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Gender Differences in Adolescent's Climate Change Knowledge and Perceptions. Meta-Analysis

Diferencias de género en el conocimiento y las percepciones del cambio climático entre adolescentes. Metaanálisis

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Abstract

Are there differences between adolescent men and women in terms of knowledge about climate change? How do adolescents perceive the climate crisis depending on their gender? In order to answer these questions, we carried out a meta-analysis on a sample of 84 international papers selected by conducting a systematic review methodology. To achieve that aim, we identified studies that showed differences according to the gender variable in terms of knowledge, perceptions, and/or opinions among adolescents pursuing secondary education. A total of 26 out of 84 papers (30.95%)—concentrated between 1993 and 2017—addressed gender differences regarding climate change. The meta-analysis revealed that women score lower than men on knowledge about climate change, with the difference increasing as they move forward in their respective secondary education courses. However, women are found to attribute greater risk to the climate crisis, they are more concerned about the problem, and—unlike men, who have a more technical worldview—they show greater ecocentric willingness to accept measures to address it.

Keywords: adolescents, climate change, gender, meta-analysis, students.

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Resumen

¿Existen diferencias de conocimiento acerca del cambio climático entre adolescentes mujeres y hombres? ¿Cómo perciben los adolescentes la crisis climática en función del género? Con el fin de dar respuesta a estas preguntas se realizó un metaanálisis con una muestra de 84 artículos internacionales seleccionados con la metodología de revisión bibliográfica sistematizada, para lo cual se identificaron aquellos en los que —de acuerdo con la variable de género— existían diferencias de conocimiento, percepciones y/o valoraciones entre los adolescentes que cursaban educación secundaria. Del total de artículos —que se concentró entre 1993 y 2017— 26 de ellos (30,95%) abordaban las diferencias de género en relación con el cambio climático. El metaanálisis reveló que las mujeres obtenían menores puntuaciones que los hombres respecto de los conocimientos en esta temática, con una diferencia aumentada conforme se avanzaba en los respectivos cursos de educación secundaria, aunque atribuían un mayor riesgo a la crisis climática, presentaban mayor preocupación por el problema y, a diferencia de los hombres que evidenciaban una cosmovisión más tecnicista, estas mostraron mayor disposición ecocéntrica para aceptar las medidas contra la crisis climática.

Palabras clave: adolescentes, cambio climático, estudiantes, género, metaanálisis.

Introduction

Because of its complexity and multidimensionality, climate change (hereinafter CC) has been included as curricular content in a space between the teaching of sciences and environmental education. In the case of the former, this is based on knowledge of its physical-chemical bases, approaching it mainly as a atmospheric phenomenon (Serantes-Pazos, 2017), drawing from literacy approaches founded on the theory of conceptual change (Oliva, 1999). In the case of the latter, this is based on social constructivism, which seeks to understand the construction of subjective meanings of the relationships between human societies and the environment through social, historical, and cultural norms (Creswell, 2013).

The long history of both disciplines can be seen in the prolific amount of literature, in which we can find studies, reviews, and meta-analyses related to existing gender differences in terms of knowledge, perceptions, or attitudes towards scientific-technical and socio-environmental content, which enables us to approach our topic of study: climate change and gender differences in how it is represented. In this respect, Fisher, Thompson, and Brookes (2020) carried out a review of the scientific literature with the aim of understanding what factors influenced the low number (less than 15%) of Australian women enrolled in university courses related to science, technology, engineering, and math (STEM) subjects. In their research, of a total of 26 studies, 20 were identified as finding a higher percentage of women who declared that they had a lower level of self-efficacy than men when it came to scientific abilities and skills, even in areas where there was a higher percentage of women enrolled, such as in biology.

So, despite the fact that the study did not explicitly examine traits of self-efficacy, the results showed that the women had less confidence in their knowledge and skills. The authors emphasize that the perception of self-efficacy is one of the main elements of motivation, ahead of possession of knowledge, which is a determining factor of gender inequality in this type of educational experience. In this regard, Schönfelder and Bogner (2020) examined the existing interactions between science education and environmental values, a cross-cutting

topic that is usually related to teaching science. This study shows that there is a higher level of self-efficacy when solving problems related to scientific-technical content among men, which could influence the lower intrinsic motivation of women towards science.

For his part, McCright (2010) conducted an analysis between 2001 and 2008 based on public surveys (Gallup polls) that were focused on issues related to the environment. The data revealed that there were differences in scientific or ecological knowledge depending on gender, with women declaring lower levels of knowledge, a difference that increased over the years and as the level of educational increased. According to Finucane, Slovic, Mertz, Flynn, and Satterfield (2000), this is related to women's lower confidence in their scientific skills and knowledge, which conditions future choices in their academic orientations and increases—even more, if possible—the gender gap.

On the other hand, various authors claim that a lower disposition towards science and technology is related to certain teaching methods in which individualistic and competitive practices—which are less interesting to women—are present in a large proportion of teaching-learning processes in the sciences. Likewise, there are explanations that highlight the lack of relevant female scientific figures, as well as the expectations of making a professional scientific career compatible with forming a family (Dijkstra & Goedhart, 2011).

With reference to this point, Fisher et al. (2020) found that 15 of the 36 studies selected examined the opinions of teaching-learning processes in STEM subjects, where the anxiety produced by the assessment of this type of knowledge is highlighted mainly amongst women and this has a direct relationship with the low levels of self-efficacy mentioned above. Moreover, this study continues the trend of those that identify traits of masculinization of STEM subjects, such as the "geek" stereotype in technology[1], with which the female students stated they did not feel identified, one of the conclusions that has been supported and detailed by Cheryan, Plaut, Davies, and Steele (2009) regarding the reasons why women are not attracted to computer science. These authors coined the concept of "ambient belonging" and developed a simulation that made it possible to identify a low sense of belonging among women to these types of places, clearly stereotyped by people interested in computing.

McCright (2010) also suggests that women declare greater concern for local environmental problems that affect health and that involve possible risks to the safety of their community, perceptions that decrease when considering problems more distant from local areas and which increase in situations that could lead to trouble. Meanwhile, Jenkins and Pell (2006) found that women showed greater expectation that their individual actions would contribute to improving the most serious environmental problems, although they showed less confidence in science and technology as a solution to the environmental crisis.

We also found reviews and meta-analyses where investigation was done into various topics related to the teaching of CC; however, only two of these studies showed differences related to gender. One of these was a study by Bozdoğan (2011), which indicated that women had more positive attitudes and were more sensitive to environmental problems, although it did not show a correlation between the teaching styles of the teaching body. Monroe, Plate, Oxarart, Bowers, and Chaves (2019) also argued that, women—unlike men, who do not show geographical bias—learn more through local rather than global examples.

Considering this situation, the literature suggests there are certain gender differences when it comes to the acquisition or provision of scientific content by showing that women demonstrate a more ecocentric worldview compared to the technocentric worldview of men (Jenkins & Pell, 2006; Schönfelder & Bogner, 2020).

1. The term "geek" refers to a person who has a somewhat fanatical interest in technology or computing. Its use is close to the more recognizable "nerd", but in each cultural context there may be variations in the specific characteristics of the people who are labeled with this nickname.

Study objective

The study examined the results in the scientific literature regarding the existing gender differences in secondary school students (12-18 years) regarding the knowledge and representation of CC, as a synthesis of the knowledge generated around this topic in the period between 1993 and 2017.

Methodology

A systematic bibliographic review (SBR) is a standardized search strategy that allows bibliographic research to be conducted in relation to a specific topic. The sequencing and systematization of the research strategy (selection of sources and thesauri, dates of access, search algorithms, inclusion/exclusion criteria, processes of refinement, etc.) allow the information to be reviewed, replicated, and updated. The singularity of this methodology, the impetus of which dates back to the late 1970s, makes it possible to identify constituent studies in a specific field of study, in addition to synthesizing their results (Littell, Corcoran, & Pillai, 2008).

Its application to the field of social sciences lies in its simple and instantaneous access to a large amount of digitized information from current databases, as well as certain guidelines for its application, such as the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses). Although this is a methodology devised for biomedical sciences, it offers a standardized protocol to improve the quality of meta-analysis reports, in addition to being adaptable to other scientific disciplines. Its characteristics of transparency, replicability, and updatability allow its findings—which represent the evidence from other studies—to be supervised and assessed by the rest of the interested scientific community.

However, an SBR may—or may not—result in a meta-analysis. The difference is that the review is intended to identify and synthesize studies on a particular issue, while a meta-analysis, in its most quantitative expression, is a set of statistical techniques that allow the results of various studies to be combined to obtain overall findings. In this respect, although they are different, the recommendation is to conduct a meta-analysis after the SBR, in order to avoid bias (Littell et al., 2008). In this case, we conducted a qualitative meta-analysis (Timulak, 2009) through the use of analysis techniques from other types of reviews, such as narrative reviews or conceptual syntheses, with the aim of looking more closely at the results and going beyond a merely causal explanation (Petticrew & Roberts, 2008).

Systematic bibliographic review

The flowchart in Figure 1 shows a summary of the steps in the SBR, which identifies the research relevant to the study of CC, with secondary school students (12-18 years) as participants and with a compendium of articles from between 1993 and 2017. An extensive and detailed explanation of the process carried out can be found in García-Vinuesa and Meira-Cartea (2019), where the bibliometric results and the detailed methodological design of this SBR are outlined.

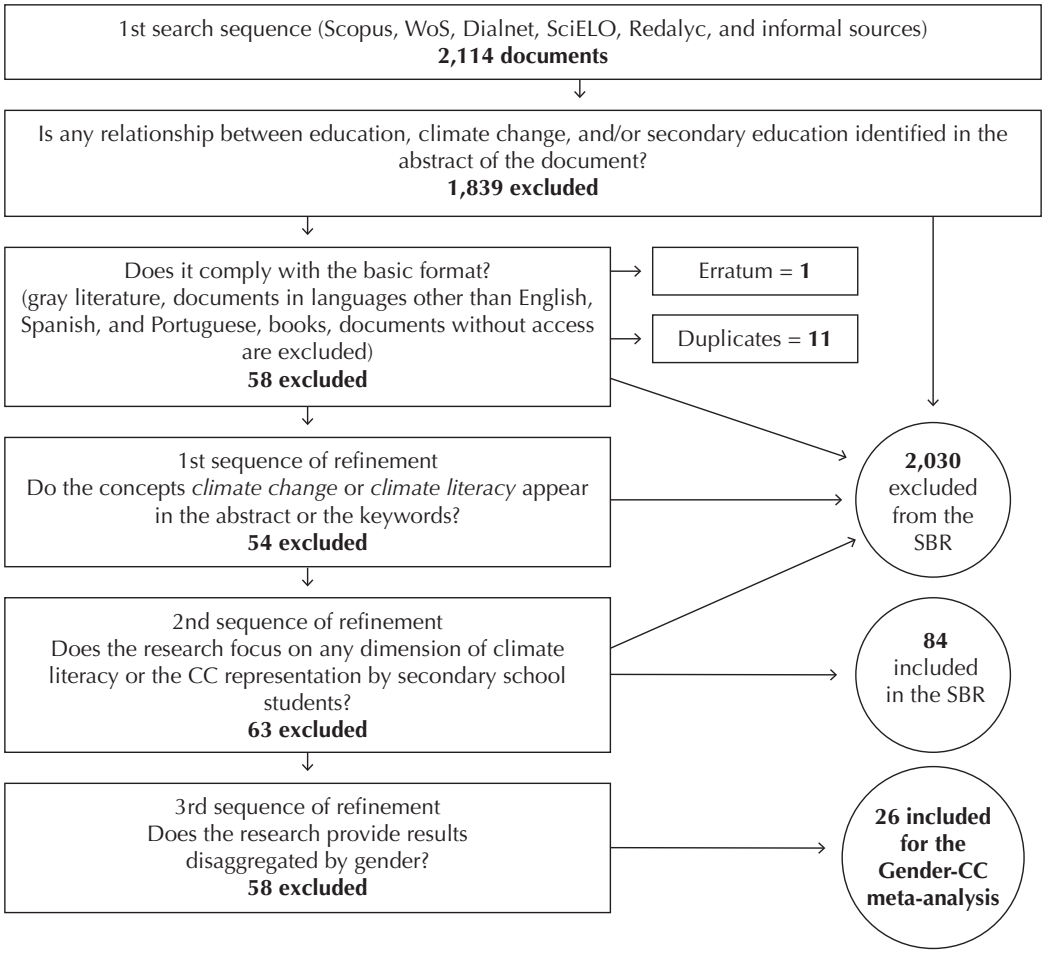

Figure 1. Flowchart of the SBR (García-Vinuesa & Meira-Cartea, 2019).
Source: Prepared by the authors

Qualitative meta-analysis

A single SBR can contain multiple meta-analyses (Littell et al., 2008). In this specific case, conducting this qualitative meta-analysis involved a third sequence to refine the SBR results (Figure 1). An automatic examination of keywords was thus carried out in the 84 documents, while we also analyzed the textual setting in which they appeared, in order to identify the studies that provided results from a gender perspective. The following search terms were used: female, women, woman, girl, and gender; femenino, mujer, niña, and *género* (in Spanish); garota, rapariga, mulher, menina, and género (in Portuguese); and muller, nena, and xénero (in Galician). In order to verify that no study had been excluded, we read all of the sections relating to the results and the discussion of the research included in the SBR, a process that confirmed the initial results and allowed the identification of a total of 26 studies.

Analysis of results

Table 1 shows the selection of the 26 studies that demonstrate gender differences regarding the understanding of CC and provides a general summary of the results to characterize the studies according to the country of origin of the participants, educational levels, object of study, and statistically significant differences between the genders.

We also established categories based on the description of the object of study and the different elements explored in each of them, which was a difficult task in terms of structuring due to the diversity of the terminology used to name the elements of representation of CC in the different studies, whether from the point of view of the perceptions, conceptions, knowledge, or beliefs, as Cubero (1994) had previously warned. This categorization considered the justifications of the researchers, as well as the methodology used, in such a way that three analytical categories emerged during the data recording process: one that encompassed the results of studies that explored different specific knowledge; the second including information regarding personal perceptions and values; and the third entailing elements related to the teaching-learning processes. Grouped into categories, these results show the variables or topics where statistically significant differences were obtained for $p < 0.05$ or $p < 0.01$.

Results

Of the 26 studies identified, three are based on a qualitative methodological design, while 23 studies have quantitative designs (Table 1). With the exception of two cases in which the samples were small (24 and 29 participants)—coinciding with the qualitative studies (Lin, 2017; Rye, Rubba, & Wiesenmayer, 1997)—the studies examined large samples, with a range from 188 to 1,532 participants. In three studies (Ambusaidi, Boyes, Stanisstreet, & Taylor, 2012; Boyes, Chuckran, & Stanisstreet, 1993; Boyes & Stanisstreet, 2012) elementary school students took part (10-12 years old). In terms of the object of study, we found various elements of representation of CC, which enabled us to establish three broad categories:

A. Knowledge of CC. This first category involves the information about CC that the subjects possess in the form of objectified knowledge. These studies examine knowledge in two of the classic typologies: conceptual and attitudinal (Tables 2 and 3).

B. Personal perceptions and opinions. This category refers to subjective processes in the sphere of personal perceptions and opinions (Table 4). In this case, the authors of the studies in the resulting sample offer a wide range of terms to refer to their objects of study, such as conception, perception, understanding, ideas, worldviews, beliefs, attitudes, and concerns, among others.

C. Teaching-learning processes. This category includes results related to the teaching-learning processes.

Table 1
Selection of studies where the object of study explores elements of the representation of CC in students from 12-18 years of age

Study	Country	N	G7	G8	G9	G10	G11	G12	Object of study	Differences	Methodology
Boyes et al. (1993)*	England	702	*	*	*	*			Understanding of the greenhouse effect	No	Quantitative
Rye et al. (1997)	United States	24	*	*	*				Understanding of global warming (GW)	No	Qualitative
Daniel, Stanisstreet, & Boyes (2004)	England	582		*		*			Ideas about mitigation of GW	Yes	Quantitative
Boyes, Stanisstreet, & Yongling (2008)	China	676		*			*		Beliefs: mitigation actions	Yes	Quantitative
Boyes, Skamp, & Stanisstreet (2009)	Australia	500	*	*	*	*			Beliefs: mitigation actions	Yes	Quantitative
Rodríguez, Boyes, & Stanisstreet (2010)	Spain	1,460	*	*	*	*			Beliefs and attitudes for action	Yes	Quantitative
Chhokar, Dua, Taylor, Boyes, & Stanisstreet (2011)	India	768	*	*	*	*			Beliefs and attitudes for action	No	Quantitative
Dijkstra & Goedhart (2011)	Europe	1,370	*	*	*	*	*	*	Attitude towards science	Yes	Quantitative
Kılınç, Boyes, & Stanisstreet (2011)	Turkey	897	*	*	*	*			Beliefs and attitudes for action	Yes	Quantitative
Malandrakis, Boyes, & Stanisstreet (2011)	Greece	1,444	*	*	*	*			Beliefs and attitudes for action	Yes	Quantitative
Liarakou, Athanasiadis, & Gavrilakis (2011)	Greece	626		*	*	*	*		Knowledge	Yes	Quantitative
Ambusaidi et al. (2012)*	Oman	1,532	*	*	*	*	*	*	Beliefs and attitudes for action	Yes	Quantitative
Boyes & Stanisstreet (2012)*	England	961	*	*	*	*			Beliefs and attitudes for action	Yes	Quantitative
Dijkstra & Goedhart (2012)	Europe	671	*	*	*	*	*	*	Pro-environmental behavior, knowledge, and attitudes	Yes	Quantitative
Barros & Pinheiro (2013)	Brazil	323	*	*	*	*	*	*	Understanding of CC	-	Qualitative
Harker-Schuch & Bugge-Henriksen (2013)	Austria/ Denmark	188 (361)					*		Knowledge and opinions	Yes	Quantitative
Yazdanparast et al. (2013)	Iran	1,035			*	*	*		Knowledge and views of CC	Yes	Quantitative

Özdem, Dal, Öztürk, Sönmez, & Alper (2014)	Turkey	646	*						Concerns, experiences, beliefs, attitudes, values, etc.	Yes	Quantitative
Stevenson, Peterson, Bondell, Moore, & Carrier (2014)	United States	378	*	*					Knowledge and risk	Yes	Quantitative
Bodzin & Fu (2014)	United States	956		*	*				Knowledge about CC	Yes	Quantitative
Stevenson & Peterson (2016)	United States	1,267	*	*					Hope and concern	Yes	Quantitative
Stevenson, Peterson, & Bradshaw (2016)	United States	369	*	*					Knowledge and beliefs	Yes	Quantitative
Stevenson, Peterson, & Bondell (2016)	United States	426	*	*					Beliefs and perceptions	Yes	Quantitative
Hermans & Korhonen (2017)	Finland	549			*				Attitudes, views, and disposition	Yes	Quantitative
Lin (2017)	China	39		*					Knowledge and actions	Yes	Qualitative
Stevenson, King, Selm, Peterson, & Monroe (2017)	United States	950	*	*					Beliefs and perceptions	Yes	Quantitative

Note: G7 = 12-13 years; G8 = 13-14 years; G9 = 14-15 years; G10 = 15-16 years; G11 = 16-17 years; G12 = 17-18 years.

* Participants of primary studies.

Source: Prepared by the authors.

Considering the results presented, 88.46% of the studies show significant differences between adolescent women and men (Table 1). In the case of the study by Barros and Pinheiro (2013), this was coded considering that there were no significant differences, since the authors state that their results do not allow a distinction to be made by gender; however, they do show a difference regarding the conservation messages stated by the participants, these being mostly expressed by women.

From the data presented in Tables 2, 3, and 4, we can highlight that, in the items or in the specific content in which the studies report statistically significant differences, women obtain higher percentages (eight out of 10 cases). However, this data should be qualified with respect to the subcategory of conceptual knowledge (Table 2), since although men—in 25% of cases—obtained higher percentages of correct answers, women obtained the same percentage of incorrect answers, with this section being where the significant differences are distributed equally between both genders. It should be added that in the two studies where the significance values are provided when comparing the total results of a questionnaire on general knowledge of CC according to gender (Harker-Schuch & Bugge-Henriksen, 2013; Yazdanparast et al., 2013), it was confirmed that men obtained better scores than women.

Knowledge about CC

The studies that either generally or partially explore diverse knowledge about CC have been grouped in this category. Table 2 only shows the results with statistical significance for $p < 0.05$ or $p < 0.01$, and in which only the gender variable was considered as a factor.

This category, as stated previously, has been divided into two subcategories: conceptual and attitudinal knowledge.

Conceptual knowledge. Table 2 shows the specific conceptual contents regarding CC that demonstrated statistically significant differences when comparing the results according to gender.

Table 2
Contents related to conceptual knowledge of CC with statistical significance when comparing results according to gender

Study	Object of study	Specific content	W	M
Daniel et al. (2004)	Beliefs about actions for mitigation of CC	Reducing sea pollution*	**53%**	41%
		Reducing garbage in rivers*	**53%**	45%
		Reducing nuclear production*	**74%**	63%
		Reducing emissions of CFCs* (chlorofluorocarbons)	**72%**	63%
		Reducing use of oil	62%	**68%**
		Reducing use of coal	69%	**71%**
		Using electric vehicles	75%	**82%**
Boyes et al. (2008)	Beliefs about actions for mitigation	Reducing sea pollution*	**73%**	64%
		Reducing garbage *	**61%**	50%
		Protecting exotic species*	**56%**	46%
		Importance of education	**83%**	76%
		Use of unleaded gasoline*	**79%**	71%
Boyes et al. (2009)	Actions for mitigation	Using smaller cars	**59%**	46%
		Switching off electronic devices	**53%**	36%
		Increasing use of nuclear energy	**40%**	30%
Rodríguez et al. (2010)	Beliefs about actions	Effectiveness of planting trees		*
Kılınç et al. (2011)	Ideas/beliefs about actions for mitigation	Production of nuclear energy	**57%**	49%
		Improving home insulation	**63%**	52%
		Reducing domestic energy consumption	**75%**	60%
		Reducing use of artificial fertilizers	**71%**	56%
		Using more energy-efficient household appliances	**63%**	56%
		Importance of education	**85%**	79%
		Buying fewer new fashionable products	27%	**34%**
		Using renewable energies	60%	**66%**
Liarakou et al. (2011)	Knowledge	The temperature of the planet is increasing	**	
		The polar icecaps are increasing*	**	
		CC will intensify extreme meteorological events	**	
		CC will affect food production	**	
		Incandescent lights save energy		**

***Ambusaidi et al. (2012)	Ideas/beliefs about actions for mitigation	CC is a real phenomenon	**82%**	78%
		Eating less meat	28%	**36%**
		Increasing nuclear power generation	53%	**62%**
		Using more efficient cars	**70%**	62%
		Reducing the use of artificial fertilizers	**60%**	54%
		Disconnecting devices that are not being used	**61%**	54%
		Recycling*	**58%**	52%
		Increasing processes of environmental education	**77%**	72%
		Building more international agreements	**77%**	70%
		Increasing environmental legislation	**77%**	70%
Harker-Schuch & Bugge-Henriksen (2013)	Knowledge/ opinions	Total correct answers on the questionnaire	50,1%	**55,6%**
Yazdanparast et al. (2013)	Knowledge	Total score on knowledge of CC		**

Note: Results are shown that indicate statistically significant differences for $p < 0.05$.

* The content expresses erroneous knowledge or an alternative conception.

** The study does not provide the disaggregated percentages, but shows that a higher number of women/men indicated this option.

*** In Oman, classrooms are divided by gender.

Source: Prepared by the authors.

Attitudinal knowledge. This subcategory includes the results of studies that explored the willingness to act and/or attitudes in relation to different dimensions of CC.

Table 3
Content related to attitudinal knowledge of CC with statistical significance when comparing by gender

Study	Object of study	Specific content	W	M
Boyes et al. (2009)	Ideas/beliefs about actions for mitigation of CC	Paying more for a well-insulated home	**37%**	31%
		Turning off electronic devices	**79%**	66%
		Changing diet (lower consumption of meat)	**28%**	12%
		Recycling*	**70%**	58%
		Considering education important	**60%**	48%
		Participating in educational processes	**30%**	27%
		Respecting the environment	**61%**	45%
		Knowing "a lot" or "something" about CC	45%	**61%**

Rodríguez et al. (2010)	Ideas/beliefs about actions for mitigation of CC	Intention to take action	**	
		Recycling*	**	
		Using public transport instead of private cars	**	
		Paying more for food produced without fertilizers	**	
		Eating less meat	**	
		Voting for environmental laws	**	
		Supporting environmental taxes	**	
Dijkstra & Goedhart (2011)	Attitude towards science	Studies on CC are important for the future	*	
Kılınç et al. (2011)	Ideas/beliefs about actions for mitigation of CC	Respecting the environment	**82%**	76%
		Paying more for nuclear-generated electricity	**60%**	54%
		Buying energy-efficient household appliances	76%	**80%**
		Paying to plant trees	**91%**	88%
		Reducing consumption of meat in the diet	**37%**	28%
		Knowing "a lot" or "something" about CC	**82%**	76%
Malandrakis et al. (2011)	Ideas/beliefs about actions for mitigation of CC	Paying more for food produced without fertilizers	**73%**	62%
		Reducing consumption of meat in the diet	**35%**	27%
		Receiving additional training in environmental education	**59%**	53%
		Using smaller and more efficient cars		**
		Buying more energy-efficient household appliances		**
***Ambusaidi et al. (2012)	Ideas/beliefs about actions for mitigation of CC	Buying more energy-efficient household appliances	71%	**78%**
		Using smaller cars	45%	**52%**
		Paying to plant trees	**77%**	72%
		Participating in educational processes	**81%**	78%
		Knowing "a lot" or "something" about CC	**75%**	70%

Boyes & Stanisstreet (2012)	Beliefs about actions for mitigation of CC	Switching off unused electronic devices	**71%**	65%
		Reducing the use of cars	**23%**	15%
		Reducing consumption of meat	**27%**	15%
		Using energy-efficient household appliances	**40%**	33%
		Buying fewer fashionable new products	**31%**	26%
		Taking environmental policies into account when voting	**48%**	38%
Barros & Pinheiro (2013)	Understanding of CC	Supporting individual and collective actions	**	
		Supporting environmental conservation measures	**48%**	35%
Özdem et al. (2014)	Concerns, attitudes, actions	Buying more efficient light bulbs	**37%**	27%
		Recycling*	**73%**	62%
Hermans & Korhonen (2017)	Attitudes, views, and disposition to act	Switching off unused electronic devices	**	
		Taking shorter showers	**	
		Switching off lights in rooms when not used	**	
		Walking and cycling for distances < 5km	**	
		Lowering the temperature in the home	**	
		Buying secondhand goods	**	
		Buying less clothing and other things		**
		Reducing consumption of meat	**	
		Selling secondhand things	**	
		Avoiding the use of motor vehicles	**	
		Can be mitigated through international cooperation	**	
		Mitigation is essential	**	
		Everyone as individuals must act	**	
		Mitigation is possible	**	
		Mitigation can be done through political actions	**	
Stevenson et al. (2017)	Beliefs and perceptions	Supporting mitigation and adaptation measures	**	
		Respecting the environment	**	

Note: Results are shown that indicate statistically significant differences for $p < 0.05$.

* The content expresses erroneous knowledge or an alternative conception.

** The study does not provide the disaggregated percentages, but shows that a higher number of women/men indicated this option.

*** In Oman, classrooms are divided by gender.

Source: Prepared by the authors.

Personal perceptions and opinions

Table 4 shows the information from studies that showed statistically significant differences when looking at personal perceptions and opinions according to gender.

Table 4
Studies in which differences in perceptions and opinions were obtained according to gender

Study	Perceptions	W	M
Chhokar et al. (2011)	Concern about CC	**93%**	88%
Kılınç et al. (2011)	Concern about CC	**95%**	88%
Malandrakis et al. (2011)	Confidence in international agreements	**64%**	54%
Barros & Pinheiro (2013)	Greater emotionality	**	
Özdem et al. (2014)	Concern about the extinction of species*	**20%**	13%
	Concern about radioactive waste*	16%	**24%**
	Concern about garbage*	30%	**41%**
Stevenson et al. (2014)	Greater risk	**	
Stevenson & Peterson (2016)	Greater concern	**	
	Greater hope	**	
Stevenson et al. (2016)	Greater concern	**	
Hermans & Korhonen (2017)	CC as a risk	**	
	Confidence in mitigation		**
Stevenson et al. (2017)	Greater concern	**	
	Greater hope	**	

Note: Results are shown that indicate statistically significant differences for $p < 0.05$.

* The content expresses erroneous knowledge or an alternative conception.

** The study does not provide the disaggregated percentages, but shows that a higher number of women/men indicated this option.

Prepared by the authors.

Teaching-Learning processes

In this section, only two of the studies we identified examined how certain educational interventions have effects on the student population and student opinions according to gender. Review of the documents indicated that some findings suggested that the classical methods used in teaching of sciences were not attractive to women. In this regard, Dijkstra and Goedhart (2011) argue that these practices are less interesting to women and in their study they observe how project work is rated more positively by female than male adolescents, despite the fact that the boys evaluate these types of collective activities as being easier. On the other hand, Bodzin and Fu (2014) implemented the so-called *geospatial curriculum*, in which they used technological tools and approaches based on scientific or geospatial literacy. The results showed that women had less confidence and learning with this type of teaching processes.

Access to information related to CC. In the compendium of articles analyzed, only a few of them looked into the way in which adolescents access information on this topic. For example, Boyes et al. (2008) state that 41% of the participants said that they frequently use the media to find out about CC, with the percentage of men (46%)

being higher than that of women (33%); and a higher proportion of men said that they do this occasionally (90% of men versus 84% of women). On the other hand, Lin's (2017) results showed that women more frequently preferred to receive information about CC in textbooks.

Evolution over time at school. Despite the fact that many studies involved a school population of different educational levels, the results shown are not disaggregated by gender and grade, which makes it difficult to form a clear idea of how the amount of school time influences the gender gap documented by other research. In spite of this, time at school, along with evolutionary development and other processes of socialization outside the school seem to influence the students' perceptions and opinions regarding CC and the environment. In this respect, Boyes et al. (2009) obtained statistically significant differences in the students' opinions about the degree to which they considered themselves respectful of the environment, with decreases that were inversely proportional to the educational level (from 12 to 16 years of age); although, as the authors state, this could be due to the fact that older students are more aware of the environmental crisis and their opinions are more severe. The authors sustain their argument on the fact that there are items such as "using small cars" or "using public transport", which represent actions that are closer to those of older students, in which the percentage of positive responses increases according to the age.

One of the studies that correlated the gender and educational level variables was that by Rodríguez et al. (2010), which involved participants between 12 and 16 years old. The authors found significant differences between younger girls, who were willing to buy fewer new products and avoid leaving garbage on beaches, while a higher percentage of the older girls stated that they were willing to pay more for a well-insulated home. Similarly, in this research, younger girls said—to a greater extent than boys of their age—that not leaving garbage on the beach and paying environmental taxes were effective measures to combat CC, while a greater number of boys of the same educational level considered that air conditioning was positive for the environment. On the other hand, older girls indicated that using more energy-efficient electrical appliances was an effective action against CC, while their male counterparts expressed that voting on international agreements is a good direction in which to guide mitigation measures.

Discussion

The results of the meta-analysis of the compendium of 26 selected articles from the SBR about the understanding of CC on the part of students between 12 and 18 years of age confirm some of the trends and findings outlined by the literature on environmental education and teaching of sciences.

This analysis only found three studies of the 26 where no significant differences were found between the gender of the participants. In two of them, the target population included students of primary (10-12 years) and secondary (12-16) education levels, so a lower age range could have an influence on the reduction of gender differences regarding certain knowledge and attitudes towards science, which are reinforced as a function of various processes of socialization both inside and outside school during adolescence.

The rest of the studies do show significant differences that corroborate some of the findings of other studies in the area of science teaching and environmental education.

In the aspect of knowledge, the literature suggests that women demonstrate less knowledge—or show less interest—in matters relating to the scientific-technological field (Fisher et al., 2020), although they also show more ecological values (McCright, 2010).

In the case of our meta-analysis, in the category of conceptual knowledge (Table 2), men obtain better results—in 24.39% of the recorded data—where two of them are related to the results of a general knowledge test on CC. The other eight items are related to specific content on actions for mitigation, such as: reducing use of oil and coal, using electric vehicles and renewable energy, increasing nuclear power generation, buying fewer new fashionable products, eating less meat, and planting trees. However, women showed better results in 21 of the significant differences reported (51.21%) on various themes related to CC, among which the following stand out: the importance of education and the increase of environmental legislation and environmental education interventions to combat CC, the reduction of domestic energy consumption, disconnection of devices that are not being used, use of more energy-efficient household appliances, improving household insulation, reducing the use of artificial fertilizers to produce food, using smaller and more efficient cars, and increasing nuclear power production. Therefore, in the content related to nuclear energy, men score more accurately (Ambusaidi et al., 2012), while women perform better in other contexts (Boyes et al., 2009; Daniel et al., 2004; Kılınç et al., 2011).

Strictly in the scientific-technological field, women achieved better results in topics related to the increasing temperature of the planet, the intensification of extreme meteorological phenomena, or the impacts on agricultural production. Nevertheless, the women also stated that they possessed a greater number of alternative conceptions[2] (Cubero, 1994) or implicit theories (Rodríguez & González, 1995), such as how reducing sea pollution, garbage in rivers, or CFC emissions are effective measures against CC, as well as protecting endangered species, recycling, or using unleaded gasoline.

In terms of attitudinal knowledge and the statistically significant differences reported in the studies (Table 3), men only indicate a greater willingness to act than women in eight of 58 significant differences found and these are related to buying energy-efficient household appliances and less clothing, as well as using smaller and more efficient cars.

Meanwhile, women are more willing to pay more for a well-insulated home, food produced without artificial fertilizers, nuclear energy, or planting of trees, buy and sell secondhand goods, buy fewer new fashionable items, use energy-efficient household appliances, reduce the temperature inside the home, use public transport, ride or use a bicycle instead of a private car, change their diet to consume less meat, recycle, switch off unused devices, or take shorter showers. Likewise, they attribute greater importance and relevance to education in general and environmental education in particular, as well as to participation in educational processes, respect for the environment through environmental policy and legislation, and mitigation and adaptation. They also show greater confidence in individual and collective actions, as well as in international cooperation.

With regard to personal perceptions and opinions (Table 4), the results show the trend of the scientific literature. Women thus declare: a greater degree of concern than men (Chhokar et al., 2011; Kılınç et al., 2011; Stevenson & Peterson, 2016; Stevenson et al., 2016; Stevenson et al., 2017), higher levels of hope (Stevenson & Peterson, 2016; Stevenson et al., 2017), a higher degree of risk perception (Hermans & Korhonen, 2017; Stevenson et al., 2014), and a higher degree of emotionality (Barros & Pinheiro, 2013). Men only show differences in favoring aspects related to concern about radioactive waste and garbage, two alternative conceptions due to their lack of direct connection with the causes or consequences of CC, which were obtained in the study by Özdem et al. (2014) with 12-13 year-old students at the lower level of secondary education, where the patterns and behaviors differentiated by gender are not yet so marked. On the other hand, the study by Hermans and Korhonen (2017) found that men show greater confidence in mitigation, which could be explained by the confidence shown in relation to science and technology as a solution to the climate crisis (Jenkins & Pell, 2006; Schönfelder & Bogner, 2020).

2. We used the term "alternative conception" to denote an idea, conception, representation, or knowledge that is not consistent with scientific knowledge. The adjective "alternative" is not intended to establish a status between scientific knowledge and common knowledge, nor does it connote those using them as naive or erroneous.

The results therefore support the conclusions of the literature reviewed, where women show significant differences compared with men regarding elements that are framed within more ecocentric and communitarian worldviews, providing more coherent responses with an appropriate representation of the climate crisis (Cantell, Tolppanen, Aarnio-Linnanvuori, & Lehtonen, 2019). On the contrary, there is specific content—such as that related to nuclear energy, an element that we can include in a technical worldview—which, depending on the study, show results according to gender, suggesting it is necessary to study them in greater depth to understand the reason for this ambivalence.

With regard to the differences found, and their reproduction and exacerbation throughout the course of secondary education, it seems that gender differences emerge and are reinforced at this educational/evolutionary level. On the one hand, and as expected, the acquisition and possession of knowledge seem to increase in proportion to the progress of the courses (Boyes et al., 2008), however, gender differences also increase—as suggested by the studies by Harker-Schuch and Bugge-Henriksen (2013) and Yazdanparast et al. (2013)—with students between 16 and 17 years of age and between 15 and 17 years of age, respectively, where men obtained a higher total score on a questionnaire referring to general knowledge of CC. The same is true—but inversely—in terms of perceptions, where gender differences relating to levels of concern, responsibility, and willingness to act in an environmentally-friendly manner decrease proportionally with age. In this vein, Chokkar et al. (2011) found a strong relationship between higher educational levels and respect for the environment, with a decrease in the proportion of students at higher levels who indicated that they felt "very" or "quite" respectful of the environment. This trend is similar to that identified by Boyes et al. (2009) among students from 12 to 16 years of age, although—as stated—this may be due to greater demand for judgment among older students (Boyes et al., 2009).

On the other hand, in the study by Stevenson et al. (2016), in which 110 elementary school students between 11 and 14 years old participated—some 25% of the sample—the authors suggest that the trend of greater concern for CC among women is maintained among both younger and older students. Compared with the studies we consulted, these results suggest that gender socialization processes take place in parallel—and interact—with socio-educational processes, that is, in terms of disposition towards certain scientific-technical content regarding greater or lesser disposition towards pro-environmental/climate behavior and in the field of perceptions of risk, concern, responsibility, or confidence.

Conclusion

With this study our intention was to examine and synthesize the results of the scientific literature regarding possible gender differences between adolescent students (12-18 years) in terms of knowledge and representation of CC. In order to achieve this, we identified and synthesized the findings produced by the scientific literature in this field of research. The results support the conclusions of the research project of which this study is part (Meira-Cartea, Bisquert, García-Vinuesa, & Pérez, 2018), which is aimed at understanding how students in secondary education represent CC.

In this respect, and considering that the objective of this study is not to assess the achievements of the various educational systems, the results suggest that educational approaches to face the challenge of climate change—whether based on the different versions that fall within the broad spectrum between the positivist and the constructivist paradigms (Busch, Henderson, & Stevenson, 2019)—seem to have reached a ceiling as an educational response to CC.

The climate crisis thus takes shape as compartmentalized content in the field of science and technology without establishing the necessary link with its socio-economic and cultural causes, as well as with the risks that humanitarian disasters and the exacerbation of the vulnerability of certain social groups pose to the world population. This view reinforces alternative conceptions regarding the explanation of the phenomenon and that—as this analysis appears to indicate—reproduces discriminatory gender patterns. This is a situation that limits the essential skills in which we must educate ourselves in order to tackle an agenda of decarbonization—already overdue—(González-Gaudiano & Meira-Cartea, 2020) which promotes eco-citizenship that participates, demands, and accepts the urgent measures and policies for which the scientific community has been calling since the middle of the last century; that is, actions aimed at drastically reducing the emission of greenhouse gases and our impact on the biosphere.

It is difficult to carry out these essential changes from a positivist scientific perspective of education for climate change since, although science explains its causes in the interactions of physical-chemical elements, they lie in the hyper-consumerist and fossil-fuel-dependent lifestyles of most industrialized societies. For this reason, a transformative reform would be necessary to facilitate the ecological transition in all of the economic sectors that are most affected (energy, the automotive industry, air transport, food, etc.) accompanied by educational innovation towards a socio-critical and transformative paradigm that enables us to keep pace with the essential economic and cultural changes required by the climate crisis (Busch et al., 2019).

It therefore seems necessary to reflect on the suitability of certain educational practices that encourage disinterest and disaffection towards scientific and environmental knowledge among half of the student population (women), but also the persistence of incorrect attitudes and perceptions to mitigate and adapt to CC among male students. There are two areas of representation in which we encounter gender differences that must be eradicated, since maintaining literacy approaches as a socio-educational response to the climate crisis involves situations of discrimination, reinforced by other processes of socialization outside the school, where half of the student population (the males) seem to know about and be more interested in science. However, although women show lower achievements regarding the acquisition of scientific knowledge, they represent the climate crisis more consistently in terms of risk perception, responsibility for its causes, and responses in accordance with environmental and community values.

These results suggest that the possession and application of scientific knowledge, along with the processes of gender socialization, do not facilitate a perception of the problem that is consistent with scientific knowledge and which is thus ineffective from the perspective of adaptation and resilience.

As in any scientific field, it is necessary to develop a critical spirit that questions absolute truths and which contrasts and creates hypotheses—through the scientific method—that allow problems to be solved and human development to advance. Therein lies the need for a society that questions and contrasts gender traditions, roles, and stereotypes reproduced by an historically patriarchal system (Lagarde, 1997). From this perspective, "feminizing" spaces of primary socialization, as well as educational spaces, should not imply attacking men, but rather a proposal that allows male patterns and stereotypes to be contrasted in order to advance in the reconstruction of new identities, in which respect and care for the environment and other living beings are not behaviors that are exclusive to women and unappealing to men.

There is also evidence that approaches based on the knowledge deficit theory and which justify their utility based on the premise that better knowledge leads to more appropriate and coherent behavior do not constitute an adequate socio-educational response to the environmental crisis (González-Gaudiano & Meira-Cartea, 2019). The results do not support this premise and suggest that as students progress in terms of educational level, and under the assumption that they have acquired more appropriate, complex, and advanced knowledge, they do

not influence behaviors such as self-efficacy, motivation, or perceptions of responsibility and risk. This analysis reveals that age does influence positive attitudes towards the environment, a depressing situation, but one that paves a way for the professional attention of teachers and eco-citizens.

By way of conclusion, in a situation of risk that is now timeless, there are records and experiences—both past and present—and forecasts of the future that confirm the exacerbation of such scenarios. Faced with this and sexist, racist, and classist CC produced by a socioeconomic system that prioritizes economic benefits over human disasters, it is of urgent importance to promote a structural and cultural transformation that is founded on ecofeminism and on climatic and social justice.

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