European Journal of STEM Education,
2025, 10(1), 02
ISSN: 2468-4368

An Exploration of Students' Attitudes Towards STEM and Climate Change: A Cluster Analysis Study with a Gender Perspective

Carme Grimalt-Álvaro [1], Cristina Valls [2]*, Gisela Cebrián [2], Luis Marqués-Molías [2]

[1] *Universitat Autònoma de Barcelona*, SPAIN
[2] *Universitat Rovira i Virgili*, SPAIN

***Corresponding Author:** cristina.valls@urv.cat

Citation: Grimalt-Álvaro, C., Valls, C., Cebrián, G. and Marqués-Molías, L. (2025). An Exploration of Students' Attitudes Towards STEM and Climate Change: A Cluster Analysis Study with a Gender Perspective. *European Journal of STEM Education*, 10(1), 02. https://doi.org/10.20897/ejsteme/16206

Published: March 27, 2025

ABSTRACT

The last decades have seen a growing political and social recognition of the role of education as a key player in transforming today's society towards more sustainable lines. Particularly, STEM education is seen as critical for promoting the acquisition of skills, knowledge, and competencies that contribute to create climate change and sustainability solutions among secondary school students. However, gender differences in students' attitudes towards STEM could hinder the success in this regard. The aim of this research was to identify secondary school students' profiles according to their STEM and climate change attitudes to explore the relationship between those two areas and students' gender. From the analysis of the answers to a questionnaire distributed among 407 secondary school students, we conducted a hierarchical cluster analysis in which five main clusters were found. Within these clusters, gendered differences associated to traditional stereotypes were identified, such as girls expressing higher concern about climate change and lower level of interest towards STEM, and boys showing less interest towards climate change, but a more positive attitude towards STEM, especially in engineering and in technology. The study results shed light on the need to develop more inclusive educational initiatives that better contribute to the achievement of STEM and climate change education from a mutual enrichment.

Keywords: gender, secondary school students, climate change, attitudes, STEM

INTRODUCTION

Societies worldwide are confronting complex, interconnected and multifaceted challenges such as climate change, poverty, and biodiversity loss, each manifesting uniquely in different regions (UNFCCC, 2022; United Nations, 2015). Over recent decades, the principle of sustainable development or sustainability has emerged as a pivotal international response, aiming to balance environmental stewardship with socio-economic advancement (Lambrechts et al., 2018; UNESCO, 2020). Therefore, developing innovative inter- and trans-disciplinary solutions is essential for promoting more sustainable lifestyles and social practices (Sterling et al., 2017; Wals, 2010). Central to this pursuit is the role of education—particularly Science, Technology, Engineering, and Mathematics (STEM) education—which aims at equipping citizens with the necessary competencies to devise innovative sustainability solutions.

This article examines the interplay between STEM education and sustainability, focusing on how students' attitudes toward STEM influence their engagement with sustainable development goals. Despite broad political and societal consensus on the importance of an educated citizenry in tackling complex and transdisciplinary problems like climate change, significant challenges persist. For instance, prevailing student attitudes towards STEM—as rational, objective, value-free, not oriented towards the care of people—or STEM people—as genius, socially awkward, unattractive, and romantically unsuccessful people—can diminish their interest and participation, especially among girls (Archer et al., 2023). Research has shown that gendered stereotypes and cultural expectations often exacerbate the disinterest of girls in STEM fields, contributing to the underrepresentation of women in these critical areas (Cian and Dou, 2024).

This dissonance between students' self-concepts and the traditional portrayal of STEM fields may significantly impact educational efficacy in fostering sustainability-minded citizens (Archer et al., 2023; Cian and Dou, 2024; Starr and Leaper, 2019). For girls in particular, overcoming these gendered barriers is crucial to ensure more equitable participation in STEM-related sustainability efforts. Addressing this gap can foster more diverse and innovative approaches towards solving global sustainability challenges.

Therefore, our study is not merely about identifying a gap, but it is fundamentally aimed at understanding the dynamic relationship between students' attitudes toward STEM and their perspectives on climate change. This understanding is critical as it informs how STEM education can be restructured to not only transfer knowledge but also inspire proactive engagement in sustainability issues (Brundiers et al., 2021; Cebrián et al., 2020; Sterling et al., 2017). By conducting a cluster analysis to identify distinct profiles based on students' attitudes, this study offers insights into how diverse student groups, including gender-based groups, perceive and engage with sustainability concepts through the lens of STEM education. This nuanced approach provides a substantive foundation for proposing educational strategies that are not only robust but also culturally and personally resonant for students. Such strategies are essential for cultivating a generation capable of addressing the urgent environmental, social, and economic challenges of our times.

BACKGROUND

There is broad agreement among academics, global citizens, and international agencies about the vital role of climate change education in reshaping educational approaches to address the climate emergency (Reid, 2019; UNESCO and UNFCCC, 2016). Despite consensus, the practical application of climate change education lacks coherent frameworks, presenting a significant challenge (Mochizuki and Bryan, 2015).

Article 6 of the United Nations Framework Convention on Climate Change (UNFCCC, 1992) highlights the necessity to incorporate climate change education across education levels, training, and public awareness to enable comprehensive responses and widespread societal participation. This commitment is echoed in later treaties like the Paris Agreement and the Glasgow Climate Pact (UNFCCC, 2015, 2022). To be effective, educational strategies must empower individuals to engage actively in socio-political processes and sustainability actions (Sterling et al., 2017; Stibbe, 2009). This requires reorienting education to promote sustainable lifestyles, tackling complex sustainability issues through creativity, critical thinking, decision-making, and value-driven competencies (Brundiers et al., 2021; Östman et al., 2019).

Successfully integrating STEM education for sustainability into secondary education curricula is crucial for the promotion of climate change awareness and action (Jucker and Mathar, 2015; Trott and Weinberg, 2020). Research indicates that adolescence is key for shaping values and environmental awareness (Ignell et al., 2019). Therefore, understanding secondary students' attitudes toward these topics is essential, as it influences value formation and informs effective sustainability education strategies (Biasutti, 2015; Deisenrieder et al., 2020).

Attitudes Towards Climate Change

Recent syntheses of the literature, such as Lee et al. (2020), predominantly focus on young adults' beliefs about climate change, including the acknowledgment of its occurrence and general knowledge about its causes, impacts, and potential solutions. However, attitudes towards climate change, as Cooper et al. (2016) define, involve evaluative categorizations of this issue along a positive-negative spectrum. These attitudes may stem from behavioral, cognitive, or affective dimensions—or often, a combination thereof. Crucially, attitudes are distinguished by their propensity to influence corresponding behaviors based on one's beliefs and emotional experiences. Hence, our argument is that when considering education for sustainability, exploring students' attitudes towards climate change offers a more reliable basis for understanding the way young individuals relate to these subjects, instead of just classifying their overarching beliefs.

While previous research such as the one conducted by Filho et al. (2023) has explored university students' climate change attitudes—particularly noting the impact of direct climate risk exposure and engagement with climate discourse—studies focusing on secondary school students remain limited. This scarcity shows a significant gap, particularly given the importance of early educational interventions.

The Revised New Ecological Paradigm (NEP), as used by Jackson and Pang (2017) to assess environmental attitudes among secondary students in Hong Kong, provides a useful metric for gauging pro-environmental attitudes. Their findings suggest that Hong Kong students exhibit greater environmental awareness compared to their global counterparts. Similarly, Kirbiš (2023) reports variability in environmental attitudes among secondary students based on their educational tracks, indicating the influence of educational content and structure on these attitudes. Thus, while existing surveys show young Europeans have comparable or higher levels of interest and concern in relation to climate change than older groups, this issue is not a top priority for secondary school students and they are not willing to take action (European Union, 2021; Hermans and Korhonen, 2017).

While indirectly related to attitudes, research also reveals distinct gender-based roles and behavioral patterns in climate change contexts. For instance, policy arguments focusing on science and business are often associated with men, whereas those centered on environmental justice and ethics tend to be linked with women (Swim et al., 2018). Similarly, Stevenson et al. (2019) found that secondary school girls perceive climate change as a more significant risk and issue than boys do. Extending beyond attitudes, studies like those by Lv and Deng (2019) show a positive correlation between women's involvement in political activities and enhanced environmental outcomes. Additionally, countries with a higher percentage of women in parliament or government roles tend to be more committed to environmental treaties and to the establishment of protected areas compared to those with more men in similar positions (Norgaard and York, 2005; Nugent and Shandra, 2009). These findings underscore the importance of incorporating a gender perspective when analyzing students' attitudes towards climate change to fully understand the results and their broader implications.

STEM Education and Its Relationship with Climate Change

The term STEM was formalized in the 1990s by the US National Science Foundation (NSF) to include Engineering and Technology alongside Math and Science in both undergraduate and K-12 education (Li et al., 2020). Research has highlighted the importance of STEM education in developing students' STEM literacy—defined as the ability to utilize conceptual, procedural, and attitudinal knowledge from STEM fields to tackle complex interdisciplinary challenges like climate change (Martín-Páez et al., 2019). Consequently, STEM education aims to equip students with the necessary skills to innovate and apply solutions across Science, Technology, Engineering, and Mathematics, fostering active engagement in creating a sustainable world (Couso et al., 2022). This approach positions STEM education as pivotal in teaching students to navigate and solve real-world problems, preparing them for rapid technological advancements (Breiner et al., 2012).

STEM-related fields have long utilized real-world complex problems, such as those outlined in the Socio-Scientific Issues framework (Zeidler, 2016), and recent PISA frameworks (OECD, 2023). Although there is no consensus on the specific problems to be included in STEM education, many scholars advocate for incorporating challenges related to energy efficiency, environmental quality, resource use, and sustainability (Bybee, 2010; Maass et al., 2019). STEM education, therefore, is well-suited for advancing climate change and sustainability education through its transdisciplinary approach (Rogers et al., 2015).

Attitudes Towards STEM

The push to promote STEM education partly stems from efforts to elevate career aspirations in these fields, particularly for women who are underrepresented compared to men (Wang and Degol, 2017). The gender gap in STEM becomes pronounced in secondary education, where subject choices diverge—boys often lean towards engineering and technology, while girls are drawn to arts, health, humanities, journalism, or science. The gender gap in STEM education becomes more evident in secondary education when students begin to choose specific subjects (Kolmos et al., 2013; McDaniel, 2016; Wong, 2015). Research indicates that attitudes and self-perceptions towards STEM significantly influence these choices (Regan and Dewitt, 2015). Gender differences persist across all educational levels, with girls generally showing less interest in technology and physics and more in health and environmental care than boys (OECD, 2019). Research has also shown that attitudes are intertwined with other factors such as self-efficacy, achievement, and self-identification, where gender differences are also marked (Grimalt-Álvaro et al., 2022). From primary through secondary education, girls consistently display lower self-confidence in science and technology (Beghetto, 2007).

Despite the development of various questionnaires to measure students' STEM attitudes such as Dökme et al. (2022), Guzey et al. (2014), Mahoney (2012) and Unfried et al. (2015), the link between attitudes towards STEM and climate change remains underexplored. While the benefits of STEM education to climate change awareness are clear, there is a significant gap in understanding how students' STEM attitudes shape their perspectives on climate change. Additionally, although studies show varying levels of interest, concern, and social engagement with climate change among genders, the role of STEM education in fostering these attitudes has not been adequately addressed. This highlights the need for a targeted exploration of how climate change is integrated within STEM disciplines to maximize sustainability education's effectiveness. Thus, redefining STEM education's purpose is essential—it should promote a collaborative approach that engages students in STEM and equips them to tackle contemporary climate and sustainability challenges effectively (Trott and Weinberg, 2020).

Research Problem and Questions

As mentioned earlier, STEM education is critical for equipping secondary school students with the skills, knowledge, and competencies necessary for creating climate change and sustainability solutions (Couso et al., 2022; UNESCO, 2017). It is important not to overlook the fact that STEM education can be part of the solution to current climate change problems. However, differences in students' attitudes towards STEM could hinder the success in the achievement of this goal. For this reason, the aim of this research was to fill in the gap identified in the existing literature, which refers to the relationship between secondary school students' STEM and climate change attitudes. The research questions guiding this study were:

1. Which profiles can be identified among secondary school students through a cluster-based analysis of their attitudes towards STEM disciplines and climate change?
2. What gender distribution differences can be found among students' profiles?

METHODS

Context of Study

This research was conceived as an exploratory study conducted with secondary school students from three semi-private schools in the city of Tarragona (Spain). The participating schools followed the Spanish curriculum for secondary education, where there is no specific STEM subject. The curriculum is structured according to the compulsory subjects of science, technology, and mathematics. In the Spanish curriculum, climate change education has not received sufficient political support and therefore has not been introduced properly (González Gaudiano and Meira-Cartea, 2020). Climate change occasionally appears in the curriculum as a privileged context to promote student learning of the different STEM subjects, especially regarding science topics. However, the new Spanish Organic Law 3/2020 on Education (LOMLOE) and its associated curriculum, which was progressively implemented in school years 2022-23 and 2023-24, has adopted the SDGs and the 2030 Agenda as a reference framework for its development and it therefore becomes an opportunity for embedding climate change in secondary education (Medina and Galván, 2021). The three schools participating in this study had specific education programs to promote the development of skills in programming and in using robotics among students.

The sample comprised 419 students, of which 196 were in their first year and 223 were in their second year of compulsory secondary education (students aged 13-14 years) from three semi-private schools in the urban area of Tarragona. A purposive sampling was used, as the schools were selected because of previous involvement in projects led by members of the research team. Students mainly came from middle-class families. Students reported having relative familiarity with STEM professions, as the 43% of participants had one of their parents working on STEM related jobs, being this percentage considered high and due to Tarragona's main socioeconomic activities, counting with the largest petrochemical industry in southern Europe (Rovira et al., 2021).

Data Collection Procedures

A questionnaire was designed with the aim of exploring the relationship between STEM attitudes and climate change attitudes amongst secondary school students. We divided the questionnaire into 2 parts. The first one was related to sociodemographic data such as age, gender, course, center, parents' job, and their future desired studies. The second part consisted of a 6-point Likert scale (totally disagree–totally agree). This second part included 30 items divided into 4 blocks. The first three blocks are related to the attitude component as Cooper et al. (2016) explain and are divided into:

1. affect: emotional responses about an object (positive emotions, feelings, etc.);
2. cognition: what the individual knows about the object and/or their beliefs about it;
3. behavior: what the individual does or plans to do in relation to the object.

The questionnaire analyses the affect, the cognition, the behavior, and the relation of climate change action in the 4 STEM subjects (Science–Technology and Engineering–Maths). The final block contains 3 items about their feelings in relation to climate change. The questionnaire was distributed online to schoolteachers from the different schools taking part in the study, and students answered the questionnaire in the classroom under the supervision of their teachers at the beginning of the second school term. Data collection was carried out between March and June 2021.

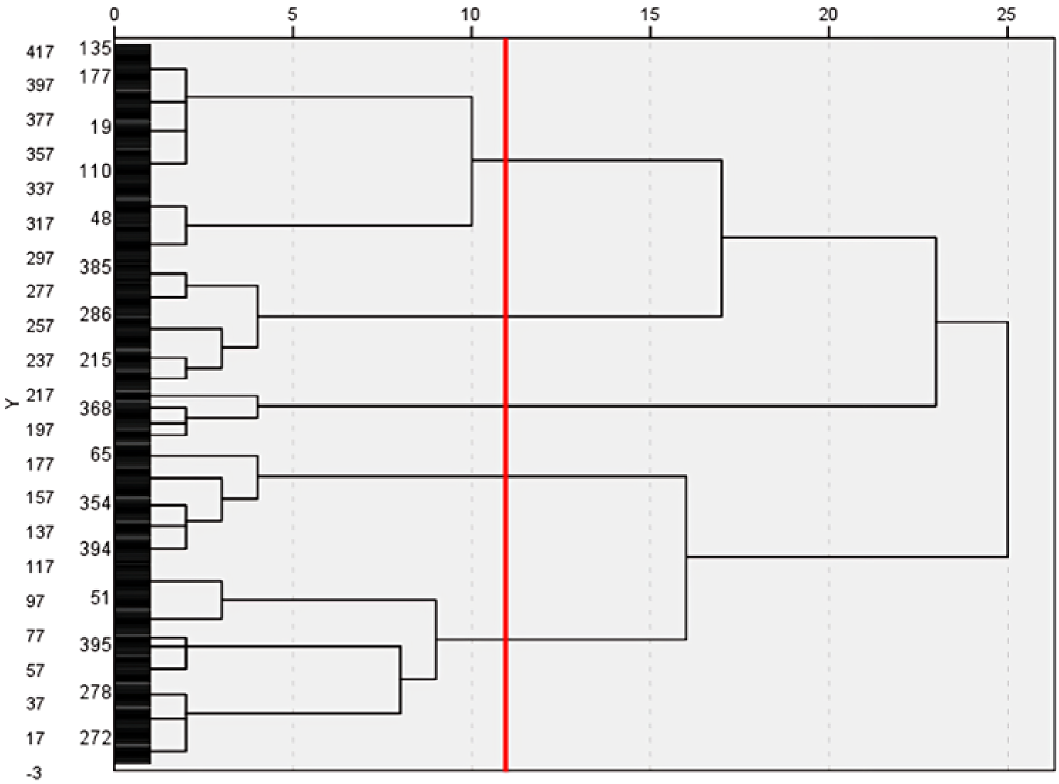

Figure 1. Dendrogram used for the selection of the optimal number of clusters

For the design of the questionnaire, we relied on previously published questionnaires by Barmby et al. (2008), Guzey et al. (2014) and Unfried et al. (2015). The questionnaire was validated by 6 teachers of compulsory secondary education considering the univocity, importance and relevance, which helped us adapt the questions to make sure students could easily understand them. Due to this teachers' validation, we decided to merge in a same block the Engineering and the Technology areas, in coherence to the distribution of STEM subjects in Spanish secondary education school.

This study was carried out under the recommendations of BERA's Ethical Guidelines for Educational Research (British Educational Research Association (BERA), 2018), and the Code of Good Practices in Research of Universitat Rovira i Virgili. The questionnaire was anonymous, and all participants received information on the study prior to giving voluntary informed consent to take part, following the guidelines of the Declaration of Helsinki.

Analysis

As a first step in the search for patterns among data, we determined the most frequent levels for each variable in the database with a descriptive statistical analysis and performed a Principal Component Analysis (PCA) as a method for data reduction. PCA allows obtaining a simplified representation of a large number of variables in a smaller number of factors according to their similarity (Hair et al., 2010), which facilitates the identification and interpretation of data trends. Four factors were found which are described in the results section. Subsequently, a hierarchical cluster analysis was performed to identify the most relevant student profiles. Following Everitt et al. (2011), we grouped students by their similar responses given according to the four factors previously calculated in several grouping steps. Differences between the groups or clusters formed in each grouping step and the subsequent one until all cases were merged hierarchically were calculated with Ward's method, using factor scores for each case. We determined five clusters to be an optimal solution (**Figure 1**): cluster 1 (N = 71, being 17% of the total participating students), cluster 2 (N = 74, 18%), cluster 3 (N = 128, 30%), cluster 4 (N = 116, 28%) and cluster 5 (N = 30, 7%).

RESULTS

Descriptive Statistics

From the sample, 51% of the participants identified themselves as boys, 43% self-identified as girls, 5% do not know or do not want to answer and 1% self-identified as non-binary.

Table 1. Simplified rotated factor loading matrix (the items have been translated from the original language)

Statement	Component			
	Factor 1 Mathematics affinity	**Factor 2 Engineering and Technology affinity**	**Factor 3 Science affinity**	**Factor 4 Climate change awareness**
Mathematics is important to my life. [M1]	.800			
I would like to continue studying more mathematics in the future. [M2]	.796			
I would choose a career that would use math in the future. [M3]	.774			
A good knowledge of mathematics will be important for my future work. [M4]	.757			
I feel confident when I use mathematics in classroom activities. [M5]	.733			
I am good at mathematics. [M6]	.703			
I would like to participate in more activities that use mathematics to reduce the effects of climate change (e.g., extracurricular activities, optional activities at the center...). [M7]	.604			
Mathematics can help lessen the effects of climate change. [M8]	.472			
I would choose a career that would use technology and / or engineering in the future. [T1]		.832		
I would like to continue studying more technology and engineering in the future. [T2]		.829		
A good knowledge of technology and engineering practice will be important for my future work. [T3]		.781		
I would like to take part in more activities that use technology and engineering practice to reduce the effects of climate change (e.g., extracurricular activities, optional activities at the center...). [T4]		.739		
Technology and engineering practice are important to my life. [T5]		.736		
I feel confident when I use technology and take part in engineering practices in classroom activities. [T6]		.720		
I am good at using technology and in engineering practice. [T7]		.699		
I would like to continue studying more science in the future. [S1]			.805	
I would choose a career that would use science in the future. [S2]			.805	
A good knowledge of science will be important for my future work. [S3]			.710	
I am good at science. [S4]			.620	
Science is important to my life. [S5]			.594	
I feel confident when I do science in classroom activities. [S6]			.574	
It is important for me to try to fight climate change. [C1]				.828
I feel confident discussing climate change. [C2]				.783
I believe that climate change is a current and important issue. [C3]				.779
I am interested in learning more about how to fight climate change using scientific knowledge or practice. [S7]				.605
Science can help reduce the effects of climate change. [S8]				.504

Notes: Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalization. Rotation converged in 6 iterations. Loadings less than .40 are not shown and variables are sorted by highest loading. Statements have been translated from Catalan to English for a better comprehension.

Profiles of Students

Results from the exploratory factor analysis

Results of the Principal Component Analysis resulted in four factors: mathematics affinity (Factor 1) comprising 8 items (α = .91), engineering and technology affinity (Factor 2) comprising 7 items (α = .91), science affinity (Factor 3) comprising 6 factors (α = .87), and climate change awareness (Factor 4) comprised 5 factors (α = .79). The simplified rotated factor-loading matrix can be found in **Table 1**, containing the correlation between the variables and the factors.

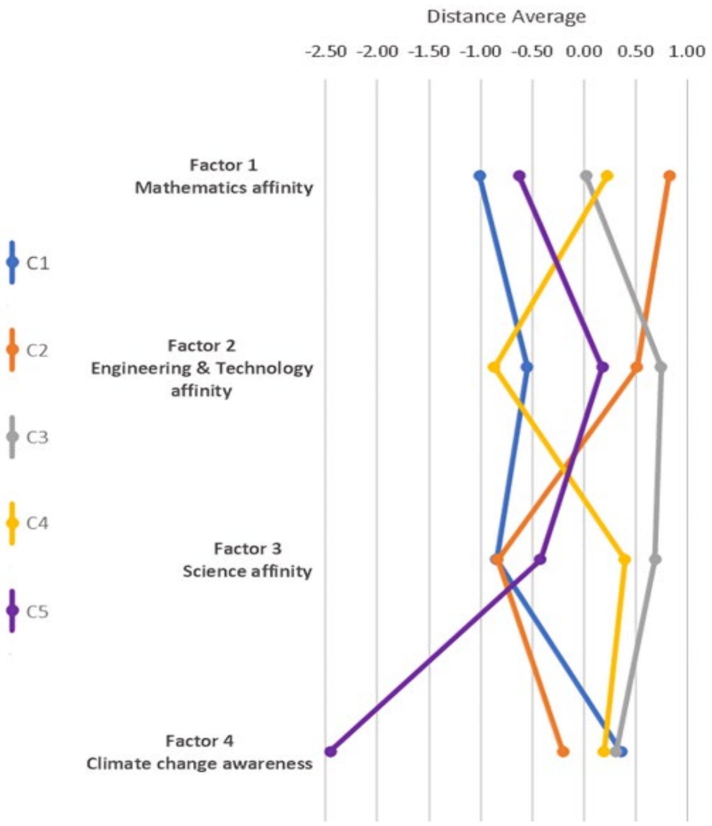

Figure 2. Representation of the five students' profiles (clusters) according to the average distance to the four factors

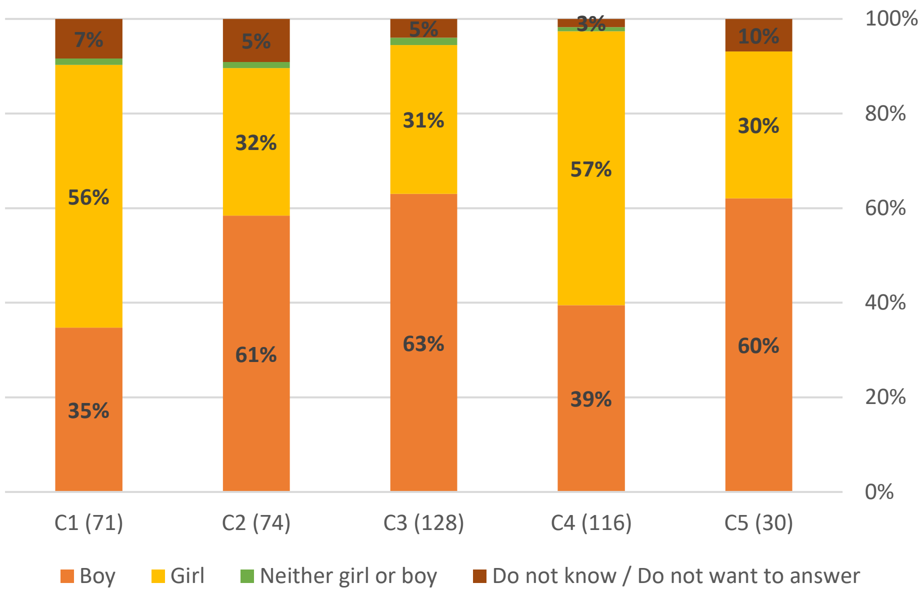

Figure 3. Gender distribution in each of the five clusters

Clustering results

Students' profiles were built according to their proximity to the four factors, identifying five different profiles. A representation of these profiles according to its average distance to each factor can be found in **Figure 2**. Additionally, gender distribution in the clusters was analyzed (**Figure 3**). The proportion of students self-identifying with the different genders differed by the clusters, χ^2 (12, N = 419) = 30.714, p < .002.

Students grouped in Cluster 1 (17%) are characterized by displaying significant aversion towards all STEM areas, especially towards mathematics, but high awareness towards climate change (**Figure 2**). In this group, there

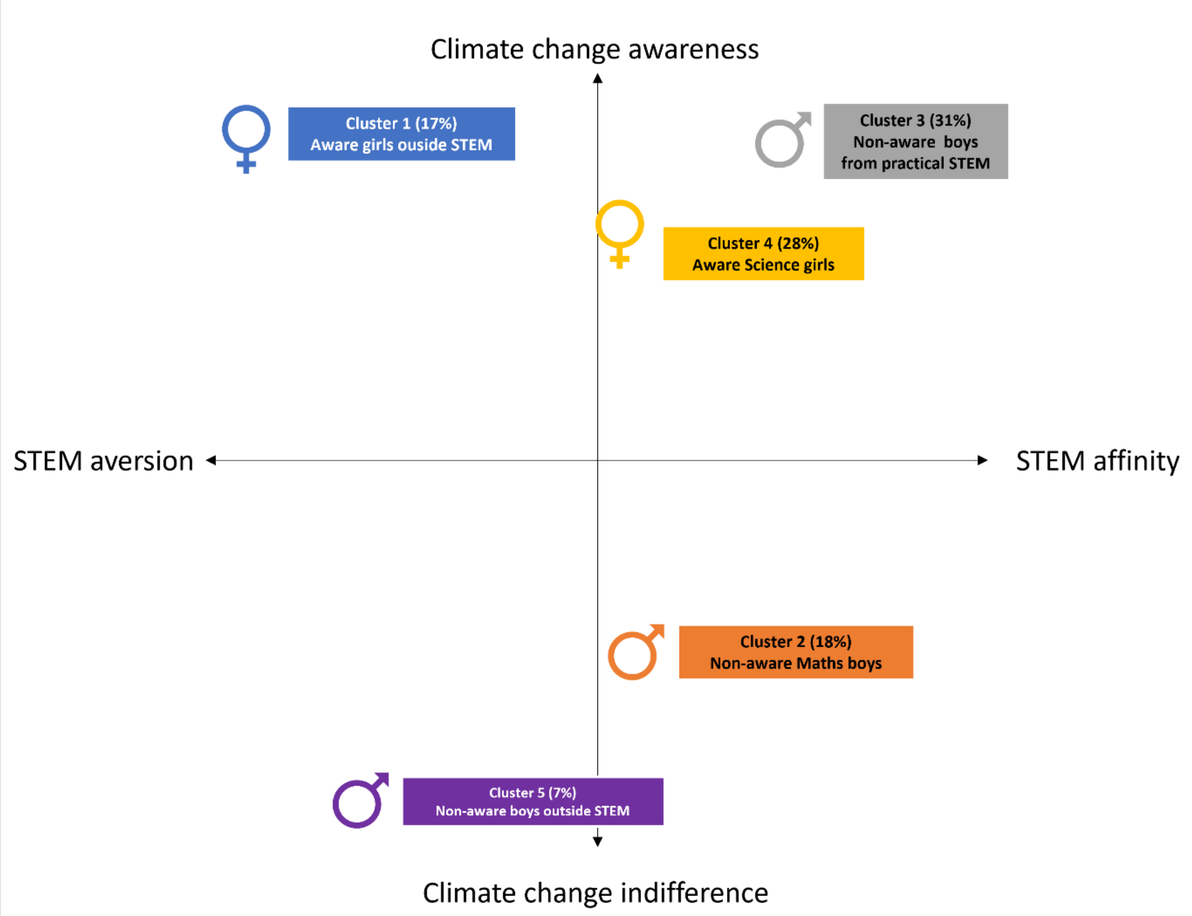

Figure 4. Overview of the main characteristics of students' profiles according to their STEM affinity, climate change awareness or indifference and main gender group (gender symbols and tags are proportional to clusters' sizes)

is a significantly higher proportion of students self-identifying as girls (Figure 3). Based on their attitudes towards STEM areas, climate change and distribution of gender, we labelled Cluster 1 as "**aware girls outside STEM**".

Students grouped in Cluster 2 (18%) are characterized by displaying high affinity towards mathematics (i.e., aspirations, self-efficacy, relevance to their lives and their future) and towards technology and engineering on a second level. Conversely, students in cluster 2 display a strong aversion towards science and a moderate but also low awareness towards climate change and its relevance (Figure 2). This cluster is significantly populated by students self-identifying as boys (Figure 3). We labelled Cluster 2 as "**non-aware maths boys**", because of their affinity towards this STEM area.

Students grouped in Cluster 3, representing the biggest group (31%), are characterized by displaying high affinity towards technology and engineering practices and towards science on a second level. These students do not show a positive affinity towards mathematics, but also neither a negative predisposition. Regarding climate change, these students are positively aware of its relevance and importance for their lives and for the planet (Figure 2). This cluster is significantly formed by students self-identifying as boys (Figure 3). We labelled Cluster 3 as "**aware boys from practical STEM**", because of their apparent affinity towards the applied STEM areas.

Students grouped in Cluster 4 (28%) are characterized by displaying high affinity towards science and a very small, but positive, affinity towards mathematics. Conversely, these students show an important aversion towards technology and engineering practices. These students are also positively aware of the issues regarding climate change (Figure 2). This cluster is significantly formed by students self-identifying as girls (Figure 3). We labelled Cluster 4 as "**aware science girls**".

Students grouped in Cluster 5 (7%) are characterized by displaying a small positive affinity towards technology and engineering practices, but moderate aversion towards mathematics and science. These students show an enormous indifference towards climate change and its implications (Figure 2). Moreover, this cluster is significantly formed by students self-identifying as boys (Figure 3). We labelled Cluster 5 as "**non-aware boys outside STEM**".

Finally, clusters' main traits are outlined with visual representation (see Figure 4), according to their STEM affinity or aversion, climate change awareness or indifference and main gender group.

DISCUSSION

In this study, 419 secondary school students from three urban semi-private schools participated in an online questionnaire aimed at characterizing their attitudes towards STEM areas and climate change. Through an exploratory methodological approach, students' answers were analyzed to identify the most relevant student profiles by using a hierarchical clustering analysis. Results show that students grouped into two clusters (Cluster 2–non-aware maths boys, and Cluster 5–non-aware boys outside STEM), corresponding to the 25% of the sample, express a little level of concern about climate change. Conversely, 75% of the participating students are concerned about climate change. These results, which are higher than in previous studies (European Union, 2021; Hermans and Korhonen, 2017), suggest an increase in the level of climate change awareness among the participants.

It is worth noting that students grouped into Cluster 2 and Cluster 5 have mostly self-identified as boys (61% and 60%, respectively). On the other side, the cluster where students show the highest level of concern towards climate change is formed by students self-identifying as girls (Cluster 1–aware girls outside STEM, formed by 56% of girls). This result is aligned with previous research that found that girls are more concerned about climate change than boys (Dijkstra and Goedhart, 2012), and gender as a variable that influences climate change attitudes in many countries (Hunter et al., 2004; Jackson et al., 2016; Poortinga et al., 2019; World Bank, 2010). Also, existing research has shown that common ways of talking about climate change are gendered, as the frequent use of ethical and environmental justice arguments in the public discourses are attributed to women (Swim et al., 2018). This behavior is related to hetero-normative gender roles, where girls tend to align more with activities about caring for people and the environment and boys with instrumental activities related to power, success, and autonomy (Sáinz et al., 2017).

Regarding student attitudes in relation to STEM disciplines, students grouped into two clusters (Cluster 2–non-aware maths boys, and Cluster 3–aware boys from practical STEM, representing 48% of the sample), express a positive attitude towards two or more STEM areas. Compared to previous research from similar contexts (Grimalt-Álvaro et al., 2022), the percentage of students expressing an interest in two or more STEM areas are slightly higher in the present study. These authors described that only 39% of students considered themselves "STEM people", which means showing a positive positioning towards two or more STEM areas (Grimalt-Álvaro et al., 2022). These differences can be due to the higher rate of students from middle socioeconomic background in the present study and, consequently, students being more familiar with STEM professions due to contextual issues such as parents' educational level and jobs, and the city of Tarragona having the largest petrochemical industry in southern Europe (Rovira et al., 2021). Moreover, Cluster 2 and 3 show differences in stereotyped gender distribution in relation to STEM attitudes, as both show that the most positive attitudes are mainly from students who self-identify as boys (61% in Cluster 2–non-aware maths boys, and 63% in Cluster 3–aware boys from practical STEM), and are inclined towards maths and engineering, and science and engineering, respectively. Students grouped in Cluster 4–aware science girls also express positive attitude, but only towards science, being this cluster formed by a higher proportion of girls (57%). Moreover, regarding students in non-STEM clusters (Cluster 1–aware girls outside STEM, and Cluster 5–non-aware boys outside STEM) engineering and technology seems to be still the most attractive area in STEM, especially for Cluster 5 (mostly formed by boys). Although technology is usually considered as being motivating for students (especially for boys), these gendered differences are aligned with prior studies where boys also showed a greater interest in engineering and technology and girls in science (UNESCO, 2017), and consequently choose studies related to these disciplines (Wong, 2015). Our results question the effectiveness of the general educational approach of STEM initiatives to engage and promote STEM literacy among all students, since engineering and technology, which are the dominant disciplines in STEM education, would only be more appealing for boys (Martín-Páez et al., 2019).

Another significant aspect is that no cluster was found in which students expressed interests in all STEM areas equally. Whereas students grouped in Cluster 2 (non-aware maths boys) are mostly inclined towards mathematics and engineering, students in Cluster 3 (aware boys from practical STEM) are inclined towards engineering and science, and students in Cluster 4 (aware science girls) are only towards science. Previous studies have shown how students, even having and expressing a general sense of "being a STEM person", either self-identify as science or technology/engineering-related person (Grimalt-Álvaro et al., 2022). However, differences in gender distribution between clusters discussed above contribute to a better understanding of how boys and girls relate to STEM. Hence, boys participating in this study present a positive attitude towards engineering and technology, and show an interest in mathematics and science, but those two fields are inversely related: a higher interest in mathematics involves a lower interest in science (Cluster 2), and vice versa (Cluster 3). Regarding this study results, a positive attitude towards science and a negative towards engineering is evidenced in girls, while mathematics plays a more neutral role (Cluster 4). These results suggest that students expressing a positive attitude towards science might have a lower interest in mathematics, possibly due to the instrumental view given to mathematics, reinforced by its secondary role in the main approach of STEM activities (Martín-Páez et al., 2019). Therefore, although some boys express positive attitudes toward mathematics, girls have more difficulties in it.

Considering how attitudes toward STEM and climate change are related, we observe that for STEM clusters, students with positive attitudes towards science show higher levels of concern about climate change (Cluster 3 and 4). These results confirm previous findings in which weak relationships between climate change attitudes and science-related attitudes were found, especially for girls (Dijkstra and Goedhart, 2012). In this study, we also interpret that for boys, positive attitudes towards engineering and technology could also be linked to a greater concern about climate change (Cluster 3). However, boys who expressed positive attitudes towards mathematics (Cluster 2) showed little levels of concern about climate change. We cautiously interpret this finding as boys in this cluster being more aligned with normative gender stereotypes, as mathematics have been shown to have the strongest attribute of masculinity in STEM fields (Makarova et al., 2019).

Regarding non-STEM clusters, the results of this study show differences in the level of student concern about climate change between boys-dominated Cluster 5 and girls-dominated Cluster 1. Girls-dominated Cluster 1 shows a higher level of concern about climate change than boys-dominated Cluster 5, which presents a lower level of interest and attitude in this topic. These findings suggest that non positive attitudes towards STEM could be related to traditional gender stereotypes. Further studies could explore how girls showing lower positive attitudes towards STEM find other ways of pursuing their climate action goals through non-STEM areas of knowledge. This information can enrich sustainability and climate change education and STEAM initiatives, expanding the scope of STE(A)M education, through providing hands-on and transdisciplinary approaches to real-life sustainability challenges (Taylor, 2016).

The study findings contribute to a better understanding of how climate change education can be promoted through STEM education, moving from conventional teaching structures and processes to transdisciplinary and hands-on learning (Nguyen et al., 2020), but also, providing more opportunities for all students to feel engaged. Therefore, including climate change as a relevant problem in STEM education initiatives. This can contribute to increasing society and citizens' climate change literacy, and in turn help increase girls' interest in STEM, through the development of more gender-balanced curricula that links abstract concepts with real-life situations (UNESCO, 2017). Moreover, the way in which climate change is addressed in STEM activities also needs to be considered, as the frequent use of ethics and environmental justice arguments can present barriers for boys (Swim et al., 2018). Hence, providing a better gender-balanced approach in the curricula also implies the use of more science-business related arguments in climate change education, which are usually more appealing for boys (Swim et al., 2018), evidencing the positive and reciprocal influence of STEM education. Climate change education must be connected to engineering design, as well as to mathematics, as this could also be beneficial for engaging boys (Nguyen et al., 2020)

This study presents some limitations mainly associated to the study sample and context, conducted with a group student from three secondary schools in a specific region and context, therefore the results obtained cannot be generalized to other contexts. Also, we acknowledge that cluster sizes might have influenced the gender differences found in our study. Thus, the results from this exploratory study provide evidence of main trends in relation to gender-based differences in students' attitudes and significant relationships in a specific group of students that can potentially help improve STEM and climate change education reciprocally. In further research, with a bigger sample from a wider geographical area and socioeconomic representation, an intersectional approach could be beneficial to identify more nuanced relationships, as the homogeneity of our sample in terms of socio-economic and racial background did not make it possible. Hence, further studies could focus on exploring how different sociocultural contexts might mediate these relationships, for example, by considering the influence of having parents in STEM jobs. Furthermore, adopting a different method to analyze the data collection could enhance our comprehension of the situation. At present, we notice variations in factor loadings for different items, but there is a lack of comprehension regarding the underlying reasons. This hinders our understanding of the connections between gender differences in climate change and STEM attitudes. In further studies different data collection methods could be used in combination to triangulate the data obtained including open-ended questions, student reflections, interviews or focus groups with students from the different identified profiles.

This study, far from seeking to reify main gender differences and compare genders, is intended to be a first step towards developing a more inclusive STEM education that can respond to the complex and current global problems associated to climate change. Hence, we are aware that to promote girls' interest towards STEM education, it is not sufficient to simply include climate change as part of the curriculum. Similarly, if the challenge is to make male students more interested in climate change, then the solution should not be simply to attract them through greater focus on engineering and design. Knowing the relationship between both, STEM attitudes and climate change attitudes, and exploring the gender distribution, enables reframing and reorienting educational approaches to engage girls and boys as active learners to disabuse gender-based biases and patriarchal discourses in STEM learning.

CONCLUSIONS

The aim of this research was to fill in the gap identified in the literature, which refers to the relationship between secondary school students' STEM and climate change attitudes through conducing an exploratory study. We identified five profiles of students (clusters), based on their different attitudes toward STEM disciplines and climate change action, collected in their answers to a questionnaire. Within these clusters, gendered distribution associated to traditional stereotypes are found, where girls express a higher concern about climate change and lower levels of interest towards STEM, and boys show less interest towards climate change, but more positive attitude towards STEM, especially regarding engineering and technology. The gender differences in the clusters identified in this study are an opportunity to develop more inclusive educational initiatives that better contribute to the achievement of STEM and climate change education goals from a mutual enrichment.

AUTHORS CONTRIBUTIONS

GC, LM and CV develop the introduction and the methodology part. CG worked in the analysis and interpretation of the results. All the authors develop the questionnaire and collect the data. All of them contributed to the discussion part and the global revision.

ACKNOWLEDGEMENTS

This publication is part of the Project EDSSE: Ecosistemas Digitales Sostenibles en Educación with reference number PID2022-142071OB-I00 2023 - 2026 and funded by MCIN/AEI/10.13039/501100011033/FEDER, UE. The title and reference number "Proyecto EDSSE: Ecosistemas Digitales Sostenibles en Educación" PID2022-142071OB-I00 2023 - 2026 the title and reference appearing in the reference listed in the grant award resolution; MCIN the acronym of "Ministerio de Ciencia e Innovación"; AEI the acronym of "Agencia Estatal de Investigación"; 10.13039/501100011033 the DOI (Digital Object Identifier) of the Agency; and FEDER the acronym of "Fondo Europeo de Desarrollo Regional."

The author Gisela Cebrián is Associate Professor in the Serra Húnter Program.

The author Cristina Valls is lecturer teacher in the Serra Húnter Program.

REFERENCES

Archer, L., Osborne, J., DeWitt, J., Dillon, J., Wong, B. and Willis, B. (2013). ASPIRES: Young people's science and career aspirations, age 10–14, *VOCEDplus*. Available at: https://www.voced.edu.au/content/ngv%3A60856.

Barmby, P., Kind, P. M. and Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education*, 30(8), 1075–1093. https://doi.org/10.1080/09500690701344966

Beghetto, R. A. (2007). Factors associated with middle and secondary students' perceived science competence. *Journal of Research in Science Teaching*, 44(6), 800–814. https://doi.org/10.1002/tea.20166

Biasutti, M. (2015). An intensive programme on education for sustainable development: The participants' experience. *Environmental Education Research*, 21(5), 734–752. https://doi.org/10.1080/13504622.2014.921805

Breiner, J. M., Harkness, S. S., Johnson, C. C. and Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, 112(1), 3–11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

British Educational Research Association (BERA). (2018). *Ethical Guidelines for Educational Research* (4th ed). London: BERA. https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M., Losch, K., Michel, J., Mochizuki, Y., Rieckmann, M., Parnell, R., Walker, P. and Zint, M. (2021). Key competencies in sustainability in higher education—toward an agreed-upon reference framework. *Sustainability Science*, 16, 13–29. https://doi.org/10.1007/s11625-020-00838-2

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30–35.

Cebrián, G., Junyent, M. and Mulà, I. (2020). Competencies in education for sustainable development: Emerging teaching and research developments. *Sustainability*, 12, 579–587. https://doi.org/10.3390/su12020579

Cian, H. and Dou, R. (2024). Masculinized discourses of STEM interest, performance, and competence that shape university STEM students' recognition of a "STEM person". *Journal of Research in Science Teaching*, 61(5), 1062–1092. https://doi.org/10.1002/tea.21937

Cooper, J., Blackman, S. F. and Keller, K. T. (2016). *The Science of Attitudes*. Oxfordshire: Routledge. https://doi.org/10.4324/9781315717319

Couso, D., Domènech Casal, J., Simarro Rodríguez, C., López Simó, V. and Grimalt-Álvaro, C. (2022). Perspectives, metodologies i tecnologies en el desplegament de l'educació STEM. *Ciències: Revista Del Professorat de Ciències de Primària i Secundària*, 44, 56–71. https://doi.org/10.5565/rev/ciencies.470

Deisenrieder, V., Kubisch, S., Keller, L. and Stötter, J. (2020). Bridging the action gap by democratizing climate change education—The case of *k.i.d.Z.21* in the context of Fridays for future. *Sustainability*, 12(5), 1748. https://doi.org/10.3390/su12051748

Dijkstra, E. M. and Goedhart, M. J. (2012). Development and validation of the ACSI: Measuring students' science attitudes, pro-environmental behaviour, climate change attitudes and knowledge. *Environmental Education Research*, 18(6), 733–749. https://doi.org/10.1080/13504622.2012.662213

Dökme, İ., Açıksöz, A. and Koyunlu Ünlü, Z. (2022). Investigation of STEM fields motivation among female students in science education colleges. *International Journal of STEM Education*, 9(1), 8. https://doi.org/10.1186/s40594-022-00326-2

European Union. (2021). *Special Eurobarometer 513. Climate change*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2834/437

Everitt, B. S., Landau, S., Leese, M. and Stahl, D. (2011). *Cluster Analysis*. Oxford: John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470977811

Filho, W. L., Yayeh Ayal, D., Wall, T., Shiel, C., Paco, A., Pace, P., Mifsud, M., Lange Salvia, A., Skouloudis, A., Moggi, S., LeVasseur, T., Vinuesa Antonio, G., Azeiteiro, U. M., Ioannis, N. and Kovaleva, M. (2023). An assessment of attitudes and perceptions of international university students on climate change. *Climate Risk Management*, 39, 100486. https://doi.org/10.1016/j.crm.2023.100486

González Gaudiano, E. J. and Meira-Cartea, P. Á. (2020). Educación para el cambio climático: ¿Educar sobre el clima o para el cambio? [Climate change education: Educating about climate or for change?]. *Perfiles Educativos*, 42(168), 157–174. https://doi.org/10.22201/iisue.24486167e.2020.168.59464

Grimalt-Álvaro, C., Couso, D., Boixadera-Planas, E. and Godec, S. (2022). "I see myself as a STEM person": Exploring high school students' self-identification with STEM. *Journal of Research in Science Teaching*, 59(5), 720–745. https://doi.org/10.1002/tea.21742

Guzey, S. S., Harwell, M. and Moore, T. (2014). Development of an instrument to assess attitudes toward science, technology, engineering, and mathematics (STEM). *School Science and Mathematics*, 114(6), 271–279. https://doi.org/10.1111/ssm.12077

Hair Jr, J. F., Black, W. C. and Babin, B. J. (2010). *Multivariate Data Analysis* (7th ed.). London: Pearson.

Hermans, M. and Korhonen, J. (2017). Ninth graders and climate change: Attitudes towards consequences, views on mitigation, and predictors of willingness to act. *International Research in Geographical and Environmental Education*, 26(3), 223–239. https://doi.org/10.1080/10382046.2017.1330035

Hunter, L. M., Hatch, A. and Johnson, A. (2004). Cross-national gender variation in environmental behaviors. *Social Science Quarterly*, 85(3), 677–694. https://doi.org/10.1111/j.0038-4941.2004.00239.x

Ignell, C., Davies, P. and Lundholm, C. (2019). A longitudinal study of upper secondary school students' values and beliefs regarding policy responses to climate change. *Environmental Education Research*, 25(5), 615–632. https://doi.org/10.1080/13504622.2018.1523369

Jackson, L. and Pang, M.-F. (2017). Secondary school students' views of climate change in Hong Kong. *International Research in Geographical and Environmental Education*, 26(3), 180–192. https://doi.org/10.1080/10382046.2017.1330036

Jackson, L., Pang, M. F., Brown, E., Cain, S., Dingle, C. and Bonebrake, T. (2016). Environmental attitudes and behaviors among secondary students in Hong Kong. *International Journal of Comparative Education and Development*, 18(2), 70–80. https://doi.org/10.1108/IJCED-10-2015-0004

Jucker, R. and Mathar, R. (eds) (2015). *Schooling for Sustainable Development in Europe*. Springer International Publishing. https://doi.org/10.1007/978-3-319-09549-3

Kirbiš, A. (2023). Environmental attitudes among youth: How much do the educational characteristics of parents and young people matter? *Sustainability*, 15(15), 11921. https://doi.org/10.3390/su151511921

Kolmos, A., Mejlgaard, N., Haase, S. and Holgaard, J. E. (2013). Motivational factors, gender and engineering education. *European Journal of Engineering Education*, 38(3), 340–358. https://doi.org/10.1080/03043797.2013.794198

Lambrechts, W., Van Liedekerke, L. and Van Petegem, P. (2018). Higher education for sustainable development in Flanders: Balancing between normative and transformative approaches. *Environmental Education Research*, 24(9), 1284–1300. https://doi.org/10.1080/13504622.2017.1378622

Lee, K., Gjersoe, N., O'Neill, S. and Barnett, J. (2020). Youth perceptions of climate change: A narrative synthesis. *WIREs Climate Change*, 11(3), e641. https://doi.org/10.1002/wcc.641

Li, Y., Wang, K., Xiao, Y. and Froyd, J. E. (2020). Research and trends in STEM education: A systematic review of journal publications. *International Journal of STEM Education*, 7, 11. https://doi.org/10.1186/s40594-020-00213-8

Lv, Z. and Deng, C. (2019). Does women's political empowerment matter for improving the environment? A heterogeneous dynamic panel analysis. *Sustainable Development*, 27(4), 603–612. https://doi.org/10.1002/sd.1926

Maass, K., Geiger, V., Ariza, M. R. and Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *ZDM*, 51(6), 869–884. https://doi.org/10.1007/s11858-019-01100-5

Mahoney, M. P. (2012). Students' attitudes toward STEM: Development of an instrument for high school STEM-based programs. *The Journal of Technology Studies*, 8(3), 24–34. https://doi.org/10.21061/jots.v36i1.a.4

Makarova, E., Aeschlimann, B. and Herzog, W. (2019). The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. *Frontiers in Education*, 4. https://doi.org/10.3389/feduc.2019.00060

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J. and Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, 103(4), 799–822. https://doi.org/10.1002/sce.21522

McDaniel, A. (2016). The role of cultural contexts in explaining cross-national gender gaps in STEM expectations. *European Sociological Review*, 32(1), 122–133. https://doi.org/10.1093/esr/jcv078

Medina, M. Á. and Galván, J. J. (2021). La nueva ley de educación (LOMLOE) ante los objetivos de desarrollo sostenible de la agenda 2030 y el reto de la COVID-19 [The new education law (LOMLOE) in light of the 2030 agenda's sustainable development goals and the challenge of COVID-19]. *Avances En Supervisión Educativa. Revista de La Asociación de Inspectores de Educación de España*, 4, 1–42. https://doi.org/10.23824/ase.v0i35.709

Mochizuki, Y. and Bryan, A. (2015). Climate change education in the context of education for sustainable development: Rationale and principles. *Journal of Education for Sustainable Development*, 9(1), 4–26. https://doi.org/10.1177/0973408215569109

Nguyen, T. P. L., Nguyen, T. H. and Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability*, 12(21), 8865. https://doi.org/10.3390/su12218865

Norgaard, K. and York, R. (2005). Gender equality and state environmentalism. *Gender & Society*, 19(4), 506–522. https://doi.org/10.1177/0891243204273612

Nugent, C. and Shandra, J. M. (2009). State environmental protection efforts, women's status, and world polity. *Organization & Environment*, 22(2), 208–229. https://doi.org/10.1177/1086026609338166

OECD. (2019). *PISA 2018 Results (Volume II): Where all students can succeed.* OECD Publishing. https://doi.org/10.1787/b5fd1b8f-en

OECD. (2023). *PISA 2025 Science Framework (Second Draft).* OECD Publishing. https://pisa-framework.oecd.org/science-2025/assets/docs/PISA_2025_Science_Framework.pdf

Östman, L., Van Poeck, K. and Öhman, J. (2019). Principles for sustainable development teaching, in K. Van Poeck, L. Östman and J. Öhman (eds), *Sustainable Development Teaching: Ethical and political challenges* (pp. 40–56). Routledge. https://doi.org/10.4324/9781351124348-4

Poortinga, W., Whitmarsh, L., Steg, L., Böhm, G. and Fisher, S. (2019). Climate change perceptions and their individual-level determinants: A cross-European analysis. *Global Environmental Change*, 21(55), 25–35. https://doi.org/10.1016/j.gloenvcha.2019.01.007

Regan, E. and Dewitt, J. (2015). Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature, in E. K. Henriksen, J. Dillon and J. Ryder (eds), *Understanding Student Participation and Choice in Science and Technology Education* (pp. 63–88). Springer. https://doi.org/10.1007/978-94-007-7793-4

Reid, A. (2019). Climate change education and research: Possibilities and potentials versus problems and perils? *Environmental Education Research*, 25(6), 767–790. https://doi.org/10.1080/13504622.2019.1664075

Rogers, M., Pfaff, T., Hamilton, J. and Erkan, A. (2015). Using sustainability themes and multidisciplinary approaches to enhance STEM education. *International Journal of Sustainability in Higher Education*, 16(4), 523–536. https://doi.org/10.1108/IJSHE-02-2013-0018

Rovira, J., Nadal, M., Schuhmacher, M. and Domingo, J. L. (2021). Environmental impact and human health risks of air pollutants near a large chemical/petrochemical complex: Case study in Tarragona, Spain. *Science of the Total Environment*, 787, 147550. https://doi.org/10.1016/j.scitotenv.2021.147550

Sáinz, M., Castaño Collado, C., Meneses, J., Fàbregues, S., Müller, J., Rodó, M., Martínez, J. L., Romano, M. J., Arroyo, L. and Garrido, N. (2017). *¿Por Qué No Hay Más Mujeres STEM? Se buscan ingenieras, físicas y tecnólogas* [Why Aren't There More Women in STEM? Female engineers, physicists and technologists wanted]. Editorial Ariel. https://hdl.handle.net/10609/86626

Starr, C. R. and Leaper, C. (2019). Do adolescents' self-concepts moderate the relationship between STEM stereotypes and motivation? *Social Psychology of Education*, 22(5), 1109–1129. https://doi.org/10.1007/s11218-019-09515-4

Sterling, S., Glasser, H., Rieckmann, M. and Warwick, P. (2017). 10. "More than scaling up": A critical and practical inquiry into operationalizing sustainability competencies, in P. B. Corcoran, J. P. Weakland and A. E. J. Wals (eds), *Envisioning Futures for Environmental and Sustainability Education* (pp. 153–168). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-846-9_10

Stevenson, K. T., Peterson, M. N. and Bondell, H. D. (2019). The influence of personal beliefs, friends, and family in building climate change concern among adolescents. *Environmental Education Research*, 25(6), 832–845. https://doi.org/10.1080/13504622.2016.1177712

Stibbe, A. (ed) (2009). *The Handbook of Sustainability Literacy. Skills for a changing world*. Green Books.

Swim, J. K., Vescio, T. K., Dahl, J. L. and Zawadzki, S. J. (2018). Gendered discourse about climate change policies. *Global Environmental Change*, 48, 216–225. https://doi.org/10.1016/j.gloenvcha.2017.12.005

Taylor, C. P. (2016). Why is a STEAM curriculum perspective crucial to the 21st century?, in *Proceedings of the 14th Annual Conference of the Australian Council for Educational Research* (pp. 89–93).

Trott, C. D. and Weinberg, A. E. (2020). Science education for sustainability: Strengthening children's science engagement through climate change learning and action. *Sustainability*, 12(16), 6400. https://doi.org/10.3390/su12166400

UNESCO and UNFCCC. (2016). *Action for Climate Empowerment: Guidelines for accelerating solutions through education, training and public awareness*. https://unfccc.int/files/cooperation_and_support/education_and_outreach/application/pdf/action_for_climate_empowerment_guidelines.pdf

UNESCO. (2017). *Cracking the Code: Girls and women's education in science, technology, engineering and mathematics (STEM)*. https://unesdoc.unesco.org/images/0025/002534/253479E.pdf

UNESCO. (2020). *Education for Sustainable Development: A roadmap*. https://unesdoc.unesco.org/ark:/48223/pf0000374802.locale=en

UNFCCC. (1992). *United Nations Framework Convention on Climate Change* (Vol. 62220). https://unfccc.int/resource/docs/convkp/conveng.pdf

UNFCCC. (2015). *Adoption of the Paris Agreement. 21st Conference of the Parties* (Vol. 21932, Issue December). https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

UNFCCC. (2022). *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021* (Issue March). https://unfccc.int/sites/default/files/resource/cma2021_10_add1_adv.pdf

Unfried, A., Faber, M., Stanhope, D. S. and Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, 33(7), 622–639. https://doi.org/10.1177/0734282915571160

United Nations. (2015). *Transforming Our World: The 2030 agenda for sustainable development*. https://sustainabledevelopment.un.org/post2015/transformingourworld

Wals, A. E. J. (2010). Mirroring, Gestaltswitching and transformative social learning. *International Journal of Sustainability in Higher Education*, 11(4), 380–390. https://doi.org/10.1108/14676371011077595

Wang, M. and Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review*, 29(1), 119–140. https://doi.org/10.1007/s10648-015-9355-x

Wong, B. (2015). Careers "from" but not "in" science: Why are aspirations to be a scientist challenging for minority ethnic students? *Journal of Research in Science Teaching*, 52(7), 979–1002. https://doi.org/10.1002/tea.21231

World Bank. (2010). Public attitudes toward climate change: Findings from a multi-country poll. https://hdl.handle.net/1903/10746

Zeidler, D. L. (2016). STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education*, 11(1), 11–26. https://doi.org/10.1007/s11422-014-9578-z

