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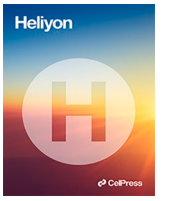

Research article

The joint influence of the variables *educational level* and *gender* on children's drawings of the plant world

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ABSTRACT

Drawing is a form of creative expression that children enjoy from a young age. Drawing is also an effective and engaging strategy for exploring children's comprehension of the natural world. Examination of the content, colours, and developmental changes of children's drawings can provide us with valuable insights into how understanding of plant life develops during childhood. In this regard, previous studies have analysed the relationship that the representations that children draw when graphically expressing their understanding of the plant world have with the variables *gender* and *educational level*. This line of research has established that children's drawings of the plant world vary significantly when those drawn by older children are compared with those drawn by younger students and that the differences between girls and boys seem irrelevant. However, no studies have investigated the combined influence that both variables (gender and educational level) have on children's representation of the plant world. This study investigated this influence by examining 251 drawings by young children (aged 4–7 years). The results indicated that gender and educational level influenced key pictorial elements. Thus, that when comparing the understanding of biological phenomena through drawings between girls and boys, it is important to control for *educational level*.

1. Introduction

The interest that human beings show in the plant world is easily recognizable in the pictorial production of practically any era or artistic movement. We could, for example, go back to the origins of the same graphic expression by appreciating the representations of plants that Palaeolithic societies captured in rocks and caves [1] or the images of flowers and other vegetables that were engraved in bones, reindeer antlers and pebbles [2]. We could also turn to classical works. For example, one could consider the details of flowers and plants drawn by Leonardo da Vinci [3], the collection of engravings of flowers and bouquets on copper plates created by Maria Sybilla Merian [4] or representations of plants in the work by Carl Linnaeus [5].

The interest in representing the details, shape and colour of plants and flowers subsists in our days and coexists with other image creation techniques. This circumstance seems to be related to the fact that drawing activity optimizes our observation capacities in such a way that drawing allows us to capture certain particulars of plants that otherwise go easily unnoticed [6].

Young children also create drawings around plant life [7]. This is documented in the digitized collections of children's drawings that can be consulted on the internet, such as the Hispanic Digital Library [8] or The International Collection of Child Art [9].

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In this sense, a growing body of research has attempted to address the question of the study of botanical knowledge that girls and boys under the age of ten express in their representations of the plant world. The common starting point of all the works included in this line of research is the idea that children's graphic expression is the reflection of their cognitive and emotional processes and that, consequently, children's drawings can offer information related to, among other aspects, thought and conceptual development during childhood [10].

Villarroel and Infante [11] provide evidence consistent with the idea that the relative understanding of the concept of live beings by those between 4 and 8 years of age is related to the pictorial content of children's drawings about the plant world. Anderson et al. [12] also find that the pictorial content of the drawings by girls and boys during the childhood stage offers relevant information about their conceptions about the structure and function of plants. These same authors point out the importance that certain pictorial elements, such as the representation of the soil, the sun, flowers and trees, have when interpreting children's knowledge about plant life. In this way, flowers are a recurring pictorial motif in children's drawings because the most basic understanding of the notion of *plant* seems to be linked especially to the idea of *floral structure*; therefore, young girls and boys may find it difficult to understand and draw, for example, trees in their botanical representations. Additionally, the drawing of abiotic elements, such as soil, sun and water (or rain), seems to be related to a better understanding of the phenomenon of plant life during childhood.

In a recent study using a different methodological paradigm, Villarroel [13] also found that the colours that children choose to paint their representations of plants are related to their level of understanding of plant life. In this way, the author provides evidence consistent with the idea that as understanding of the plant world improves, the palette of colours that girls and boys choose to paint their drawings decreases. For example, colours such as brown, green and yellow seem to acquire special importance in children's drawings as the plant world is better understood, and to the same extent, the range of colours, such as pink, violet or orange, decreases.

In a methodologically similar work carried out in a different cultural context, Berat Ahi [14] reported highly consistent results with those previously published regarding the recurring representation of elements such as the sun, rain or the soil, which were associated with the botanical knowledge of students.

In all the studies that examine both the pictorial content and the colour used in children's drawings about the plant world, analyses of the relationship that the variables *gender* and *academic level* have with the drawings have been performed independently. Therefore, to date, no work has addressed the joint effect that both variables have on dependent variables related to the pictorial content and extension of the colour of children's drawings.

As Derek Cheung [15] warns, studying the joint effect that the variables *gender* and *educational level* have on dependent variables is a crucial question when validating methodological designs that examine these factors independently. This importance lies in the fact that if both variables are studied separately without having proof of the significance of the effect that their joint influence has, the results of such studies may lead to incorrect conclusions because the effects of the two factors overlap.

Considering this lack of previous research, this study starts from the following research question:

Can evidence that may lead to the assumption that there are differences between girls and boys in terms of pictorial content and use of colour in children's drawings about plants be presented when the variable *educational level* is controlled?

In other words, the question investigated by this study is whether there is a significant effect of the interaction between *gender* and *educational level* on the content and colours of drawings by children to express their knowledge of the plant world.

In this context, the objective of this study is to evaluate the effect of the interaction between the independent variables *gender* and *educational level* on dependent variables related to the analysis of children's graphic expression linked to the drawing of the plant world. More specifically, this study examines the pictorial content and colour surface area of spontaneous drawings by children between the ages of 4 and 8 years to express their knowledge about the plant world and assesses the effect that the interaction between *educational level* and *gender* has on these variables. The ultimate purpose of this research is to provide evidence about the relevance that should be attributed to the effect of the interaction between independent variables in the design of studies related to the analysis of the knowledge that children show in their drawings about biological phenomena.

2. Methods

In this section, the sample is described first, followed by an explanation of the procedure used when meeting with the participating children. Subsequent sections introduce the ethics statement, study variables, and statistical procedures.

2.1. Sample

The object of this research comprises 251 drawings made by 120 girls and 131 boys. Regarding educational level, 89 students were in the second year of kindergarten (4–5 years) at the time of participating in the study, 83 were in the third year of kindergarten (5–6 years), and 79 were in the first year of primary education (6–7 years).

Table 1
Descriptive statistics of the educational level variable ($n = 251$).

Educational level	*Age (years)*	%
2nd Year of Kindergarten	4–5	35.4
3rd Year of Kindergarten	5–6	33.1
1st Grade (Primary Education)	6–7	31.5

The sample was gathered through interviews with the participating boys and girls during the first semester of the 2015–2016 academic year. To this end, the research team visited four public schools: three located in the Uribe Kosta region (Spain) and a fourth school located in the Las Merindades region (Spain). The schools were chosen based on the criteria of accessibility and proximity to the people who carried out the data collection.

Table 1 and Table 2 display the demographic characteristics of the sample (i.e., in terms of *educational level* and *gender*).

2.2. Interviews

The procedure followed in the interviews with the students is similar to the methodology used by the research team in previous studies [16]. The researcher met individually with each of the children involved in the study in order to ensure that the conditions for the activity were the same for all the participants and that each child completed their drawing without being influenced by classmates. No additional information was requested from the participants during this drawing activity, nor was any question posed to them.

Essentially, the interviews with the children were conducted using the following protocol.

a.) Initial phase: The person in charge of interview with a certain group of schoolchildren went to the regular classroom of the students the day before the interviews to present the activity. This presentation was carried out in the classroom with all the students and with the help of the teacher responsible for the group. During this presentation, the classroom teacher helped the researcher introduced themselves to the children. Subsequently, the children listened to a story told by the researcher. This story's protagonist had come from a place where there were no plants and knew very little about plants. However, he wished to learn more about the plant world. The story ended with the suggestion that the children could make a drawing to teach the protagonist of the story about what plants are like, where they grow, and what they need to grow. During the story, the researcher used a stuffed animal that was presented as the protagonist of the story. The purpose of the story was to motivate the children to engage in the task of explaining, through drawing, everything they knew about the world of plants to the story's protagonist. These ideas regarding the characteristics and needs of plants were mentioned only during this initial phase of the task and were not repeated during the individual interviews.

b.) Individual interviews: With the agreement of the classroom teacher, a place was prepared to carry out the interviews; this place was preferably inside the classroom, in a small corner, so that the girls and boys would feel comfortable. In some cases, this area was located outside the classroom but close to it. The interview always began by offering the child the chance to pick up and briefly play with the stuffed animal and recalling the story presented in the classroom. During the individual interviews, the researcher only reminded the children that they could make a drawing to help the stuffed animal understand what plants are like, where they grow, and what they need to grow. The children were not provided with further information about the plant world or about how to depict, draw, or colour plants during the drawing activity.

Initially, students were offered a blank sheet of paper and several pens and pencils to begin the drawing. When the girl or boy expressed that he or she had finished the drawing, the person in charge of the interview asked about the meaning of each of the pictorial elements in the drawing. Then, to finish the activity, the student was offered markers (ten different colours), arranged at random, and the student was asked to colour the drawing. The following ten colours were offered: black, grey, brown, red, orange, yellow, green, blue, pink and violet.

The drawing activity was terminated when the student expressed that he or she no longer wanted to paint or had already finished. The researcher asked the children about the meaning of the pictorial elements in their drawings, especially if the content was blurred or unclear, and recorded the children's explanations. This activity usually lasted between 10 and 15 min, and most of the girls and boys were enthusiastic about participating. No pictures, videos, or audio recordings were taken during the interviews with the children in order to preserve their privacy and allow them to focus on the drawing activity.

2.3. Ethics statement

The procedure for the interviews with the children was supervised by the Ethics Committee for Research on Human Beings of the Universidad del País Vasco (University of the Basque Country). This committee approved the research procedure (CEISH/214/2013/Villarroel Villamor).

Following the approved protocol, the families of the students participating in the study were informed in writing of the objectives and procedures of the research and had to agree in writing that the children could participate in the interviews. The management personnel at the centres were also informed in writing of the procedures for data collection, and they also provided written consent.

Table 2
Descriptive statistics of the gender variable (n = 251).

Gender	%
Girls	47.8
Boys	52.2

2.4. Study variables

The following variables were included in this study.

a) Independent variables: *educational level* (that is, the academic grade in which the participants were enrolled at the time of the study) and *gender* of the students participating.
b) Dependent variables: *pictorial content* of the drawings and *colour surface* area of the drawings.

Regarding the codification of the pictorial content of the drawings, the procedure established in previous research was followed [11,17]. Using this procedure, the different pictorial elements were identified in each drawing. In this research project, a pictorial element was considered the representation of an entity, real or imaginary, that the boy or girl elaborated in his or her drawing and that had a marked degree of independence with respect to other elements of the drawing [18,19]. Thus, the drawing of a tree, a house or a flower are examples of pictorial elements because they represent singular entities that are clearly distinguishable from other pictorial elements in children's drawings.

Finally, repeated pictorial elements in the same drawing were considered only once; therefore, the variable *pictorial content* refers to the number of different pictorial elements identified in each drawing. Thus, in a drawing with 2 flowers, 1 tree, 3 clouds and a car, 4 different pictorial elements were recorded: *flower*, *tree*, *cloud* and *car*.

The second dependent variable in this study was the colour surface area of each of the colours used by children in their drawings. The coding of this variable was carried out following the procedure published in previous studies [13] and involves the quantification of the colour surface area in total in relation to each of the ten colours that were available to the students. To this end, digital copies of the drawings (TIFF format with 300 dpi resolution) were made using an HP Scanjet G4010 scanner, and the surface of each colour in the drawings was measured using ImageJ software (http://rsb.info.nih.gov/ij/). This is an open source application that is widely used in image processing studies [20].

In summary, the following information was coded for each drawing.

- *Gender* and *educational level* of the child who made the drawing;
- Number of *different pictorial elements* in each drawing;
- *Total surface coloured* and *surface covered with each of the ten colours* that were available to the children during the test: black, grey, brown, red, orange, yellow, green, blue, pink and violet.

Four examples of the analysed drawings are presented in the annex (Figs. 1–4).

2.5. Statistical procedures

The hypothesis that pictorial content varies with *gender* and *educational level* was tested using the χ^2 test and the Kruskal – Wallis test [21]. Likewise, the hypothesis that *pictorial content* is associated with *gender*, controlling the *educational level*, was tested using the Cochran–Mantel–Haenszel test [22,23]; for this analysis, the homogeneity of the odds ratio (OR) between *educational levels* was tested using the Breslow–Day test [24].

The hypothesis that *painted surface* is associated with *educational level* and *gender* and the *effect of the interaction between them* was tested using the Scheirer–Ray–Hare test [25]. This statistical test is a two-factor extension of the Kruskal–Wallis test and, therefore, does not require that the data conform to a normal distribution [26].

The procedure followed in this study to carry out the Scheirer–Ray–Hare test is similar to the method described by Dytham [27]. First, ANOVA of the ranges corresponding to the observations for the dependent variable was performed. Next, the quotients of the sum of squares (SS) and the total mean square (MS_{total}) were calculated for each independent factor and for the interaction. Based on these ratios, the p values were estimated based on the chi-square distribution, setting the level of significance at 5 %. The effect size was estimated using *Cramer's V* [28] and *eta-squared* [29]. A mean effect was considered 0.3 (1 df) or 0.25 (2 df). For *eta-squared*, a mean effect was considered from 0.06 to 0.14 [30].

The calculations were performed using SPSS v.24 software and a spreadsheet application.

3. F. 3. results

The results of the study are presented below. First, the results of the pictorial content analysis of the drawings is provided, and then the results related to the colour surface area of each of the colours used. For both sets of results, the presentation begins with a synthesis of the data for the entire sample, and subsequently, the results are detailed considering the independent variables (*gender* and *educational level*) and the interaction between the two.

3.1. Pictorial content analysis

In the set of representations of plant life composing the study sample ($n = 251$), nineteen different types of pictorial elements were identified. Fig. 1 details which pictorial elements were identified and the percentage of the total number of drawings in which each of the pictorial elements was represented. The pictorial element *Others* refers to representations of objects without direct relation to the

plant world, for example, decorative elements, cars, balls, etc. The pictorial element *Other vegetables* refers to drawing of vegetables.

In 27.5 % of the drawings, at least two different pictorial elements were identified; in 43.4 %, between 3 and 5 elements were identified, and in 29.1 %, 6 or more different pictorial elements were identified. The maximum number of different pictorial elements in the same drawing was 14.

Regarding the study of the differences between girls and boys in relation to the pictorial elements identified, there were significant differences in the inclusion of *flowers* ($\chi^2 = (1,\ n = 251) = 14.63,\ p < 0.01,\ Cramer's\ V = 0.241$), *leaves* ($\chi^2 = (1, n = 251) = 7.1, p < 0.01, Cramer's\ V = 0.168$) and *fruits* ($\chi^2 = (1, n = 251) = 0.031, p < 0.05, Cramer's\ V = 0.136$). However, the effect size *(Cramer's V)* linked to these comparisons did not reach an average level; therefore, the differences between boys and girls should be interpreted, in these cases, with caution.

Table 3 shows the differences in the frequency of pictorial elements by *educational level*. As described in the aforementioned table, of the ten pictorial elements in which significant differences were identified, four (trees, leaves, ground and clouds) were associated with medium or high effect sizes.

To complement the information presented in the previous table, the frequencies of the four types of pictorial elements associated with a medium or high effect size with respect to the educational level variable are presented in Table 4. The table shows that younger children were less likely to depict trees, leaves, the ground, and clouds than their older classmates.

Next, the results of the analysis of the differences between girls and boys in terms of the frequencies of representation of pictorial elements are presented, controlling for the variable *educational level*. As seen in Table 5, significant differences were identified related to the representation of *flowers*, *leaves* and *fruits*.

The Breslow–Day test results indicated that there was no evidence to reject the hypothesis that the odds ratio (OR) is homogeneous across the three educational levels. Therefore, an estimate of the common risk (OR) can be considered. This indicates that the representation of a flower was three times more likely to appear in drawings by girls than by boys and, likewise, that the representation of leaves and fruits was twice as likely to be associated with drawings by girls than by boys.

Complementing the above information, Table 6 shows the percentages of pictures in which *flowers*, *leaves* and *fruits* were depicted, broken down by *gender* and controlling for *educational level*.

3.2. Colour surface area analysis

The girls and boys who participated in the study coloured an average of 50.2 cm^2 of their drawings, i.e., approximately 8 % of the surface of a sheet. The drawing with the largest colour surface area covered 37 % of the area of sheet, and the drawing with the smallest colour surface area covered less than 1 % of the area of the sheet.

Fig. 2 shows the average surface area (in cm^2) of each of the 10 colours available to the children in the drawings (n = 251). The colours are arranged in descending order of the average surface area of colours. Green (13 cm^2) was the most popular colour, followed by brown (9.2 cm^2) and blue (8.8 cm^2). Yellow, red, orange, violet, pink, and black were used less frequently.

Table 7 shows the results for the study of relationship between the coloured surface in the drawings and the independent variables *gender* and *educational level* and, as well as with the effect of the *interaction* between the two variables. Specifically, the table shows the F statistic (calculated as the ratio between the sums of squares and the mean squares), the degrees of freedom, and the effect size (eta-squared, η^2). Significant differences are indicated by asterisks and shown in bold for medium or high effect sizes. When the effect size is low ($\eta^2 < 0.05$), the statistical significance of differences should be interpreted with caution.

Complementing the above information, Table 8 provides statistical descriptors of the violet surface area by boys and girls. The table shows that girls tended to colour a larger area in violet than boys, as indicated by the mean values of 3.7 and 1.7, respectively. This observation is consistent with the effect size reported in Table 7 for this colour.

Table 9 provides descriptive statistics for the red, pink and brown surface areas according to *educational level*. The data indicate that

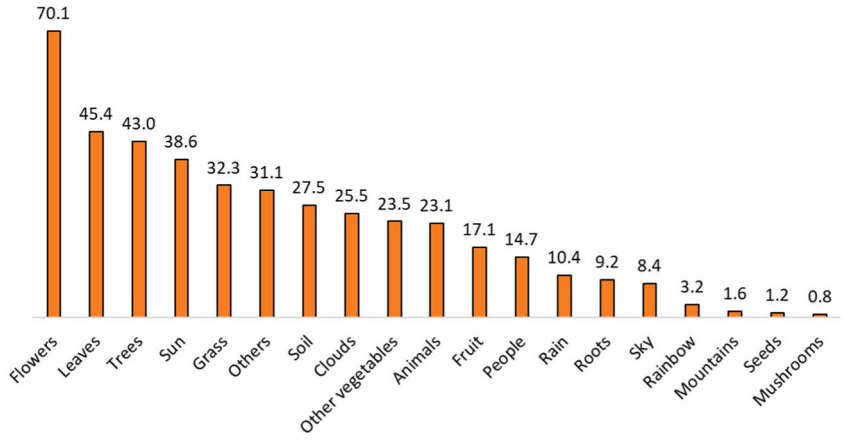

Figure 1. Relative frequency (%), based on the total number of drawings, of each type of pictorial element identified in the sample ($n = 251$)

Table 3
Frequencies of pictorial elements in relation to the variable educational level ($n = 251$).

	Kruskal – Wallis test			Effect size	
	χ^2	df	*p* value	*Cramer's V*	*Interpretation*
flowers	10.42	2	<0.001	0.204	low
trees	30.95	2	<0.001	0.351	**high**
leaves	21.32	2	<0.001	0.3	**medium**
seeds	6.15	2	<0.05	0.16	low
roots	8.1	2	<0.05	0.18	low
fruits	8.38	2	<0.05	0.18	low
ground	18.35	2	<0.001	0.27	**medium**
sun	8.19	2	<0.05	0.18	low
clouds	20.48	2	<0.001	0.29	**medium**
sky	12.21	2	<0.01	0.22	low

Table 4
Relative frequencies (%) of drawings that present the pictorial elements *trees*, *leaves*, *ground* and *clouds*, considering the variable *educational level*.

Educational level	*n*	Trees	Leaves	Ground	Clouds
2nd Year of Kindergarten	89	20.2	27	11.2	9
3rd Year of Kindergarten	83	50.6	61.4	37.3	37.3
1st Grade (Primary Education)	79	60.8	49.4	35.4	32

Table 5
Comparison by gender, controlling the variable educational level, of the frequencies of the drawing of *flowers*, *leaves* and *fruits*.

	Cochran–Mantel–Haenszel test				Breslow–Day test		
	χ^2	df	*p*	OR (*)	χ^2	df	*p*
flowers	14.26	1	<0.0001	3.210	1.13	2	>0.05
leaves	7.24	1	<0.01	2.146	1.25	2	>0.05
fruits	4.68	1	<0.05	2.263	0.71	2	>0.05

(*) Girl/boy for the representation of the pictorial element.

Table 6
Relative frequencies (%) of drawings in which the pictorial elements of *flowers*, *leaves* and *fruits* were represented, broken down by gender and controlling for educational level.

Gender	Educational level	*n*	Flowers	Leaves	Fruit
Girls	2nd Year of Kindergarten	45	75.6	**31.1**	**8.9**
	3rd Year of Kindergarten	43	86.0	**74.4**	30.2
	1st Grade (Primary Education)	32	84.4	59.5	31.3
Boys	2nd Year of Kindergarten	44	**40.9**	22.7	6.8
	3rd Year of Kindergarten	40	75.0	47.5	12.5
	1st Grade (Primary Education)	47	63.8	42.6	17.0

Bold indicates a significant difference, $p < 0.01$.

younger students were more likely to colour a larger area in red and pink in their drawings than older children, but the opposite pattern was observed for brown.

Table 10 presents the surface coloured orange by girls and boys, considering the educational level of the students. As shown in Table 7, orange was the only colour with significant sex differences after controlling for educational level. Table 10 shows that the largest differences occurred among boys in different academic grades.

4. Discussion

The object of study of this research was the spontaneous drawings by children between 4 and 8 years old to express their knowledge about the plant world. More specifically, this study examined the relationship that pictorial content and the use of colour have with the combined effect of the variables *gender* and *educational level*.

The evidence collected and the conclusions regarding the stated objective are discussed below, first, with respect to the pictorial content of the drawings and then with respect to the use of colour. In both cases, the discussion begins by reviewing the evidence collected in relation to the variables *gender* and *educational level*, independently, and then, the results for the effect of their joint

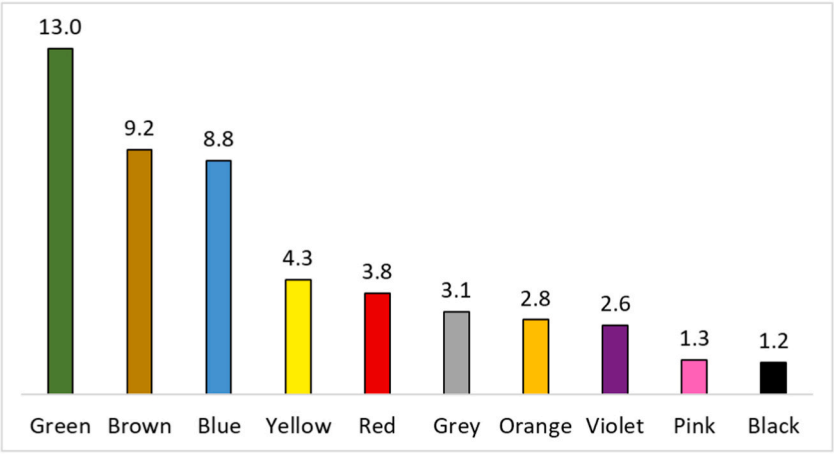

Fig. 2. Average colour surface area (cm^2) in the drawings composing the sample ($n = 251$) for each of the ten colours available to students.

Table 7
Scheirer–Ray–Hare test results for the analysis of the relationship between surface coloured with each colour with the independent variables *gender* and *educational level* and with the interaction between the two.

	Gender			Educational level			Interaction		
	SS/MS	df	η^2	SS/MS	df	$\eta\eta^2$	SS/MS	df	η^2
Yellow	**9.37****	1	0.04	1.30	2	0.01	2.89	2	0.01
Orange	1.88	1	0.01	**12.05***	2	0.05	**6.03***	2	0.02
Red	0.78	1	0.00	**15.48*****	2	**0.06**	3.14	2	0.01
Blue	0.09	1	0.00	1.43	2	0.01	2.26	2	0.01
Green	2.21	1	0.01	**12.08****	2	0.05	0.46	2	0.00
Violet	**15.59*****	1	**0.06**	**12.26****	2	0.05	4.30	2	0.02
Pink	**9.50****	1	0.04	**14.72*****	2	**0.06**	4.33	2	0.02
Brown	0.46	1	0.00	**16.38****	2	**0.07**	0.48	2	0.00
Grey	0.00	1	0.00	8.90*	2	0.04	0.33	2	0.00
Black	0.13	1	0.00	6.03	2	0.02	1.76	2	0.01

*p < 0.05 **p < 0.01 ***p < 0.0001.

Table 8
Statistical descriptors of the area coloured violet (cm^2) in relation to the variable *gender*.

	n	Mean (SD)	Median
Girls	120	3.7 (7.2)	1.05
Boys	131	1.7 (4.4)	0.0

Table 9
Statistical descriptors of the area coloured red, pink and brown (cm^2) in relation to the variable *educational level*.

	Educational level	*n*	Mean (SD)	Median
Red	2nd Year of Kindergarten	89	5.8 (10.4)	1.5
	3rd Year of Kindergarten	83	3.6 (10.4)	0.5
	1st Grade (Primary Education)	79	1.7 (3.8)	0.3
Pink	2nd Year of Kindergarten	89	2.5 (5.4)	0.0
	3rd Year of Kindergarten	83	1.0 (2.0)	0.0
	1st Grade (Primary Education)	79	0.4 (1.0)	0.0
Brown	2nd Year of Kindergarten	89	4.7 (9.6)	0.6
	3rd Year of Kindergarten	83	12.6 (19.6)	3.7
	1st Grade (Primary Education)	79	10.8 (16.3)	4.7

Table 10
Statistical descriptors of the area coloured orange (cm^2) by girls and boys, considering the variable *educational level*.

	Educational level	*n*	Mean (SD)	Median
Girls	2nd Year of Kindergarten	45	2.5 (5.3)	0.0
	3rd Year of Kindergarten	43	2.9 (10.1)	0.0
	1st Grade (Primary Education)	32	2.9 (8.2)	0.0
Boys	2nd Year of Kindergarten	44	5.8 (11.3)	1.47
	3rd Year of Kindergarten	40	0.8 (1.5)	0.0
	1st Grade (Primary Education)	47	1.14 (1.4)	0.38

interaction on the dependent variables are considered.

4.1. Pictorial content

This study did not generate evidence that allows the conclusion that the pictorial content of the drawings differed between girls and boys when *gender* was considered independently.

The data allowed accepting, however, that the representations of *trees*, *leaves*, *clouds* and the *ground* were more frequent in the drawings by students with higher educational levels when the variable educational level was considered independently. Regarding the joint consideration of the variables *gender* and *educational level*, the evidence showed a significant effect on the frequencies of drawings that included flowers, leaves and fruits.

With regard to the representation of *flowers*, girls, compared to their peers, were more inclined to include such representations, regardless of the academic level considered. Furthermore, the data collected were consistent with the assumption that the frequency of flowers in drawings produced by the girls was essentially identical for the three educational levels. In contrast, not only did boys draw flowers less frequently than did girls at all educational levels, but boys in the 2 nd year of kindergarten also drew flowers less frequently than did their peers in higher grades.

Regarding the frequencies of drawings that included leaves and fruits, which is considered the beginning of the most detailed representation of the plant world [16], the data obtained indicated that girls were, again, significantly more likely to include these elements in drawings at all academic levels. The frequencies of flowers, leaves and fruits in drawings are shown in Table 6. Nevertheless, the frequency of representation of these pictorial elements was not homogeneous across the three educational levels; therefore, the evidence presented indicated that this frequency was significantly lower among girls in the 2 nd year of kindergarten. In contrast, the available data could not confirm that the frequencies of leaves and fruits in drawings by the boys varied significantly among academic levels.

This discussion shows, on the one hand, similarities with the conclusions reported in previous studies and, on the other hand, introduces some novel findings that could serve to guide future research. Previous studies have noted the scarce relationship that *gender* has with the pictorial content of undirected drawings by boys and girls of heterogeneous educational levels about plant life when this variable is considered independently [11,31]. Likewise, previous studies also indicate that there are relationships between certain pictorial elements and educational level when analysed independently. Thus, the representation of trees seems to be strongly related to the educational level of students [13], a fact that is understood to be connected with the difficulty that children express when considering trees as plants [12,19].

However, the most relevant contribution of the present study may be related to the fact that the joint consideration of the variables *gender* and *educational level* had a significant effect on those pictorial elements considered key in the development of the understanding of the plant world. More explicitly, if the *gender* variable is analysed independently (that is, without considering the educational level of students), it can be erroneously concluded that there was no evidence to affirm that there were significant differences. However, the differences between girls and boys in terms of pictorial content relative to at least three pictorial motifs (*flowers*, *leaves* and *fruit*) were only revealed when the educational level of the students was controlled.

4.2. The use of colour

The evidence provided by this research indicated that of the ten colours offered to the students during the drawing activity, only the use of violet was significantly different between girls and boys when *gender* was considered independently. In this sense, girls coloured more area with this colour than did their peers.

In the drawings made by students of different educational levels, there were significant differences in terms of the surface area coloured red and brown. When considering the *educational level* variable independently, students with higher educational levels coloured larger areas of their drawings with brown and less with pink and red. This evidence agrees with the data obtained in our previous study, i.e., few differences found in terms of the use of colour in drawings by girls and boys and the connection that colours such as brown and pink have with the variable *educational level* [13].

The observations presented above fit somewhat with the findings published in previous research. Thus, Villarroel [13] also reported few differences between girls and boys in terms of the surface coloured with similar colours by students between 4 and 8 years old in drawings of plants. In that study, the differences were centred around the colour pink, unlike the results in this study, in which there was a difference in the use of the colour violet.

Another relevant aspect that previous research has noted is the characteristic increase in the use of brown in drawings by students at higher academic levels. This observation is consistent with the one presented above in the sense of the close relationship that was found in the analysed sample between *educational level* and frequency of trees in drawings. As Villarroel et al. [13] noted, children tend to paint tree trunks brown, which is why both variables (frequency of drawing of trees and surface coloured brown) would be associated with the variable *educational level*. In this sense, from 4 to 8 years of age, children begin to understand that plants are living beings and that trees are considered plants [31–33].

Finally, the data provided in this study did not definitively support the hypothesis that the joint consideration of *gender* and *educational level* had a significant effect on the surface area coloured by children in their drawings of plant life. Significant differences were found but with a low correlation, linked to the colour orange. In this way, the data suggest that the use of orange varies in children's drawings and that girls colour similar surfaces in orange, regardless of educational level. As Cohen [34] warns, the fact that the effect size is low may indicate that further studies are necessary to corroborate the hypothesized relationship between the variables.

5. Conclusions

In conclusion, the evidence presented in this work urges us to take into account in future research the study of the joint effect that the variables *gender* and *educational level* have on the pictorial content of drawings by girls and boys in kindergarten and the first years of primary education to express their knowledge about the plant world. The data presented indicate that when the frequency with which children draw key elements of plant knowledge, such as flowers, leaves and fruits, is considered, these frequencies cannot be analysed without being broken down by educational level. Previous research has not reported significant differences in relation to *gender* [35], but this observation could be a consequence of the fact that during the data analysis, the *educational level* of the students was not controlled.

Finally, this study does not allow us to assert conclusively that the joint consideration of the variables *gender* and *educational level* has a notable effect with regard to the use of colours in children's drawings of the plant world. The fact that a significant but weak relationship exists between the joint consideration of *gender* and *educational level* seems to suggest the need to take these variables into account in related analyses in future research.

Limitations of the study and future lines of research

The research presented attempts to establish whether the joint consideration of the variables *educational level* and *gender* has any relationship either with the pictorial content or with the colours that children in the first year of primary education and last cycle of kindergarten use when expressing their knowledge about the plant world. The conclusion derived from the data obtained suggests that the analysis of relevant aspects of the pictorial content of plant representations produced by girls, in comparison with that in the drawings by boys, should be analysed by controlling the academic level of the participants. The data provided, however, do not allow us to conclude that this type of analysis is, at least, in the first instance, justified in the study of the colours with which they paint their plant representations.

The main limitation of the work presented is centred on the fact that the results are essentially relational in nature, without being able to establish connections with a certain theoretical framework that facilitates understanding why the expression of plant knowledge in the analysed age group would evolve throughout the initial educational phases differently in girls and boys. Solving this deficiency is not immediate but requires a research programme to be developed in the coming years. It is necessary to accumulate, through the study of new samples, more evidence that allows us to establish the regularity of the observations noted and that, therefore, the conclusions reached with the students in this study are similar for other groups.

Moreover, the temporal gap between data collection and the present time suggests that the findings of this study should be interpreted with caution. The data were collected during the 2015–2016 academic year, and changes in educational practices and societal norms since then may have influenced children's understanding and representation of plant life. Accordingly, further research is needed to confirm these findings and to explore how these influences may have evolved over time.

Furthermore, it would also be interesting to study children's representation of knowledge related to other areas of the biological domain, in addition to the plant world, [36,37]. It is essential, in the event that the trends reported in this work are observed in other samples, to develop connections with theoretical frameworks linked to the world of evolutionary psychology that allow making sense of these findings.

The corollary of this research is related to the need to develop research that enables, on the one hand, to gather evidence for generalizing the described phenomenon and, on the other hand, to construct explanatory frameworks that establish connections with a broader theoretical corpus.

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Data availability statement

The data that support the findings of this study are freely available in Mendeley Data at http://doi.org/10.17632/hn4m7pjtb2.1.

CRediT authorship contribution statement

José Domingo Villarroel: Writing - review & editing, Writing - original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Alvaro Antón:** Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Teresa Nuño:** Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Daniel Zuazagoitia:** Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Annex.

Fig. 1. Drawing by a child in the first year of primary education.

Fig. 2. Drawing by a child in kindergarten.

Fig. 3. Drawing by a child in the first year of primary education.

Fig. 4. Drawing by a child in kindergarten.

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