Eccles, 2011). Closely related, traditional gender roles refer to normative cultural expectations about what individuals "should be" and "should do" in society, assigning socially accepted functions to men and women (Harper et al., 2018; Stromquist, 2007). These phenomena contribute to the underrepresentation of women in science by discouraging their scientific aspirations in a field historically dominated by men. One prevailing stereotype suggests that scientific work is more appropriate for males (Hill et al., 2010; De Gioannis, 2023), who would be objective and rational; in contrast to the stereotype that depicts women as affective, empathetic, and intuitive (Vázquez-Cupeiro, 2015; McKinnon & O'Connell, 2020). It is essential to recognize that inequalities in access to knowledge are not merely the result of individual factors but are deeply rooted in social and cultural structures that determine educational experiences.

In Chile, access to knowledge is determined by multiple structural variables, including socioeconomic status, parental education level, and teacher quality (Román, 2009). These are compounded by educational policies and school organizational factors. Within this framework, socioeconomic status emerges as the central variable for understanding educational segregation in the country (González, 2017; Gutiérrez & Carrasco, 2021). Elements as family, school, peers, and media constitute socialization factors—sets of social and institutional influences that influence attitudes, beliefs, and behaviors related to gender and education (Deng, 2024; Ngigi & Lyria, 2014; Tal et al., 2024). These dynamics are linked to the gap between curricular intentions and their effective implementation in the classroom (Bellei, 2015).
The gender gap in education is shaped by both individual and social factors. At the individual level, boys tend to exhibit more disruptive behaviors, lower self-discipline, and a tendency to overestimate their abilities, often attributing their achievements to innate talent. Socially, a culture of hegemonic masculinity prevails within school environments, expressed through sexist attitudes and practices that marginalize femininity (Vantieghem et al., 2014; Blondé et al., 2024). This phenomenon is embedded in gender socialization processes, defined as the learning and internalization of gender norms, roles, and expectations from early childhood through interaction with key socializing agents (Harper et al., 2018; Stromquist, 2007; Pérez, 2018).

Attitudes Toward Science in Formal Education

Attitudes toward science are enduring beliefs—either positive or negative—linked to scientific learning and its relationship with society. They are shaped by cognitive, affective, and behavioral factors (Serje Gutiérrez et al., 2021; Aguilera & Perales-Palacios, 2019).

In Chile, the national curriculum aims to foster students' holistic development through competencies that integrate skills, knowledge, and attitudes. However, it often lacks a contextualized and interdisciplinary approach, which hinders the connection between scientific content and children's everyday lives (Aguilera Morales & Perales Palacios, 2018). This contributes to negative attitudes toward science, reducing students' motivation and interest, which in turn affects academic performance and future professional opportunities (Talavera et al., 2018; Kotsis, 2024; Ahmad et al., 2025).

The deterioration of attitudes toward science is a gradual process influenced by variables such as gender, classroom climate, and instructional methodology. These factors reinforce stereotypes that associate science with masculinity and diminish girls' interest in scientific disciplines (Aguilera Morales & Perales Palacios, 2016; Talavera et al., 2018). This underscores the need to revise teaching complementary methodologies to encourage more equitable interest in science.

Informal STEM Learning Environments

Informal education is defined as a lifelong process in which individuals acquire attitudes, knowledge, and skills by engaging in daily experiences while interacting with their environment (Aguirre Pérez & Vázquez Moliní, 2024). The context and spaces where this learning occurs play a key role in sculpting the educational process. Informal STEM Learning Settings (ISLS), such as museums or science centers, provide opportunities for children to explore and connect with science beyond formal education (Saidi & Sigauke, 2017; Dierking & Falk, 2018; McGuire et al., 2020).

Moreover, ISLS promotes the development of positive attitudes toward science, encompassing emotions, interests, skills, and identities. These settings also have the potential to significantly enhance science learning among girls and women (National Research Council, 2009). By providing inclusive and engaging experiences, ISLS contributes to building a more robust scientific culture within society. Museums, particularly the Natural History Museums (NHMs), are among the most extensively studied ISLS. They support science learning and engagement for both teachers and students through digital technologies, game-based learning, and interactive artifacts. (Mujtaba et al., 2018).

Science Communication and Public Perceptions

In this study, science communication (SciCom) is defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science, following the AEIOU vowel analogy: Awareness of science; Enjoyment of science; Interest in science; the formation of Opinions or attitudes related to science; and Understanding of science" (Burns et al., 2003). The fundamental goal of SciCom is to convey scientific disciplines or applications effectively and clearly to non-expert audiences, where promoting positive attitudes toward science is a critical component (Kappel & Holmen, 2019).

The literature highlights a significant relationship between scientific knowledge and attitudes toward science (Allum et al., 2008). Accordingly, a better-informed population is theoretically more capable of engaging critically and making informed decisions. Thus, SciCom ultimately aims to democratize knowledge and reduce disparities in access to it. Beyond improving public engagement, SciCom could also serve as a tool to address persistent inequities, such as the gender gap in science. This question is relevant in Chile, where stark inequality persists in the educational system. In fact, only 15% of the population considers the quality of education to be "good", while 34% consider it to be "neither good nor bad", and 49% consider it to be "bad" (Ipsos Education Monitor, 2024). Additionally, 66.2% of the population reports a lack of access to SciCom activities (Ministry of Science, Technology, Knowledge, and Innovation of Chile & Cliodynamics Ltd, 2022).

Microworlds: Science and Art in Your Hands Exhibition

An example of informal education and SciCom is *Microworlds: Science and Art in Your Hands* (MSA). MSA is an interactive, interdisciplinary, and museographic project derived from scientific-artistic workshops titled Nanobiomaterials: An Interactive Experience. These workshops were conducted in 2022 in three public schools in Valparaíso, Chile, involving children aged 9 to 13. Their goal was to communicate scientific concepts and applications related to macro, micro, and nanoscale phenomena. The MSA aims to achieve the same objective by showcasing the children's artworks created during the workshops. This approach seeks to bring science closer to people through a child's perspective, expressed via play and curiosity. It also serves as an engaging and novel way to communicate science and nanoscience.

The exhibition features 17 interactive wooden panels, including a whiteboard, a blackboard, origami microscopes, magnifying glasses, tactile samples, bacterial cultures, a short documentary video about the workshops, and a panel featuring only Chilean female scientists. The MSA was inaugurated in March of 2023 at the Extension Center of the Ministry of Arts, Cultures, and Heritage. It was moved to The Natural History Museum of Valparaíso in July 2023, where it currently resides as part of the Museum's permanent collection. To date, the exhibition, with free admission at both locations, has welcomed more than 100,000 people. Despite its broad audience, the exhibition's reception has yet to be formally evaluated. Therefore, this study aims to identify attitudes and gender stereotypes toward science among students in grades 4 to 7 in public schools in Valparaíso.

HYPOTHESES

H1: In formal education—particularly within the natural sciences curriculum—girls exhibit fewer positive attitudes toward scientific work compared to boys. In this context, gender stereotypes in science persist among both girls and boys due to socialization factors that reinforce traditional gender roles.

H2: Informal educational environments, specifically the MSA exhibition, promote positive attitudes toward scientific work among both girls and boys. Within this setting, girls demonstrate a positive shift in their perceptions of gender-related stereotypes in science.

H3: The Microworlds exhibition fosters more positive attitudes toward scientific work among students than their formal science classes. While gender stereotypes in science are present in both contexts, the exhibition exerts a lesser influence in reinforcing them.

METHODOLOGY

A quasi-experimental, quantitative study was conducted using a stratified non-probabilistic sample. A standardized questionnaire was administered to students in grades 4 through 7 from seven public schools in Valparaíso during their visit to the MSA exhibition. To validate the instrument, a pretest was conducted at the museum with 16 participants (7 girls and 9 boys), all of whom were between 9 and 12 years old.

Research Approach and Procedures

Data collection took place over eight sessions during a one-month period, each lasting approximately three hours. These sessions were part of scheduled school visits, coordinated with the participating schools and accompanied by signed informed consent and assent forms.

The entire process was conducted by a team composed exclusively of women scientists. The data collection process included: visiting the Microworlds exhibition, completing the survey, and touring the museum. Two groups were organized per school, with each session involving approximately 30 to 40 students. During the activity, the first group explored the exhibition for 20 minutes and then completed the survey in a separate room, while the second group toured the museum. Once the first group finished the survey, the second group proceeded to the data collection phase.

The survey room was organized into four areas with groups of 4 to 5 students. Each table was led by a female facilitator who guided the application of the instrument. For the 4th and 5th-grade groups, the facilitator read the survey aloud while students completed it simultaneously. For the 6th and 7th-grade groups, students could choose whether the facilitator read the survey or complete it independently. This stage lasted approximately 20 to 30 minutes. Teachers accompanied the process, offering support in complex situations such as disruptive behavior or language translation for migrant students.

Survey Dimensions

The questionnaire included a total of 85 items across the following dimensions:

1. Demographics: school, grade, age, gender, religion, and nationality
2. Participation in scientific activities in both formal and informal education
3. Microworlds: Science and Art in Your Hands exhibition
4. Influence and support from family and peers in natural sciences
5. Perception of natural science teachers
6. Perception of scientific work
7. Attitudes and gender stereotypes in natural sciences

Sample

This study focuses on public school students in grades 4 to 7, corresponding to children around 9 to 12 years old, including students aged 14 who were repeating a grade. This age group was selected based on research indicating that by the age of 5 or 6, children begin to categorize occupations according to gender roles and associate them with specific skills and careers (Bian et al., 2017). Furthermore, around the age of 11, children develop deductive reasoning skills that allow them to solve logical problems, such as "Girls are not good at math; I am a girl, so I am ___ good at math" (Patterson & Bigler, 2018). Given these developmental milestones, we consider late childhood (ages 9-12) to be a crucial stage for examining gender stereotypes.

A total of 241 surveys were collected from students who identified as “female,” “male,” and “other.” However, the “other” category was excluded from the analysis due to the small number of respondents (only six), which could skew the results. Therefore, the final sample included 235 students: 126 boys (54%) and 109 girls (46%).

Questionnaire Analysis

After data systematization and coding, analysis was conducted using SPSS Statistics 30.0 (IBM). Sections 1 and 2 were categorized as nominal variables due to binary responses, while the remaining variables were treated as ordinal, except for age and activity preference ratings, which were analyzed as scale variables. Descriptive analysis and chi-square tests were applied to evaluate statistical associations ($p < 0.05$), along with Cramer's V to estimate the strength of these associations with 95% confidence.

Additionally, based on the study's objectives, only the most representative items and questions —focusing on attitudes toward science and gender stereotypes— were selected for analysis to optimize data interpretation while maintaining validity.

RESULTS

Attitudes Toward Scientific Work and Gender-Related Stereotypes in Science in Formal Education

To evaluate our first hypothesis, we adopted a multidimensional framework for defining attitudes (Carrasquilla, 2020) and examined gender stereotypes in science (Vásquez-Cupeiro, 2015). Consequently, Tables 1 and 2 present four relevant dimensions: family, teaching, natural sciences, and scientific work. These dimensions were summarized in questions focusing on attitudes toward scientific work (Table 1) and gender-related stereotypes in science (Table 2).

According to Table 1, 48.9% of the students reported that their families do not engage in conversations about science and technology. However, within their schools, 43.3% indicated that their teachers actively motivate participation in science-related activities across all science lessons. Additionally, 51.7% stated that science lessons inspire them to deepen their understanding of the subject. Lastly, students perceive scientists as both creative and highly intelligent individuals, with 57.9% and 62.6% respectively endorsing these views. These findings highlight the positive attitudes that students hold toward scientific work, suggesting the need to examine potential gender-based differences.

Table 1 Attitudes Toward Scientific Work

Dimension	Affirmation	Answers (Total %)		
		"Yes"	"Maybe"	"No"
Family	We attend to scientific talks with my family	9.8	16.2	74.0
	My family talks to me about science and technology	18.3	32.8	48.9
	I visit museums with my family	23.1	32.5	44.4
		"In every science lessons"	"In some science lessons"	"Never"
Teachers	My science teachers motivate me to participate in science activities	43.3	39.9	16.7
	*I understand the scientific concepts explained by the teachers	34.0	47.2	18.7
	We perform science-related experiments with my teachers	19.1	39.6	41.3
		"I totally agree"	"Maybe"	"I disagree"
Natural Sciences	Natural science lessons motivate me to learn more	51.7	31.6	16.7
	What I learn in science lessons helps me in my daily life	41.9	40.6	17.5
	Natural science lessons are boring	17.0	33.2	49.8
		"Yes"	"Maybe"	"No"
Scientific Work	Scientists are creative	57.9	36.6	5.5
	Scientists are odd	4.7	19.6	75.7
	*Scientists are smart	62.6	29.8	7.7

*An asterisk in the statement indicates a statistically significant association regarding gender, chi-square test ($p<0.05$)

Table 2. Gender-Related Stereotypes in Science

Dimension	Affirmation	Gender	Answers (Gender %)		
			"Yes"	"Maybe"	"No"
Family	My family talks to me about science and technology	Boy	23.8	29.4	46.8
		Girl	11.9	36.7	51.4
	My family gets excited when I talk about what I learned in science lessons	Boy	44.4	31	24.6
		Girl	45.9	32.1	22
	When I need help with my science homework, I know I can rely on my family	Boy	63.5	23.8	12.7
		Girl	49.5	36.7	13.8
			"In every science lessons	"In some science lessons"	"Never"
Teachers	My science teachers say that boys are better than girls in natural sciences	Boy	9.6	14.4	76
		Girl	5.5	11.9	82.6
	My science teachers say that girls are better than boys in natural sciences	Boy	14.3	12.7	73
		Girl	14	18.7	67.3
			"I totally agree"	"Maybe"	"I disagree"
Natural Sciences	*My male classmates know more about science than my female classmates	Boy	19	23.8	57.1
		Girl	3.7	20.2	76
	My female classmates know more about science than my male classmates	Boy	13.5	27	59.5
		Girl	11	27.5	61.5
	*Boys stand out more than girls in natural sciences	Boy	21	37.1	41.9
		Girl	7	35.8	56.9
	*Girls stand out more than boys in natural sciences	Boy	22	36.8	41.6
		Girl	33	41.3	25.7
			"Yes"	"Maybe"	"No"
Scientific Work	*Only men can do science	Boy	10.4	24.8	64.8
		Girl	5.5	11.9	82.6
	Only women can do science	Boy	7.9	24.6	67.5
		Girl	4.6	14.7	80.7

*An asterisk in the statement indicates a statistically significant association regarding gender, chi-square test ($p<0.05$)

To address this question, we first examined whether students display gender stereotypes in science. Table 2 reveals that students do not perceive their teachers as favoring one gender over the other or attributing greater scientific knowledge to either gender. Furthermore, students believe that both men and women can pursue careers in science. Therefore, no significant associations were identified in gender stereotypes in science within this group of students.

Attitudes and Gender Stereotypes Toward Natural Sciences

Building on previous studies showing negative attitudes among girls toward chemistry or mathematics (Suárez et al., 2020, Bian, et al., 2017), we examined attitudes and gender stereotypes toward natural sciences. Figure 1a shows that boys perceive both themselves and their female peers as equally likely to stand out. In contrast, girls exhibit a different response pattern. A statistically significant association is observed in A1 (*standardized residual of -2.0*), suggesting that the perception that "Boys stand out more than girls..." is shared by only a minority of girls (7%). Additionally, responses from girls in A2 indicate a positive reinforcement of their gender, with 33% stating that they stand out more than their peers.

Figure 1b reveals that both boys and girls believe that neither gender has greater knowledge than the other. However, in A3, a higher-than-expected percentage of boys indicates that they strongly agree with this statement (*standardized residual of +2.3*), suggesting a positive perception of their gender by a small group. In contrast, girls respond with lower-than-expected agreement (*standardized residual of -2.5*), indicating that fewer girls endorse this notion. Whereas sections a) and b) reflect perceptions of others, sections c) and d) focus on self-perceptions. In c), boys respond at a higher-than-expected rate in the category "I totally agree" (*standardized residual of +2.1*), while girls respond at a lower-than-expected rate in the same category (*standardized residual of -2.3*). This suggests that boys may express greater confidence than girls in natural sciences. Although girls do not perceive natural sciences as easy (16.5% "I totally agree"), more than 40% find them interesting (43.1%). While the overall responses reflect positive attitudes toward science, statistically significant associations suggest the persistence of subtle gendered perceptions.

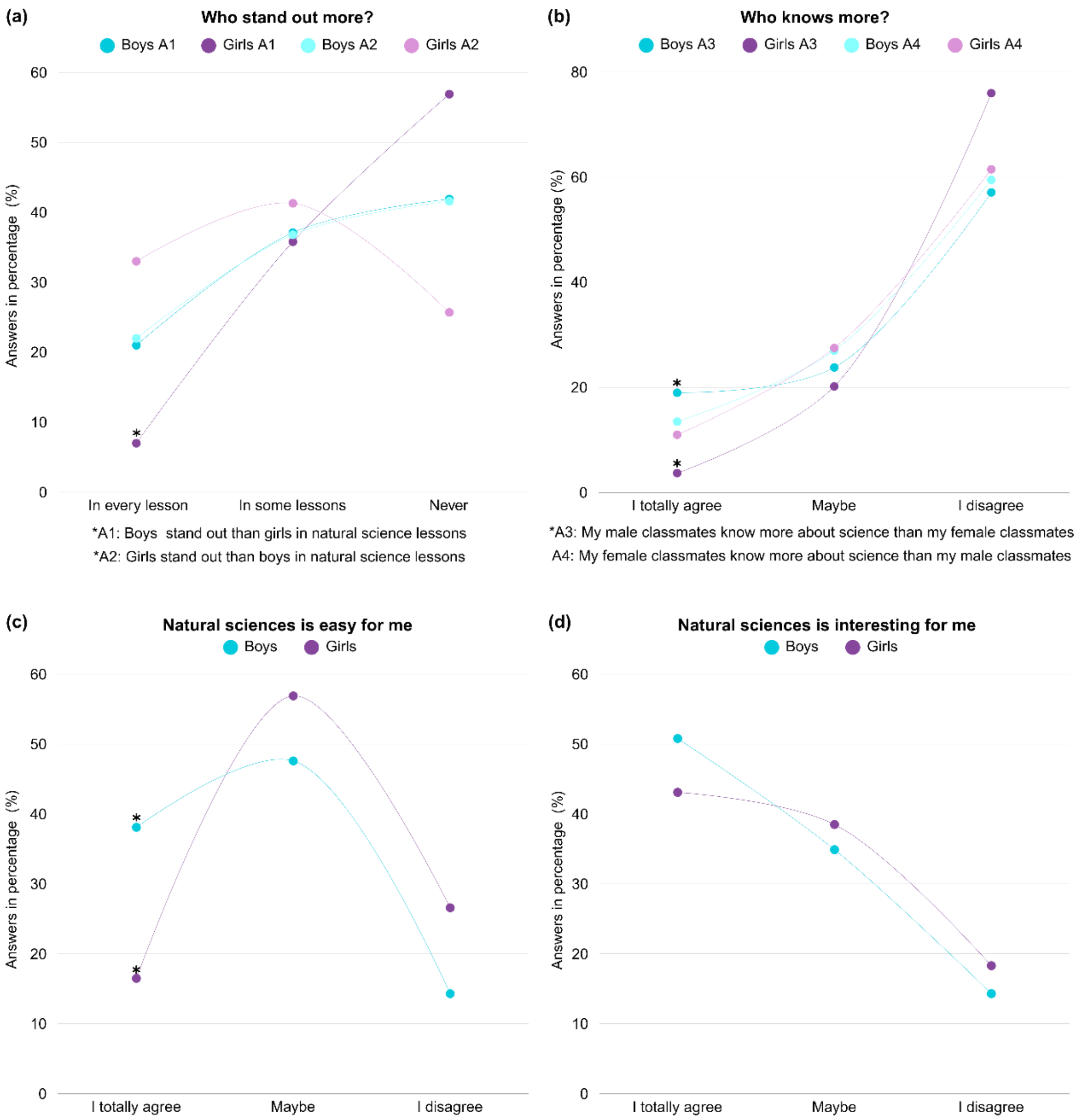

Fig. 1 Students' Attitudes and Gender Stereotypes Toward Natural Sciences. a) Both statements show a statistically significant association with gender: A1 ($p = 0.007$), A2 ($p = 0.024$). b) A3 ($p = 0.001$). c) ($p = 0.001$). An asterisk accompanying the statement indicates a statistically significant association regarding gender, chi-square test ($p < 0.05$). An asterisk on top of the data points indicates a statistically significant association represented by a standardized residual higher than +2.0 or lower than -2.0

Attitudes Toward *Microworlds: Science and Arts in Your Hands* as an Informal Educational Experience

The scale parameters - fun, motivation, and interest - serve as key metrics for assessing attitudes in MSA. These parameters indicate a positive response from students with no statistically significant association with gender (Figure 2). The fun parameter attained the highest approval rate at 77.9%. The scales parameter refers to the understanding of macro, micro, and nano scales, though MSA garnered 56% approval. Science-related motivation received 52.4% approval, while interest in science generated 38.3% affirmative responses. Additionally, approximately 30–35% of responses for most parameters fall into the "maybe" category, except for the fun parameter. The interest parameter attracted the highest percentage of negative responses at 28.1%. In summary, both girls and boys evaluated MSA positively, with the fun component emerging as a crucial factor in fostering positive attitudes toward scientific work.

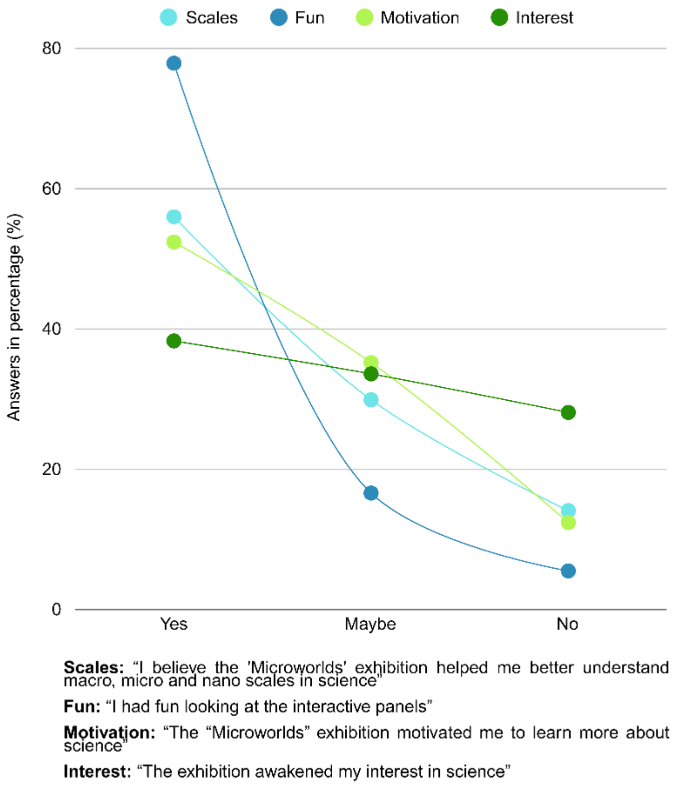

Fig. 2 Students' Attitudes Toward *Microworlds: Science and Art in Your Hands* Exhibition. The scales, fun, motivation, and interest parameters are presented as the total percentage of student responses. No statistically gender-related association was found

Attitudes Toward Women Scientists and Gender Stereotypes in Science

Figure 3a indicates that 65.1% of students provided a positive response to A7, while 27.2% responded "maybe" and only 7.7% responded "no." Statement A7 corresponds to a section of the Microworlds exhibition, suggesting a positive impact from the women scientists' panel. Furthermore, 45.5% of students believe that female scientists can contribute more, in contrast to 27.7% supporting the same view from male scientists. Consequently, the contribution of male scientists received the highest percentage of negative responses, at 30.2%.

Figure 3b presents responses to statements A5 and A6 disaggregated by gender. Among boys, the predominant response for both statements is "maybe" (approximately 25–26%). In contrast, girls' responses differ between statements; for A6, girls exhibit a higher-than-expected rate of "yes" responses (*standardized residual of +2.6*), suggesting a reinforcement of their gender self-perception. In summary, students exhibit positive attitudes toward women scientists. As with the previous results, although some gender stereotypes persist, there is a positive trend toward equity in science. A questioning of male superiority is observed, along with a greater appreciation of the role of women scientists, especially among girls.

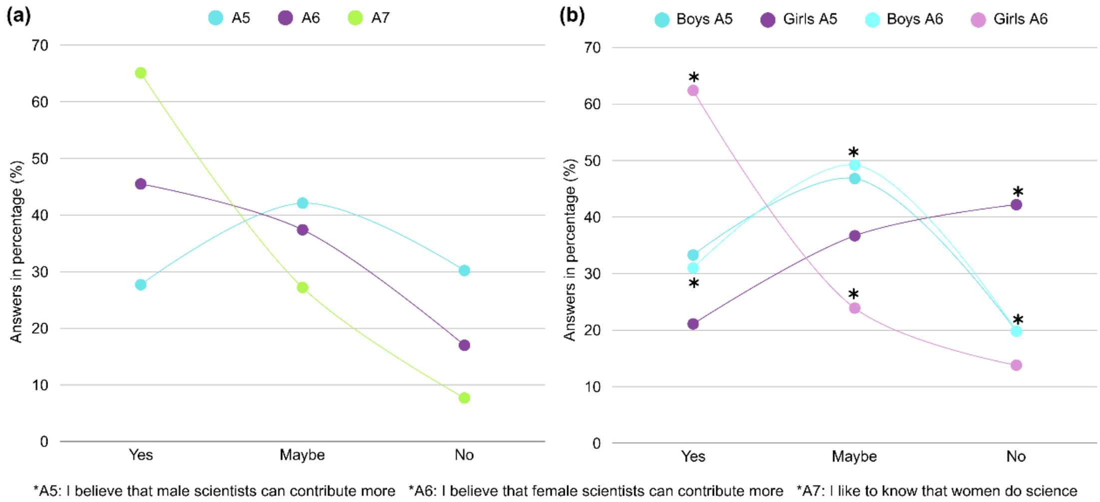

Fig. 3 Students' Attitudes Toward Women Scientists and Gender Stereotypes in Science. a) Percentages represent the proportion of responses among the total number of students. b) Percentages are adjusted by gender. Statements A5 (p = 0.001), A6 (p = 0.001), and A7 (p = 0.002) indicate a statistically significant association with gender. An asterisk accompanying a statement denotes a statistically significant gender association (chi-square test $p < 0.05$), while an asterisk on top or under the data points indicates a statistically significant association as evidenced by standardized residuals higher than +2.0 or lower than -2.0

Motivation Toward Science and Gender Stereotypes in Science

As illustrated in 4a and 4b, Microworlds apparently awakens a greater motivation in girls compared to their natural sciences; however, there are no significant differences between the motivation of students related to science in both formal and informal educational settings.

Figure 4c does not demonstrate a statistically significant association by gender. Despite this, girls' responses suggest a trend indicating that their teachers may provide less motivation to pursue a scientific career compared to boys', with only 17.4% of girls responding positively. Interestingly, 18.3% of girls indicate that "they would like to study a science-related profession" (Figure 4d), suggesting encouragement-related sciences from teachers to their students. Furthermore, in Figure 4d, the highest percentage of girls' responses was 45% in the "maybe" category, in contrast with 41.3% of boys' responses in the "I disagree" category. These girls' responses indicate indecision about pursuing a scientific career and may reveal a hidden gender stereotype in the sciences based on insecurity.

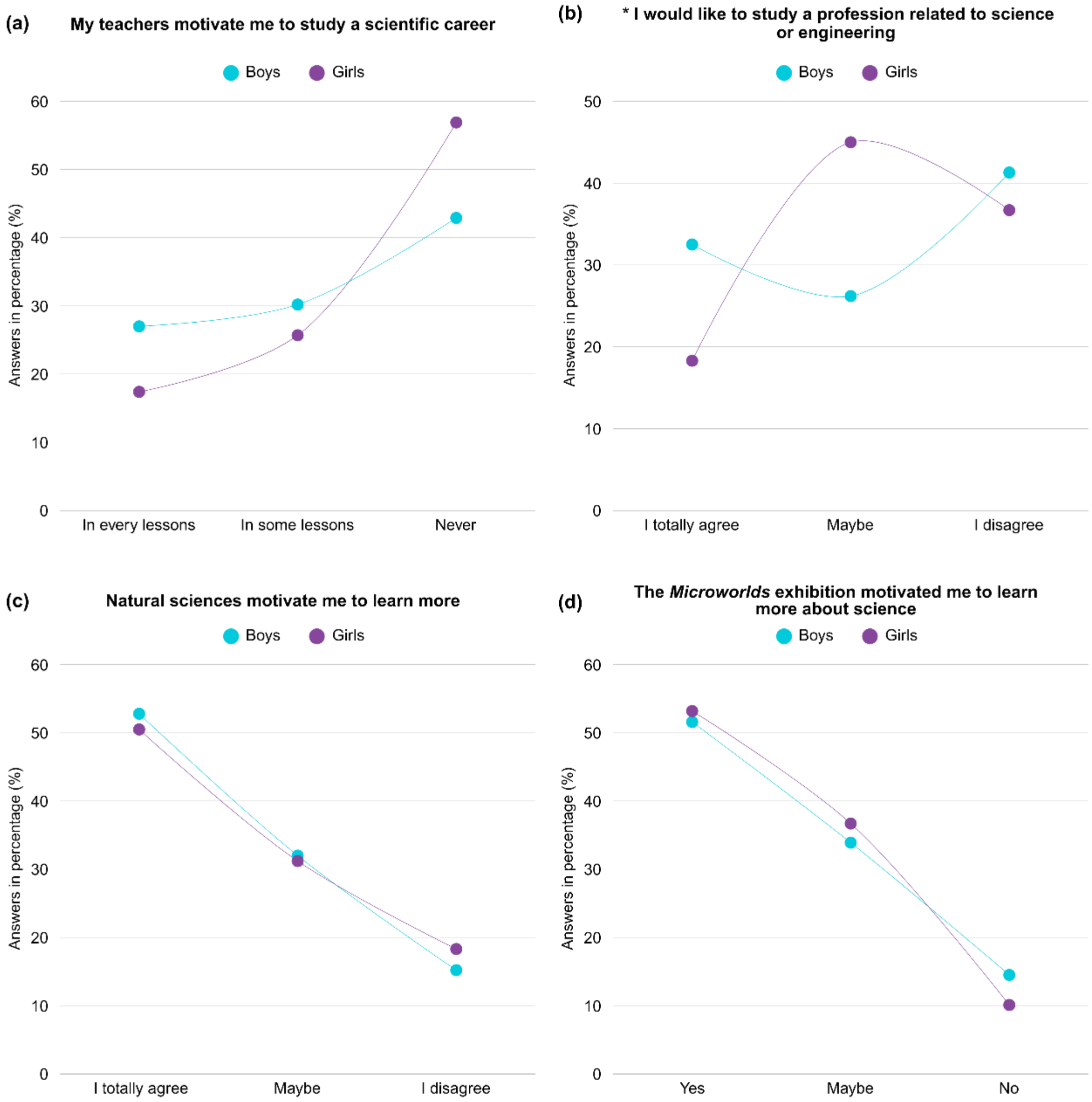

Fig. 4 Comparison Between Formal and Informal Education Related to Students' Motivation in Science. Percentages are adjusted by gender. a), b), and c) No statistically gender-related association. d) An asterisk accompanying a statement denotes a statistically significant gender association ($p = 0.005$), according to the chi-square test ($p < 0.05$)

DISCUSSION

Formal Education and Empowered Girls: A Cultural Shift?

In this study, students reported limited encouragement from their families regarding science (Table 1), which may be explained by the sociodemographic characteristics of the sample—students with an 89–97% Student Vulnerability Index according to Chile's National System for Equitable Allocation (JUNAEB, 2023)—and by existing literature indicating that parental socioeconomic and educational levels influence students' attitudes toward science. Children from higher-income families tend to exhibit more positive attitudes toward science than those from vulnerable sectors, as they have greater access to enriching opportunities such as museum visits, science activities, books, and materials (Hacieminoglu, 2016).

Despite the lack of family support, students demonstrated positive attitudes toward scientific work (Table 1), suggesting that schools and teachers play a central role in shaping these perceptions. Natural science teachers were generally well evaluated, and this aligns with findings by Denessen et al. (2015), who observed that students form attitudes toward a subject based on teachers' comments and enthusiasm. However, 47.2% reported understanding scientific concepts only in some lessons ($p = 0.02$). This finding is consistent with Chile's 2023 TIMSS report, which shows that students who enjoy learning science do not necessarily perform better in the subject (Agency for Quality Education, 2025).

Additionally, most students indicated that their schools do not conduct scientific experiments (Table 1). Evidence shows that laboratory practices stimulate creativity, inquiry, and openness to new ideas, while also developing problem-solving and reasoning skills (Hacieminoglu, 2016; McDonald, 2016). Encouraging curiosity through experimentation improves both attitudes toward science (Cermik & Fenli-Aktan, 2020) and academic performance. This finding aligns with Chile's PISA 2022 report, which associates curiosity with higher student achievement in science. Therefore, incorporating experimental practices in formal education could further motivate children in scientific fields.

Regarding gender stereotypes in science, results show a significant association between gender and the perception that "boys know more about science than girls" ($p = 0.001$) (Table 2). This indicates that boys may be overestimating their abilities, potentially reinforcing gender stereotypes.
In natural science classes, Figure 1a reveals a gender-based difference in academic self-assessment, with girls perceiving themselves as outperforming boys by a 15% margin—contrary to literature suggesting that boys are more associated with mathematical or scientific achievement (del Río et al., 2016). While differences in self-assessment exist, there is also a general perception—shared by both genders—that girls excel in science. Notably, girls show a higher-than-expected self-assessment, challenging traditional paradigms about women's roles in science (Hill et al., 2010). Furthermore, the notion that science is exclusive to one gender is broadly rejected: 65% of boys and 83% of girls disagreed with the statement "only men can do science." Girls appear more critical of this idea, while boys seem more uncertain. This may relate to differences in gender socialization, where girls may be more exposed to equality discourses in certain educational or family contexts.

These findings correspond with the absence of significant associations between gender and stereotype perception in both family and educational contexts, suggesting a possible shift in educational and cultural norms regarding traditional gender roles. These changes are reflected in the growing prominence of gender equity debates in education, where access to schooling has been key to increasing women's participation in STEM careers. In this context, new questions have emerged around gender roles, sexuality, dissidence, masculinities, autonomy, and forms of discrimination and violence. Feminist and educational social movements have played a critical role in raising awareness, influencing government agendas, and promoting social consciousness. As Zerán (2018) states, the aim of these movements was to challenge "the patriarchal ideological structure of Chilean society and its resulting gender inequities and violence against women (...) sexist education, discriminatory language, and other social ills" (p. 10).

In this scenario—and contrary to literature suggesting that boys exhibit more positive attitudes toward science than girls (Hernández et al., 2011; Suárez et al., 2020; Bian et al., 2017)—the results of this study allow us to reject Hypothesis 1 regarding girls' attitudes toward science. Despite reporting that science is less easy for them, girls exhibit high interest in the subject and—most notably—a higher-than-expected self-assessment, reinforcing the notion of a shift in traditional roles and, therefore, a sociocultural change in progress.
That said, Hypothesis 1 cannot be fully rejected regarding the persistence of gender stereotypes in science. While some questions showed no statistically significant associations, this does not imply their absence. Many discriminatory practices may be normalized, making them harder to identify. Additionally, girls' high self-assessment may reflect an overcompensation in response to historically unfavorable conditions in science, along with a desire to demonstrate confidence and align with current discourses promoting equity and female empowerment in the face of structural inequalities.

Microworlds: Science and Art in Your Hands, a Significant and Effective Experience of Science Communication

Informal learning environments are highly effective spaces for sparking curiosity, intrinsic motivation, and appreciation for science. These settings, such as science museums, offer emotionally resonant experiences that strengthen scientific identity through multisensory exploration, free from evaluative pressure (Falk & Dierking, 2010).

This aligns with the Microworlds exhibition, which uses artistic, tactile, and audiovisual resources to make complex scientific concepts accessible through a playful and inclusive narrative. As documented by

Mujtaba et al. (2018), museographic exhibitions that incorporate interactive technologies and interdisciplinary approaches significantly increase interest and participation in science—especially among girls and underrepresented student groups.

Figure 2 confirms these findings:

- 77.9% of students rated the "fun" dimension positively
- 56% reported improved understanding of macro, micro, and nano scales
- 52.4% felt motivated toward science
- 38.3% expressed increased interest in science after the visit

These results validate Microworlds as an effective informal educational experience, positioning it as a successful science communication initiative consistent with the AEIOU model by Burns et al. (2003). Thus, part of Hypothesis 2 is confirmed: both girls and boys expressed positive attitudes toward scientific work during their visit to Microworlds. This underscores the value of informal science experiences as complementary pedagogical strategies that activate interest, understanding, and motivation through emotionally engaging and accessible formats.

Consequently, compelling science communication experiences—like Microworlds—have the potential to positively transform students' attitudes toward science, highlighting the need to examine their impact on gender stereotypes.

Attitudes Toward Women Scientists and Gender Stereotypes in Science Communication

Although empirical data in Chile on this topic remain scarce, there is growing scholarly reflection on the importance of incorporating a gender perspective in Chilean museums and the impact that content can have on shaping children's perceptions. As De la Jara-Morales (2020) notes, "the exclusion of women from the fields of art or science creates a void akin to falsehood: it's not that they weren't there, it's just that their presence isn't acknowledged" (p.16). We interpret the absence of narratives about women scientists in museums as a form of symbolic erasure—one that perpetuates the gender gap in science and may eventually crystallize into a stereotype (Catherine et al., 2010). This underscores the significance of the panel dedicated to Chilean women scientists in the Microworlds exhibition. Its presence in a public, free-access space located in the heart of Valparaíso—visited by nearly 100,000 people annually—marks a meaningful intervention.

In line with this, Figure 3b reveals a positive self-perception among girls regarding their gender, reinforcing and valuing it. Similarly, Figure 3a shows that 65.1% of students responded affirmatively to the statement "I like knowing that women do science." This may be explained by the scarcity of female scientific role models (López Capdevilla, 2020), suggesting that the women's panel may have contributed to the strengthening of female role models in science (Olsson & Martiny, 2018). However, since this cannot be confirmed for all students, we propose that this response is largely driven by a generational shift—similar to what was observed in formal education—supported by advances in public policies with a gender perspective (Library of the National Congress of Chile, 2024) and sociocultural changes in Chile since 2018, when the feminist movement increased the visibility of gender inequalities and gaps (Reyes-Housholder & Roque, 2019; Ibáñez Carrillo & Stang Alva, 2021).

Therefore, in contrast to several of the reviewed evidence—such as socioeconomic vulnerability (del Río et al., 2016), limited family support (Table 1), and the gender gap in science education (Agency for Quality Education, 2022)—we argue that this group of students reflects a positive sociocultural shift regarding gender stereotypes in science. While the visit to Microworlds may have had a positive effect on girls, Hypothesis 2 cannot be fully validated. To accurately measure the exhibition's impact on gender stereotypes, a similar survey would have needed to be administered prior to the visit, allowing for a comparison of students' perceptions before and after experiencing MCA. However, this methodological strategy was not included in the study design.

A Necessary Comparison Between Formal and Informal Education

Out-of-school learning environments are often more flexible and engaging than classroom-based education. This active engagement tends to foster more positive attitudes toward science compared to what is typically observed in formal education settings (Lin & Schunn, 2016; Şentürk & Özdemir, 2014; Yildirim, 2018). Based on this, Hypothesis 3 was expected to be validated. However, students' attitudes toward both the MCA and their natural science lessons yielded similar percentages, as shown in Figures 4a and 4b. No substantial differences were found in students' motivation toward science across formal and informal educational settings. Additionally, no statistically significant gender associations were observed in these statements, which may suggest that Hypothesis 3 is not supported—at least when motivation is used as the sole criterion.

Figure 4 was analyzed using motivation as the key variable, defined as "an internal state that initiates, directs, and sustains behavior" (Koballa & Glynn, 2007; Carrasquilla, 2020, p. 227). Motivation has been shown to influence learning, performance, and behavior in science, and may serve as a predictive factor for students' engagement with the subject (Chan & Norlizah, 2017). It is also considered a critical affective component in science learning (Osborne, Simon & Collins, 2003), making it a valuable indicator for this study—especially when paired with the prospective element in Figure 4d.

It is essential to consider the role of educational agents—teachers in formal education and mediators or science communicators in informal settings—in shaping students' motivation and attitudes toward science. Teachers influence students by transmitting values, beliefs, and enthusiasm through their instruction. Notably, girls' attitudes may be more affected by less encouraging female teachers, who often serve as role models (Denessen et al., 2015). This is particularly relevant in Chile, where 78.1% of primary school teachers are women (Research Center MINEDUC, 2024). Female teachers are often the first representatives of the scientific community that girls encounter (Navarro et al., 2022), making their verbal and non-verbal cues, as well as their affective-motivational signals, highly influential.

This teacher influence is reflected in Figures 4c and 4d. In Figure 4c, only 17.4% of girls reported feeling motivated by their teachers to pursue a science-related career—a figure closely aligned with the 18.3% of girls who stated they would like to pursue a career in science (Figure 4d). This suggests a direct relationship between teacher encouragement and vocational projection. The low percentage may be explained by girls' heightened need for emotional and social validation to envision themselves in traditionally male-dominated fields like science (Archer et al., 2013). Thus, in Figure 4d, girls may still associate science with masculinity. Nevertheless, 21% of girls responded "maybe" to the idea of studying a science-related career, compared to 14% of boys. This could indicate emerging interest among girls, linked to the sociocultural shift discussed earlier. The "maybe" response may reflect not disinterest, but rather persistent insecurities within a system still shaped by gender stereotypes (González Gaspar, 2019; Dierking & Falk, 2003).

On the other hand, informal education environments allow students to engage with science without fear of failure or performance-based stereotypes (Braund & Reiss, 2006). These settings also offer opportunities to interact with non-stereotyped educational agents (McGuire et al., 2020), such as cultural mediators and science communicators, who serve as alternative role models that may increase interest and reduce gender stereotypes in science (Nuño Angos, Rico Martinez & Vidal Vanaclocha, 2016). While we cannot definitively claim that Microworlds reduces gender stereotypes in science, it is noteworthy that girls' responses in Figure 4b diverge from the formal education norm, reflecting a positive effect from the exhibition and the overall experience—including interaction with an all-women team of scientists.

Moreover, the relationship between students and the exhibition content extends beyond cognitive learning to include emotional, imaginative, and sensory dimensions (Aguirre Pérez & Vázquez Moliní, 2004). These elements are explicitly embedded in Microworlds and were key to its positive evaluation (Figure 2). Therefore, Microworlds constitutes an effective science communication experience and a meaningful informal educational intervention. We argue that such experiences can have a lasting impact on students and should be incorporated into the educational curriculum as permanent pedagogical complements.

LIMITATIONS AND PROJECTIONS

This study presents several methodological limitations, particularly related to the challenges of collecting data from children, as difficulties in reading and understanding the survey questions, accurately interpreting the interactive panels, managing group dynamics, language barriers, and time constraints during the activity. Additionally, some responses were excluded due to unforeseen issues, such as students opting out for personal reasons or to language limitations.

Another key limitation was the absence of baseline data regarding students' gender stereotypes in science prior to visiting Microworlds. This made it difficult to assess the exhibition's impact on stereotype reduction. Furthermore, the lack of a complementary qualitative methodology restricted the interpretation and the precision of conclusions.

Future research should aim to complement quantitative data with mixed methods approaches to explore students' perceptions in greater depth. It would also be valuable to include the "other" gender category to enrich the gender analysis with more inclusive and updated data. Additional comparisons could be made across age groups, between coeducational and single-gender schools, and among public, private, and subsidized institutions to better understand the socioeconomic dimension.

Finally, further investigation into students' emotional responses—particularly self-assessment, motivation, and limiting beliefs—could reveal associations with emerging forms of academic pressure or positive discrimination, and how these relate to attitudes and gender stereotypes in science.

CONCLUSIONS

This study reveals the presence of positive attitudes toward science among students, even in the absence of family support in this area—highlighting the influential role of teachers in fostering curiosity and motivation in scientific learning. Notably, girls demonstrated higher-than-expected self-assessments in science, suggesting a potential sociocultural shift that may challenge traditional gender roles in STEM fields.

Regarding the Microworlds exhibition, students expressed positive attitudes toward scientific work, largely driven by the element of enjoyment. The exhibition increased students' motivation and appreciation for science and reinforced girls' positive perceptions of women scientists. Therefore, we propose that science communication and out-of-school learning experiences should be integrated into the educational curriculum as ongoing pedagogical resources. These experiences can foster positive attitudes toward science from early childhood and promote reflective and critical thinking as a foundation for reducing both knowledge gaps and gender disparities in STEM.

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AUTHOR CONTRIBUTIONS

DB-S: Conceptualization, Survey application, Analysis, Writing – review & editing. CS-P: Methodology, Survey application, Analysis, Writing – review & editing. PM: Survey application, Data systematization, Writing – review & editing. VM-P: Survey application, Data systematization, Writing – review & editing. CP: Conceptualization, Funding acquisition, Supervision, Review

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