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43	Abstract	Tables are a presentation format that is commonly used to organize information, and they are widely present in many scenarios of our students' everyday activities; however, there is a scarcity of studies devoted to their analysis. Some of these studies point out that the organization of data into a double-entry table presents difficulties for primary and secondary school students. The present study analyzes the following: (1) the level of competency of primary and secondary school students in constructing a double-entry table from a set of data and (2) the main difficulties encountered by these students during the task. Our findings showed that the percentage of middle-school studentswho succeeded in contructing a conventional table was relatively low, and the number did not significantly increase over four school years. A set of difficulties is identified and discussed in terms of cognitive and graphical processes. **Résumé:** Les tableaux sont un format de représentation fréquemment utilisés pour organiser des informations. Les tableaux sont très présents dans l'entourage quotidien des étudiants mais on trouve peu d'études concernées par leur analyse. Certains de ces études signalent que l'organisation de données dans un tableau à double entrée peut être difficile pour des étudiants de primaire et secondaire. La présente étude analyse: 1) le niveau de compétence des étudiants de primaire et secondaire lors de la construction d'un tableau à double entrée en partant d'un ensemble de données et 2) les principales difficultés rencontrées par les étudiants pendant la tâche. Nos résultats montrent que le pourcentage d'étudiants que réussissent à construire un tableau conventionnel est relativement bas, et aussi que ce pourcentage n'augmente pas de façon significative au cours de la scolarité. Un ensemble de difficultés sont identifiées et analysées en termes de processus cognitifs et graphiques.

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The construction of a double-entry table: a study of primary and secondary school students' difficulties

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Abstract Tables are a presentation format that is commonly used to organize information, and they are widely present in many scenarios of our students' everyday activities; however, there is a scarcity of studies devoted to their analysis. Some of these studies point out that the organization of data into a double-entry table presents difficulties for primary and secondary school students. The present study analyzes the following: (1) the level of competency of primary and secondary school students in constructing a double-entry table from a set of data and (2) the main difficulties encountered by these students during the task. Our findings showed that the percentage of middle-school studentswho succeeded in contructing a conventional table was relatively low, and the number did not significantly increase over four school years. A set of difficulties is identified and discussed in terms of cognitive and graphical processes.

Résumé Les tableaux sont un format de représentation fréquemment utilisés pour organiser des informations. Les tableaux sont très présents dans l'entourage quotidien des étudiants mais on trouve peu d'études concernées par leur analyse. Certains de ces études signalent que l'organisation de données dans un tableau à double entrée peut être difficile pour des étudiants de primaire et secondaire. La présente étude analyse: 1) le niveau de compétence des étudiants de primaire et secondaire lors de la construction d'un tableau à double entrée en partant d'un ensemble de données et 2) les principales difficultés rencontrées par les étudiants pendant la tâche. Nos résultats montrent que le pourcentage d'étudiants que réussissent à construire un tableau conventionnel est relativement bas, et aussi que ce pourcentage n'augmente pas de façon significative au cours de la scolarité. Un ensemble de difficultés sont identifiées et analysées en termes de processus cognitifs et graphiques.

Keywords Graphic literacy · Table construction · Cognitive difficulties · School

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Learning science and mathematics requires the use of various formats for representing information. In addition to written text, science and mathematics textbooks normally include graphical formats to represent information, such as maps, diagrams, graphs, and tables (Lemke 1998). These representational formats are also commonly found on digital formats (Wright et al. 1999). Each type of representation has its own peculiarities that enable the communication and organization of the information in different ways. Thus, the proper use of these graphical formats for presenting information and the ability to transform the information from one format to another are essential skills for succeeding in an environment in which information becomes progressively more complex and diversified. In fact, one of the increasingly recognized goals of primary and secondary education is to develop students' awareness of the fact that information can be presented in different ways. Moreover, students need to acquire the ability not only to critically interpret information presented in these various formats but also to construct tables and graphs from different sources of data.

According to some published reports about the graphic competencies of students at different educational levels (Barquero et al. 2000; Eshach and Schwartz 2002; Leinhardt et al. 1990; Postigo and Pozo 1999; Wu and Krajcik 2006), the difficulties with producing, interpreting, and using graphically presented information persist beyond the end of compulsory education. Thus, it is essential to identify these difficulties so as to develop teaching approaches that foster students' graphic competencies. The present study focuses on the difficulties involved in constructing a table, a format that has received very little research attention compared to that devoted to graphs (Brizuela and Lara-Roth 2002; Martinez and Brizuela 2006). One reason for this limited attention may be that tables are wrongly considered to be a simple and easy way of transmitting and communicating information; as such, they are not thought to require any explicit learning or teaching. In this paper, we argue that tables, just like other graphic devices, have their own specificity and require a particular set of cognitive and graphical abilities.

Let us consider the specificity of tables compared with other closely related graphic devices, such as lists. Although there is a wide variety of table formats, the fundamental characteristic is that the information layout is based on lines and columns. Information in a table is clearly separated so that it can be rapidly identified. When a table needs to be interpreted, the interpreter must look for the cell that provides a given datum. This search is done by cross-tabulating the row with the corresponding column to find the datum at the intersection. Regarding its construction, a table requires a process of segmentation and the choice of significant units of information. It is also necessary to organize this information (categorization of variables, matching correspondences), which must be translated into a given spatial layout.

In his matrix theory of graphics, Bertin (2000/2001) makes a semiotic analysis of the properties of the visual image, data tabulation, and graphing and shows how these properties help identify relationships among data. His claim is that the table implies that certain *re-ordering and classification* and a *double-entry structure* be applied to data. In line with Bertin's theory, Novick and Hurley (2001) proposed a series of structural parameters that define a table (or matrix): (1) the representation expressing a factorial combination of possibilities; (2) the cell as a building block, denoting the intersection or combination of value *i* on one variable and value *j* on the other variable; (3) two distinct variables, as a result of the layout in rows and columns, that specify values; and (4) the same row or same column may not be linked. In addition, these authors mention two further characteristics related to specific information: (5) purely associative and non-directional links between row and column and (6) the capacity to make the absence of a relationship explicit.

Lists are a type of written representation that has some commonalities with tables. The list consists of information organized in a sequential manner with the goal of facilitating enumeration or making a catalogue of items, such as people, names, or other types of information. Examples include a shopping list, an inventory of furniture in a house, or a list of the kings of France. Like tables, lists are formed by discrete information laid out in a graphic space; indeed, this information is spatially organized by means of a graphic criterion. Some lists organize enumerations linearly and separate them by a sign such as a comma or other graphical sign (i.e., horizontal lists). Other lists are organized vertically and are separated by a return key (vertical lists). Therefore, unlike tables, lists are organized according to a single spatial dimension (horizontal or vertical).

Given the apparent similarity of the two formats (lists and tables), it is worth analyzing the transformations that enable a table to be constructed from a list. The step from enumeration in a list to a table involves identifying several underlying variables in the list whose values are organized into two (or more) dimensions that intersect. The particular case of frequency tables also requires that the cases enumerated in the list are counted for each category of a variable. Therefore, it is normally assumed that a table combines two or more lists in a coordinate manner; thus, it is a more complex and elaborate format than a list (Duval 2003; Goody 1993). Historical research has shown that tables took a long time to become widespread in Mesopotamian documents. They accounted for only 1% to 2% of all administrative documents, and scribes continued to prefer simpler linear methods of managing information, such as lists (Robson 2003).

According to the prior analysis, we can conclude that one of the central features of tables is the double-entry structure. It is interesting to remember that Piaget and Inhelder (1976), in one of their classic studies about logic operations, show that the capacity to double classify a set of objects is related to concrete operations, an achievement that appears around 8 years. In this sense, we hypothesize that students that are finishing primary level will have this general cognitive capacity. Our claim is that to spatially organize a set of objects according to two dimensions (for example, color and size) is a less demanding task than constructing a double-entry table (for example, a frequency table that includes the distribution of boys and girls according their weights). In the table construction task, a set of graphical requirements and specific cognitive abilities are required. Some of the graphical requirements are to situate the categories of the two dimensions horizontally and vertically, to create cells, to define the labels of the categories, and to write the result in the cells. Some of the specific cognitive abilities are to categorize students according gender, to categorize students according height intervals, to cross-categorize students according both variables, and to count the items of each cross-category (frequencies). Thus, it is possible that cross-classification is a necessary condition to construct a table although it may not be a sufficient one.

An interesting finding from a study with second and fifth graders is that the list format was more commonly used than tables. These students were asked to notate a series of data (the number of beads of different colors that belonged to three sisters) with the aim of remembering these data later on. They mostly used lists that were often used as bridges to the tabular organization of information (Martí 2008).

The management of tables may involve several goals: interpretation, using them to explain several phenomena or make predictions, using them to communicate, or constructing a table with the goal of reorganizing a table to better visualize the relationships between data. The present study focuses on table construction, which is a fundamental consideration in terms of determining the level to which students have interiorized tables as a semiotic tool capable of organizing several sets of data according to given conventional criteria that are specific to this representational format. Although the literature in the vygostkian tradition states the idea of semiotic devices as tools for thinking and problem solving (Kozulin 1998), only occasional theoretical (Bertin 2000/2001; Novick and Hurley 2001) and empirical studies (Brizuela and Lara-Roth 2002; Lehrer and Schauble (2000); Martí 2008; Wu and Krajcik 2005) advocate for the role of tables in problem solving. Q3

Brizuela and Lara-Roth address the construction of a table by second graders. The task consisted of a problem with a statement that showed an increase in three children's savings (in dollars) over three different days. The goal of the problem was to find out the amount each child had at the end of the third day. Participants were asked to illustrate what happened from day 1 to day 3 in a table. Specifically, they had to show how the initial amount of money ($7, $4, and $0 for each child, respectively) changed with the increase on the second day (+$2) and that on the third day (+$3). A conventional table would include three columns (or rows) with the names of the children and three rows (or columns) with the days, and the task would then be to fill in the cells as a product of the cross-tabulation of rows and columns with the corresponding amounts. Although the students had previously worked with conventional tables related to additive functions and were able to use them for modeling, they tended to build tables that significantly differed from these conventional tables, when asked to solve problems like the one mentioned above. This result suggests that the construction of a table to solve a given problem is not restricted to the reproduction of a known conventional table but, rather, implies a process of re-construction in which students introduce original elements. One of the examples highlighted by Brizuela and Lara-Roth is the repetition of redundant information (e.g., the initials of each of the three children's names) in the cells of the table, rather than including this information in the margins. The authors highlighted the importance of the choice that the children made concerning information considered relevant (and made explicit) in the table versus that which was considered irrelevant (and which did not appear explicitly in the table).

These results are also supported by naturalistic research. Wu and Krajcik (2006) had seventh graders participate in an inquiry-based learning environment where they were asked to construct inscriptions while making predictions, designing investigations, and presenting and sharing data about water quality. Their study shows the progress in students' design and interpretation of data tables with the teacher's scaffolding. It is worth noting the time spent by the groups of students discussing the categories and structure of a table. As the authors illustrate using excerpts of group discussions, the teacher's scaffolding was crucial in helping students decide which categories the variables should be organized into and what format the table should follow.

Using a similar approach, Lehrer and Schauble (2000) analyze students' progress in inventing and conventionalizing data structures to "mathematize" their classification activities in the class. Working with first, second, fourth, and fifth graders, they showed a bias toward spontaneously organizing the data into disjointed categories and that the students had difficulty with having one category provide information for the rest of the cells in the same column of a table. Another interesting finding reported by these authors is the resistance on the part of the middle-school students toward compacting the information in the table by making it implicit. They report the common heuristic of "the more stuff (in the cells) the better" (p. 66).

The studies mentioned above suggest that, although students may be familiar with this presentation format and have used it previously, the process of constructing a table is not an easy task. The authors conclude that when students are presented with a new problem that requires the construction of a table, they get involved in a reconstruction process that does not always lead them to known conventional tables.

The first goal of the present research was to determine the performance of primary (fifth and sixth grade) and secondary (seventh and eighth grade) school students' when they are asked to build a table from a series of data organized into a list; the paper includes an analysis of the students' progress over the four grade levels. The second goal was to analyze the main difficulties that appear in this construction process.

The choice of the four school grades was driven by two criteria. First, a previous study by Martí (2008) showed that when children are asked to spontaneously organize a series of data, without any specific prompt, none of the second graders and only a few fifth graders constructed a table as the organizational format. It appears that fifth graders begin to have the knowledge required to come up with this format spontaneously. In addition, the official mathematics curriculum for these grades clearly includes two types of activities related to tables: (a) "Data tables. Introduction to the use of efficient strategies for data counting" and (b) "Reading and interpretation of double-entry tables that are normally used in everyday life". These contents are designed to be specifically reviewed and extended during secondary education.[1]

Method

Participants

One hundred and fifty-three students were drawn from five state schools in a major metropolitan area. The students' distribution according to grade level was 31 fifth graders (primary school; mean age 10.8; range 10.4–11.1; 18 girls and 13 boys), 39 sixth graders (primary school; mean age 11.7; range 11.3–12.8; 19 girls and 20 boys), 43 seventh graders (secondary school; mean age 13.0; range 12.3–14.3; 20 girls and 23 boys), and 40 eighth graders (secondary school; mean age 13.8; range 13.3–15.2; 24 girls and 16 boys).

Task and procedure

The task consisted of constructing a table and a graph[2] from a list containing information about the height of students in a given class (see Table 1). This content was chosen because it was believed to be familiar to students and did not present any difficulty for students at these grades. They could thus focus on the format rather than the content.

[1] The Spanish Educational System considers fifth and sixth grades as primary education and seventh and eighth grades as secondary education. Seventh and eighth grades are called first and second year in secondary school. As with any change of educational levels, the transfer from primary to secondary education implies important contextual and curricular changes. Two of the most salient changes are (1) the students in public schools change schools and (2) they have a teacher who specialized on a specific subjet area, instead of having a generalist teacher across most subjects. In primary education, these goals appear in the mathematics curriculum in the area of "Managing information: Probability and randomness". In secondary education, the importance of the variety of ways to present information (verbal, numerical, symbolic, and graphic) is mentioned in the introduction of the subject areas of Science and Social Science, although the skills appear best defined and concretized in the area of Mathematics, normally under the block of "Graphs and Functions". (Real Decreto sobre enseñanzas mínimas de la Educación Primaria 2006; Real Decreto sobre enseñanzas mínimas de la Educación Secundaria Obligatoria 2007; Spanish National Syllabus for School Mathematics).

[2] The reference to a graph in the task demands is explained by the fact that the present study belongs to a major project aimed at analyzing the role of tables in graphing from the point of view of production and interpetation processes. The analysis in the present paper only focuses on production of tables.

Table 1 Data list from which the students were asked to build the table Q4

	First name	Family name	Age (years)	Measure (cm)
1	Ana	Aliaga	12	126
2	Pau	Blanco	14	174
3	Silvia	Cano	14	165
4	Lucas	de los Santos	13	171
5	Marta	Fernández	13	154
6	Fatima	García	13	148
7	Olga	García	14	172
8	Miquel	Gisbert	14	173
9	Nuria	Gómez	13	156
10	Ainhoa	Gri	13	147
11	Andreu	Guillén	13	157
12	Ismael	Jiménez	13	165
13	Montse	Martín	13	142
14	Joana	Martínez	12	134
15	Marc	Molero	13	146
16	Enric	Molina	12	141
17	Eva	Molina	12	128
18	Alicia	Moreno	13	151
19	Victor	Pajares	13	167
20	Sara	Peiro	12	144
21	Joan	Planas	12	134
22	Judith	Romero	13	139
23	Francesc	Sánchez	13	149
24	Aitor	Toledo	13	160
25	Sergi	Vega	13	155

The task was presented with the following prompt: "The students attending another school have been gathering the data presented on the attached sheet of paper. With these data we want you to make a table and a graph that enables us to know how many boys and how many girls are shorter than 130 cm, how many measure between 130 and 149 cm, how many measure between 150 and 169 cm and how many are taller than 169 cm." The task was presented by the teacher in the regular classroom setting.

An analysis of the task shows that the step from a list to a conventional table (double-entry table with frequencies in the cells) required the following: (1) identify the goal of the task (students must pay attention to the instructions so that they can organize the data according to height intervals), (2) construct the categories (boys vs. girls) of the first variable (gender), (3) construct the categories (height intervals) of the second variable (height), (4) count the data that must be included in each category, and (5) cross-tabulate both variables in a double-entry table. This cross-tabulation would also require the organization of data into two graphical dimensions (vertical and horizontal). The next section presents the analysis of the students' answer sheets from a dual perspective: different formats of productions and identification of the main difficulties in constructing a double-entry table.

Results

Analysis of productions according to format

The first analysis was conducted to address the first goal, i.e., studying the ability of students to build a table and observing the extent to which they can build a table at each grade level. Most of the students (94.8%) gave some sort of graphic answer to the task presented, indicating that they understood the basic request to construct a graphic display from the initial list. Within this group, a small percentage of students (11.8%) created a graph instead of a table, indicating that the difference between a table and a graph was not completely clear, even among students in the early secondary grades (Table 2). In each grade, the number of students who made a graph instead of a table was four (13%), three (7%), seven (17%), and four (10%) for fifth, sixth, seventh, and eighth grades, respectively (Table 2).[3]

An analysis of the graphic format of students' responses revealed two basic categories: lists and tables. Lists are characterized by a listed enumeration of data, without any cross-tabulation. The students produced the following four types of lists: (1) lists without any grouping, (2) lists where data were grouped according to gender, (3) lists where data were grouped according to height intervals, and (4) lists where data were grouped by gender and height. The students produced two types of tables. In the first, the cells contained the names of the students in the list, rather than the frequency. In the second type, which we would consider a conventional table, the frequencies were clearly indicated in the respective cells. The students' productions were coded by two independent judges, who reached 90% agreement in their coding. All discrepant cases were resolved by a second coding process.

Some of the lists (lists whose data were grouped according to height intervals and lists whose data were grouped by gender and height) and the two kinds of tables are productions that responded to the the task's demand (to compare the number of boys and girls in each of the height intervals). In this sense, they were considered correct productions. Student responses that fell into the categories "no answer", "graphs", "others", "lists without organization", and "lists organized only by gender" were considered incorrect responses. Although the organization of the data by gender was a step forward from the initial list, it did not fulfill the task's demand. In fact, only one child did so. The distribution of the correct productions by school grade was as follows: 64.5% in fifth grade, 71.7% in sixth grade, 72.1% in seventh grade, and 80% in eighth grade. The chi-squared test for the comparison of frequencies was performed, and it yielded non-significant differences ($\chi^2(3) = 2.13, p = \text{ns}$).

As the data show, more than half of the students across the four grades produced correct responses, presenting no differences between groups. However, the different formats included within the correct productions differed in the way they fulfilled the task demand. Whereas conventional tables allowed a direct comparison of the numbers of boys and girls at each height interval, the other formats required the number of boys and girls in each interval to be calculated. Table 3 shows the distribution of the students' productions according to the different formats.

[3] A new crosstab analysis was performed comparing the students who made a table vs. a graph across grade levels. Cell-standardized residuals showed no over- or underrepresentation (0.4, −0.7, 0.7, and −0.4, respectively for fifth, sixth, seventh, and eighth grade; $\chi^2(3) = 1.46, p = \text{ns}$).

Table 2 Distribution of frequencies (and percents) of types of construction according to correct/incorrect production across grades

	Correct tables and lists	Incomplete list[a]	Incorrect graphs	Others	NA	Total
Fifth grade	20 (64.5)	1 (3.2)	4 (12.9)	4 (12.9)	2 (6.5)	31 (100)
Sixth grade	28 (71.7)	3 (7.7)	3 (7.7)	2 (5.1)	2 (5.1)	39 (100)
Seventh grade	31 (72.1)	3 (7.7)	7 (16.3)	1 (2.3)	1 (2.3)	43 (100)
Eighth grade	32 (80.0)	1 (2.5)	4 (10.0)	0 (0)	3 (7.5)	40 (100)
Total	111 (73.0.0)	8 (5.2)	18 (11.8)	7 (4.6)	8 (5.2)	152 (100)

[a] Unorganized lists or organized only by gender

The chi-squared test for the distribution of frequencies yielded significant differences $(\chi^2(9) = 2.37, p = 0.005)$. Cell-standardized residuals were calculated to show the over- and underrepresented cells within the distribution. According with these results, the most frequent format in fifth grade was "list organized by gender and height"; in sixth grade, it was "conventional table"; in seventh grade, it was "list organized only by height"; and in eighth grade, it was again "conventional table". These format differences do not indicate any progression from fifth to eighth grade. The percentage of conventional tables with respect to the total responses (n=152, see totals in Table 2) was 30.2% across all grades. The distributions of conventional tables in the fifth, sixth, seventh, and eighth grades were, respectively, 19.3% (six out of 31), 46.1% (18 out of 39), 18.6% (eight out of 43), and 35% (14 out of 40). We observed that these percentages were quite low, prompting further analysis to determine why conventional tables were so difficult for students to construct. We hypothesized that developing a table presents three basic difficulties: (1) difficulty graphically crossing the two variables, (2) difficulty categorizing the variable gender within the variable height, and (3) difficulty indicating the numbers of boys and girls. The following section compares the frequencies across grades of the productions that overcame these difficulties. Correct productions were subjected to statistical analysis.

Analysis of difficulties

Difficulty graphically crossing the two variables The numbers of students who made a correct production but did not produce a double-entry table were 12 out of 20, eight out of 28, 17 out of 31, and nine out of 32 (60%, 28.6%, 54.8%, 28.1%) for fifth, sixth, seventh, and eighth grades, respectively. A chi-squared analysis yielded significant differences in the distribution according to grade $(\chi^2(3) = 9.38, p = 0.025)$.

Almost half of the students with a correct response across all grades made a list, which is a lower-level production than a table in terms of format and compactness because the different categories are organized in a single dimension. Although some of these lists contained all of the elements necessary to be considered a table, the data were not organized in a double-entry format. Therefore, they were less compact than tables.

Figure 1 shows Maria's[4] attempts to categorize the students in a list according to height intervals (pooling boys and girls). She created a vertical list, differentiating blocks that corresponded to different heights, but then realized that she did not have the variable gender

[4] All names are pseudonyms.

t3.1 **Table 3** The distribution of frequencies of students, percents, and cell-standardized residuals by type of correct production across grades

	Format	Fifth grade			Sixth grade			Seventh grade			Eighth grade			Totals
t3.2		Frequency	%	CSR	Frequency	%	CSR	Frequency	%	CSR	Frequency	%	CSR	
t3.4	List by height	5	25	−0.2	6	21.4	−0.7	14	45.2	1.8	6	18.8	−1.0	31
t3.5	List by height and gender	7	35	2.6	2	7.1	−0.9	3	9.7	−0.6	3	9.4	−0.6	15
t3.6	Table without frequencies	2	10	−0.8	2	7.1	−1.3	6	19.4	0.3	9	28.1	1.5	19
t3.7	Table with frequencies	6	30	−0.8	18	64.3	1.9	8	25.8	−1.4	14	43.8	0.2	46
t3.8	Totals	20	10		28	100		31			32	100		111

CSR cell-standardized residuals

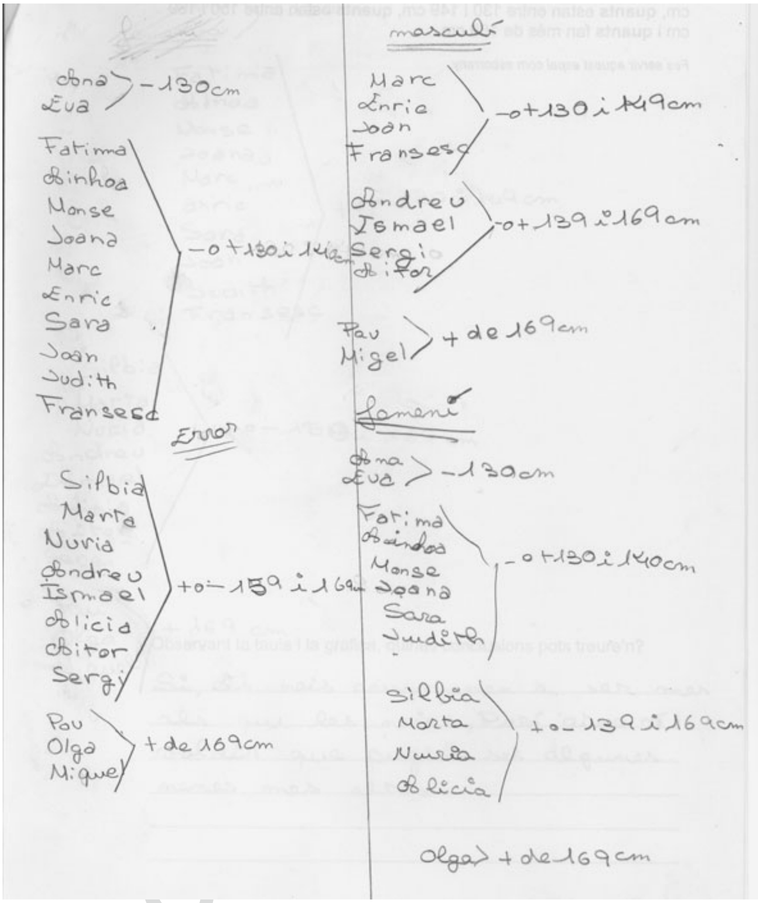


Fig. 1 Maria's production (sixth grade, primary education)

structured according to the problem statement. She made another list (see the right-hand side of the production), but this time, she separated boys and girls (see the heading in Catalan for boys (*masculi*) and girls (*femení*)). She then made a list of the students, separating them into blocks (within each category) that corresponded to height intervals. Maria's production thus responded to the problem as set. She simultaneously separated the students by gender and height, listing them in order from top to bottom. However, she did not organize the data by crossing the variables (gender and height), nor did she indicate the frequencies within each category.

Difficulty categorizing the variable gender within the variable height In some lists, the participants did not separate the categories according to gender. The distribution of the students according to whether they subcategorized the variable gender within height intervals did not yield significant differences ($\chi^2(3) = 6.58, p = 0.086$). The percentages of productions that categorized gender within height across each grade were 75% (15 out of 20), 78.5% (22 out of 28), 54.8% (17 out of 31), and 81.25% (26 out of 32) for fifth, sixth, seventh, and eighth grades, respectively. A relatively high percentage of students in all grades organized the data according to the two variables (Fig. 2). Q5

Fig. 2 Ilenia's production (fifth grade, primary education)

Similar to Maria in her first attempt, Ilenia made a list of all of the students and differentiated the categories. The result was a list organized according to only one of the variables (height).

Difficulty aggregating the data to indicate the frequencies of boys and girls In some tables and in most of the lists, the names in the lists were enumerated without indicating the resulting frequency. Thus, the step that enables the viewer to make quantitative comparisons of the information is missing. Additionally, this difficulty was related to the students' reluctance to remove redundant information. In some of the lists and tables, the participants wrote the names of the boys and the girls from the given list, and they sometimes also included the specific heights of each student on the list. That information was redundant because it was already specified in the margins of the table. The corresponding chi-squared analysis showed differences in the distribution of this response by grade ($\chi^2(3) = 1.03, p = 0.016$). The percentages of responses across each grade that included frequencies in the cells were 30% (six out of 20), 64.3% (18 out of 28), 25.8% (eight out of 31), and 43.75% (14 out of 32) for fifth, sixth, seventh, and eighth grades, respectively (note: these figures are based on the total number of correct responses. This explains why the percentages on page 13 are lower; they were calculated with respect to the total number of responses, correct or incorrect).

This difficulty with aggregating data is illustrated in Marina's production (Fig. 3). In fact, Marina proposed a double-entry table organized according to the height variable (columns) and the gender variable (rows), but rather than showing the frequencies for each cell, she listed the names of the relevant students and their corresponding heights. The height information included in the data list enabled the participants to categorize the information into intervals, but it was not necessary to include such information in the table.

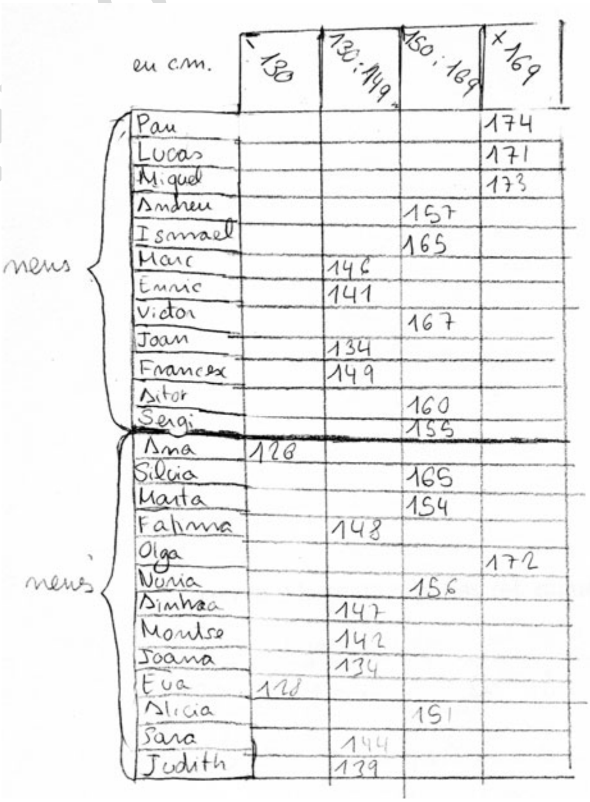


Fig. 3 Marina's production (sixth grade, primary education)

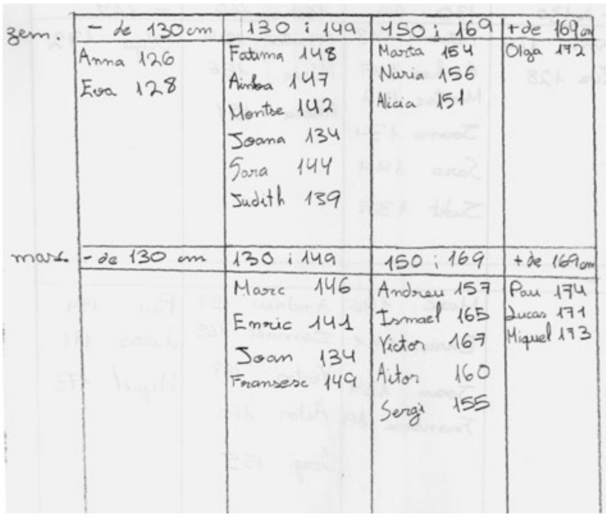
The participants' inclusion of this unnecessary information in their constructions can be interpreted as a step in the construction of a conventional table. The students organized the boys and the girls in the list into height intervals, including their names and heights. This step must be taken before all of the members of the cells could be counted, and it also may have helped the participants check the accuracy of their transcription from the initial list.

Another aspect related to the students' reluctance to remove redundant information was the repetition of information from the table's margins in each table cell. In some tables, the relative titles (especially the height intervals) were repeated. This repetition was redundant, given the graphic organization of the information. In these cases, the participants did not take advantage of the graphical structure of the columns, which enable data of the same category to be inserted without repeating the underlying concept. In other words, some data were unnecessarily made explicit. Toni's attempts (Fig. 4) illustrate this difficulty.

Like Marina, Toni organized the data in a double-entry table, with the columns corresponding to height intervals and the rows to gender differentiation. However, in the resulting cells, he wrote the names and the heights of the boys and girls on the list, rather than the frequencies within each category.

It is worth highlighting, however, that he repeated the height interval information twice in the same columns (once for the boys and once for the girls). This repetition was superfluous because each column heading was valid and applied to all of the cells in that column. However, for Toni (and many other students), it seems very difficult to leave this information implicit in the table, where it acquires meaning through the graphic organization into columns (same column/same label in the margin = same concept).

Marina's and Toni's productions show that answers to the task assignment can adopt formats other than the conventional table format and still be considered correct. In fact, in Marina's and Toni's productions, it is possible to count the number of boys and the number of girls in each height interval (boys and girls who have their heights written in the cells) because the data are well organized according to height intervals and gender. In this sense, both are correct responses to the task demand. However, in both cases, it is necessary to count the frequencies before comparing them. The advantage of the conventional table (i.e.,



gem.	- de 130cm	130 i 149	150 i 169	+ de 169cm
	Anna 126 Eva 128	Fatima 148 Ainoa 147 Montse 142 Joana 134 Sara 144 Judith 139	Marta 154 Nuria 156 Alicia 151	Olga 172
mas.	- de 130 cm	130 i 149	150 i 169	+ de 169cm
		Marc 146 Enric 141 Joan 134 Francesc 149	Andreu 157 Ismael 165 Victor 167 Aitor 160 Sergi 155	Pau 174 Lucas 171 Miquel 173

Fig. 4 Toni's production (seventh grade, secondary education)

a table that includes frequencies in the cells) is that a direct comparison is possible between the number of boys and girls at each height interval.

Discussion

One of the competencies that children are supposed to acquire during their compulsory studies is the ability to manage data using graphic representations. Tables are among the most fundamental and often-used graphic formats in scientific reports, handbooks, and textbooks. The ability to organize a series of data using a table format is, therefore, a basic competency for primary and secondary school students, along with the abilities to interpret, read, and complete a table. From a wider perspective, the ability to construct a table is very revealing and supports the claim that tables are psychological tools that students must internalize and use to solve different kinds of problems.

However, this internalization process appears to be rather difficult, and it does not develop from incidental contact or occasional learning activities with tables. Indeed, studies of children's and young adults' graphic competencies reveal their difficulties with graphic representations in general (Ainley 2000) and of tables in particular (Brizuela and Lara-Roth 2002; Lehrer and Schauble 2000; Wu and Krajcik 2006), despite their apparent simplicity and transparency as a means of communicating information. In addition, an analysis of the particularities of tables compared with other graphic forms of data organization (such as lists) has led to the proposal that certain cognitive skills are prerequisites for table construction.

Our results appear to support this argument. First, we found that most students were able to respond to the task and propose some kind of graphic disposition of data that differed from the initial list. However, not all of the students constructed a graphic display that met the task demand ("make a table to show how many boys and how many girls are in the different height intervals"); students did not respond, made a graph, or presented a list that was not organized according to height intervals (these were considered incorrect answers in our analysis). This result demonstrates that a noteworthy percentage of students were able to construct a graphic display (some kind of list or table) that fulfilled the requirement of the task, but few students developed a conventional table with cross-tabulated variables and with frequencies indicated in the corresponding cells (30.2%).

One interesting finding, contrary to what we expected, was the absence of any clear progression across school grade levels. In fact, our results showed format differences between grades, but there was no regular progression of skills from fifth to eighth graders in any format, particularly concerning the development of conventional tables. This lack of progression has also been reported by other authors (Barquero et al. 2000; Parmar and Signer 2005). One possible interpretation is that the task of constructing a table was not one that was explicitly taught across these educational levels and that experience with activities involving tables varied considerably from one group to another. Our results cannot support this claim. Supplementary research dealing with educational practices is needed.

Regardless of the external factors that might explain this lack of progression in primary and secondary school students' ability to construct tables, the most interesting finding concerns the identification of a set of difficulties that hindered the construction of a table. These difficulties were directly related to the cognitive and graphical demands of the task.

The first difficulty involved a categorization process, that is, the organization of the information according to categories of the two variables (gender and height). This organization was essential for constructing a table because the experimental task specifically required participants to indicate the frequency of students that resulted from the cross-tabulation of the two variables (gender and height). Participants needed to organize the data according to gender using the names of the students on the list, and they needed to organize the height interval data based on the height values next to the names on the list. Both categorization processes required the student to reorganize the data into subcategories (boys/girls and height intervals). For some students, this categorization process was difficult. They presented a single list with boys and girls undifferentiated; alternatively, they did not separate the heights into categories or note the exact height for each student on the list. In both cases, the explicit definition of the two variables and their corresponding categories were missing.

The second difficulty refers to the graphic cross-tabulation of the two variables. To construct a table, the categories of the two variables must be set out in rows and columns, so all of the categories of the first variable are crossed with the categories of the second one (Novick and Hurley 2001). In this way, all possible combinations of the categories are generated by means of the cells. In the present study, one of the variables was gender (with two subcategories: "boys" and "girls"), and the other was height (with four subcategories: the four intervals indicated in the problem statements).

Some of the students' constructions organized the data according to the two variables, but they did not display them graphically in crossed rows and columns. Rather, they presented lists in which the information was aggregated into the corresponding categories in a single dimension, i.e., one after the other in a vertical dimension (from top to bottom). These are less compact constructions than tables because they do not take advantage of the two spatial dimensions. A similar result was also found in the study by Lehrer and Schauble (2000).

This apparent difficulty with crossing the two variables cannot be exclusively explained by the lack of a general cognitive capacity to cross-categorize. As we have mentioned, the studies of Piaget and Inhelder (1967) show that the goal of classifying different items into two dimensions and simultaneously organizing them in a crossed structure is achieved at the concrete operational stage, which, according to Piaget, takes place at around 8 years of age. Given the age of our participants, we assume that they all have the basic general cognitive skill needed to organize a set of data and take two variables into consideration. This basic competency would be a necessary but not sufficient condition for building a table. From our data, it appears that other specific graphical and cognitive abilities are also required. Examples of such specific cognitive abilities might include the following abilities: to categorize students according to gender based on their names, to categorize students according to height intervals based on their given heights, to cross-categorize students according to gender and height intervals, and to count the number of students in each cross-category. Examples of such graphical abilities might include the ability to place the variables along an axis, write the names of the categories in the margins of the two-dimensional structure, generate the corresponding cells, and note the corresponding frequencies in the cells. These abilities imply the need for specific instruction on the rules for constructing a conventional table.

The third difficulty refers to the process of abstracting information, which is necessary to transform the list of data into a table. The list, as presented to the participants, contained more information than was required to construct the table (i.e., age and class number, which were irrelevant to the task). On the other hand, the exact heights and names of the students were necessary to assign each student on the list to a given category, but they were not strictly necessary to build the table. The age and class number information on the list had to be discarded because it was irrelevant to solving the problem; in the case of height and name, the detailed information had to be used to infer the category (gender and height interval) to which the item (students) on the list belonged.

According to our results, the first type of information did not appear in the students' productions, which may indicate a basic understanding that the task demand did not concern the age of the boys and girls or their class number. In contrast, some productions did include the name and the height of each student on the list. These cases illustrate that the difficulty lies in discarding the unnecessary information and, therefore, the non-constituent elements of a frequency table. The process of transforming the list by discarding data appeared to be an obstacle for some students, who included some aspects of the data that did not belong in the table.

This difficulty is closely related to another that appeared in some of the students' productions, namely that they included the names of all of the students in their productions instead of the frequencies for each category. The participants were correct to include a list of all of the students in each category; doing so implied that they organized the data (what Lehrer and Schauble (2003) have termed the "idea of aggregates") by assigning each student on the list to the correct category for each variable (height and gender). However, the next step, counting the items in each category and noting their frequencies, was missing. This is the exact step that transforms the list into a frequency table, which presents information in a more compact form.

In keeping with the heuristic of Lehrer and Schauble (2000), "the more stuff the better", there is a final difficulty related to the students' reluctance to reduce redundant information and make their responses more compact and implicit. Some students' productions could be considered correct because they organized the data into rows and columns that crossed each other. However, information about the category names was repeated superfluously. For instance, instead of writing the height interval information (less than 130 cm, between 130 and 149 cm, etc.) once in the margins of the table (as column headings), some students noted this information twice, once for the row of girls and again for the row of boys (see Fig. 4). This repetition also occurred with the two categories of gender, which were repeated for each height interval. Results from the study by Brizuela and Lara-Roth (2002) also demonstrated the repetition of information in the cells of the same column. This repetition is worth mentioning for three reasons. First, it shows a lack of efficacy in the use of spatial layout. When a category title is added, it appears in the heading of a column or a row and is sufficient for the reader to infer the information about each cell in that column or row. The fact that the information is in the same row or column indicates that the data reflect the heading of that column or row. However, this heading generalization was not heeded by students when they repeated the same information in each cell. Second, the repetition of information indicates that the variable (height or gender) was not defined explicitly as a dimension for which the categories could be crossed with the categories of the other variable. Third, this repeated information was a solution created by the students and did not correspond to any conventional table that could have been taken as a model (Brizuela and Lara-Roth 2002).

All of the above suggest that the elaboration of tables is a constructive process and that, although it may be based on existing models that are readily available in the students' environment, it is better explained by the reconstructive work of students. This reconstructive work is manifested in the students' idiosyncratic productions, which do not correspond to conventional tables. Examples of these idiosyncratic productions include productions that repeat the same information inside the cells instead of writing them in the margins of the table and productions that juxtapose the data for boys and the data for girls instead of cross-categorizing this variable with height interval information. Our results indicate that constructing a table is a cognitively demanding process for students in the fifth to eighth grade, which are the central primary and secondary school grades. Based on the main difficulties we have identified, we propose a focused intervention in classrooms to help students internalize tables as an important tool for organizing information and solving problems. Teachers can help students develop their table-related skills by analyzing the graphical conventions of tables and by proposing tasks that require the construction of conventional tables.

There are certainly many kinds of situations that require the construction of a table to solve a problem. In the task presented in this study, students were prompted to produce a table to compare the numbers of boys and girls at different height intervals. It would be interesting to imagine other situations in which students had to decide for themselves the best way to represent information to solve a problem. Such a situation would illuminate the degree to which students have internalized tables as cognitive tools. In fact, a previous study of second- and fifth-grade students showed that very few fifth graders spontaneously produced a double-entry frequency table as a way to solve a problem (Martí 2008). It is also true that the prompt proposed in the current study ("…to know how many boys and how many girls are shorter than 130 cm…..") did not necessarily require the calculation of frequencies and could be fulfilled by showing all of the boys and all of the girls at different intervals instead of summing the totals. It is reasonable to suppose that a more detailed requirement (as "are there more boys or girls shorter than 130 cm….") could lead to more productions that include frequency calculations.

The present study covers a gap on the topic of table construction by students in the compulsory school grades. We think that it represents a starting point that presents some of the processes and difficulties these students experience, along with some specific issues that should be addressed in the instructional process. Of course, our emphasis on table construction does not mean that other aspects of table comprehension, such as interpretation, are not equally crucial to improving students' competence with tables (Gabucio et al. 2010); rather, we claim that it is essential to relate both aspects (interpreting and constructing tables). It would be interesting to relate students' ability to understand one format (for example, tables) with their understanding of other formats (for example, Cartesian graphs). More studies are needed to address these other aspects of graphic literacy.

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Gabucio, F., Martí, E., Enfedaque, J., Gilabert, S., & Konstantinidou. K. (2010). Niveles de comprensión de las tablas en Primaria y Secundaria. *Cultura y Educación*, *22*(2), 183–197.

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Kuhn, D., Garcia-Mila, M., Zohar, A., & Andersen, C.L. (1995). Strategies of knowledge acquisition. *Monographs of The Society for Research in Child Development, 60* (4), 1–127
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Current themes of research:

Development of external systems of representation. Development of scientific reasoning.

Most relevant publications in the field of Psychology of Education:

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Current themes of research:

Argumentation and science learning. History of science. External Representations and learning. Appropriation of graphs and tables.

Most relevant publications in the field of Psychology of Education:

Gabucio, F., Martí, E., Enfedaque, J., Gilabert, S., & Konstantinidou. K. (2010). Niveles de comprensión de las tablas en Primaria y Secundaria. *Cultura y Educación*, *22*(2), 183–197.

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES.

Q1. Please check if the alteration made in the article title was appropriate.

Q2. “Piaget and Inhelder (1976)” was cited here but not found in the reference list. Please provide complete bibliographic information.

Q3. The citation “Wu and Krakjic 2005” was changed to “Wu and Krajcik 2005”. Please check if appropriate and please provide complete bibliographic information as this was not found in the reference list.

Q4. There were modifications made in Table 1. Kindly check if appropriate.

Q5. Fig. 2 citation (previously uncited) was inserted here. Please check if appropriate.

Q6. Citation “Real Decreto sobre las Enseñanzas Mínimas de la Educación Primaria y Secundaria de la Ley de Educación 2006, 2007” was changed and linked to “Real Decreto sobre enseñanzas mínimas de la Educación Primaria 2006; Real Decreto sobre enseñanzas mínimas de la Educación Secundaria Obligatoria 2007” Please check if appropriate.