Chapter 8
How Kindergarten and Elementary School Students Understand the Concept of Classification

Gilda Guimarães and Izabella Oliveira

Abstract Teaching statistics has been increasingly valued in recent years. To understand the physical and social world that surrounds us, knowing how to systematize information and/or understand the information matched is fundamental. Thus, knowing how to classify data is a fundamental skill. This article aims to analyse what students between 5 and 9 years old and teachers who teach those grades know and can learn about activities involving classification. To this end, we present the results of three different studies conducted with elementary school children and teachers. The results reveal that children are able to classify from a previously defined criterion and to discover a classification criterion, but experience more difficulties when creating criteria to classify. We believe this may be explained, partially, by the lack of familiarity with this type of activity both in everyday life and at school, as they are generally asked to classify from pre-defined criteria instead of producing their own. However, since kindergarten children are already able to classify in different situations and, most importantly, they are able to learn easily the skills needed to classify, we believe that if they have instruction that leads them to reflect about classification, they learn easily, thereby evidencing the important role of the school.

Keywords Classifying · Kindergarten · Elementary school · Statistics

One of the phases of an investigative cycle is data classification. Only with classified data is it possible to interpret the situation and obtain conclusions. We consider it fundamental that people are able to create criteria so that they can organize the information from the goals defined by them.

G. Guimarães (✉)
Universidade Federal de Pernambuco, Recife, Brazil
e-mail: gilda.lguimaraes@gmail.com

I. Oliveira
Université Laval, Quebec City, Canada
e-mail: Izabella.Oliveira@fse.ulaval.ca

A. Leavy et al. (eds.), *Statistics in Early Childhood and Primary Education*,
Early Mathematics Learning and Development,
https://doi.org/10.1007/978-981-13-1044-7_8

Fig. 8.1 Example of a student using two criteria (colour and means of locomotion)

8.1 What Is Classification?

Classification is a natural activity that begins very early for humans. From a very early age, children classify objects according to analyses based on similarities and differences (Vergnaud, 1991). Piaget and Inhelder (1983) defined classification as a procedure that enables the individual to assign all the elements of a certain collection to a category, according to certain criteria. For them, a classification is correct when the exhaustiveness and exclusivity criteria are met. Exhaustiveness implies that all elements are classified, and exclusivity implies that each element can only be part of one of the classes or groups. In other words, categories must be able to exhaust and, at the same time, be mutually exclusive. In the following example, the child used two different criteria (colour and means of locomotion) when trying to classify the nine cartoon figures. The child verbally explains that "they are the yellow ones" (SpongeBob, Tweety, Garfield), "they are the ones who swim" (Shrek, Nemo, and Little Mermaid), "are the ones who fly" (OddParents, Monica, Superman, and Spider-Man). In this case (Fig. 8.1), it did not meet the exclusivity criterion.

On the other hand, it is fundamental to point out that there is more than one way to classify. The same elements may be classified in different manners one at a time or in hierarchical classifications.

For example, animals may be classified according to their origin: in cooking, we might divide them into seafood and red meat. We can classify animals as carnivorous or herbivorous, according to an ecological classification in their natural habitats. These same elements may also be classified as echinoderms and mollusks, according to a zoological classification based on their biological evolution (Lecointre, 2004). Is there a hierarchy among these criteria? No. So, which of them should be used for classification? The choice depends on the purpose of who classifies. Different objectives suggest different classifications. Within a zoology laboratory, the term "seafood" is meaningless. Similarly, referring to echinoderms and mollusks in a kitchen makes no sense. These differences go beyond the vocabulary used; it is the specific objectives of the context of a kitchen or a zoology laboratory that determine the coherence and pertinence of a classification. Therefore, it is of fundamental importance to use a classification system that is related to the established goals and the context in which they are stipulated. Classifications are not neutral operations. Thus, it is important to point out that the objective of a classification is to understand a set of data and/or information. The one who classifies chooses the criteria according to his/her needs.

We would further point out that the classification criteria adopted depend on the context in which the classifications take place, including the historic moment and the person's needs. Thus, it is possible to find as many classification systems as there are classifiers.

Classifying is part of people's daily lives, and activities that involve classification can provide children and adults with models for organizing things in the real world, such as putting blocks away or setting the table for dinner.

Ware (2017) and Kalénine and Bonthoux (2006) state that categorization is a fundamental aspect of cognition and a critical task of child development that helps children to organize experience and understand relations between entities. Classifications may be based on thematic, causal, functional, temporal, perceptual and relational criteria, among others. Bonthoux and Kalénine (2007) state that children classify based on different aspects and that their choices depend on development, context, and individual factors.

8.2 The Investigative Cycle as a Means of Developing Statistical Reasoning

One way to develop statistical literacy is to carry out an investigative cycle. The investigative cycle relates to the way an individual thinks and acts during an investigation (Wild & Pfannkuch, 1999). Statistics can be considered an important tool for carrying out projects and investigations in various areas, used for planning, data collection, and analysis, and in inferences for decision-making with the intent to support statements in various areas, such as health, education, science, and politics. When students carry out an investigation, they may reflect autonomously and consequently be capable of interpreting reality through their own data systems or of interpreting the data systems of others critically (see this chapter). Therefore, statistics plays a fundamental role in education for citizenship.

An investigative attitude must necessarily include a concern for developing questions; elaborating hypotheses; defining samples; collecting, classifying, and organizing information in graphical or table representations; analysing and reaching possible conclusions to solve the proposed problem; and making decisions based on said information (Gattuso, 2011).

In this sense, we believe that statistical investigation must be the main axis in students' and teachers' statistical education from the earliest grades through every educational level. Research must be an essential element in teachers' education and practice, since it allows a reflective attitude in teaching and requires teachers to master the procedures of scientific investigation (Guimarães & Borba, 2007).

However, to understand fully how statistical investigation is developed, students must participate in it from its very beginning to its conclusion, experiencing every phase (Gal & Garfield, 1997; Ponte, Brocardo, & Oliveira, 2003; Batanero & Diaz, 2005; Ben-Zvi & Amir, 2005; Makar & Rubin, 2009; Fielding-Wells, 2010; Leavy & Sloane, 2017; among others). It is in these situations that students are able to perceive the function of statistical concepts.

Having statistical investigation as a structural axis of statistical learning and teaching, it is fundamental to consider that this can happen throughout a whole investigative research cycle, as well as reflect on each of its phases. So, one of the phases of the investigative cycle is data classification.

More precisely, in this chapter, we are interested in discussing the development of understanding about creating criteria to classify.

8.3 What Is the Importance of Classification in the Statistical Investigative Cycle?

One way to organize statistical thinking is the realization of the research cycle. Wild and Pfannkuch (1999) argue that the investigative cycle concerns the way the individual acts and thinks during an investigation. In this sense, Silva and Guimarães (2013) propose different phases of an investigative cycle (Fig. 8.2).

This diagram presents the different stages of the investigative cycle. Each of these elements contributes to the development of students' investigative skills. Even though they are all important, this chapter will deal with classification.

To reflect on this relationship, we begin by presenting an example. Luanna, a teacher, asked her fourth-grade students (aged 9) to build a bar graph based on a list of items bought at a supermarket. To build the graph, students first had to create criteria to organize the products. One student created the criteria "storage place", with the categories freezer, fridge, cupboard, open air. Accordingly, he built a database with which he could check if all the products had been classified and that none of them was in more than one category, meeting the criteria of exhaustivity and exclusivity.

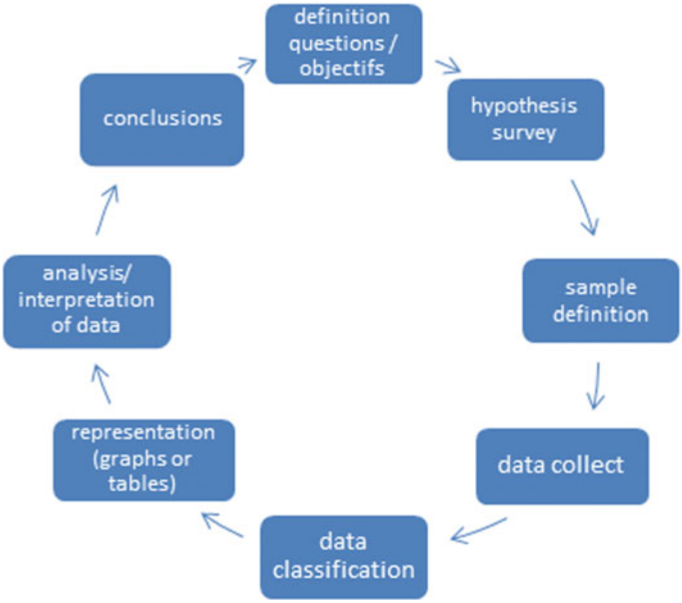

Fig. 8.2 Investigative cycle proposed by Silva and Guimarães (2013)

Graphs and tables are ways of representing these classifications when we deal with quantitative data.

The ability to build and interpret a graph also depends on understanding the categories that are represented. In a bar graph, for instance, each bar represents one category of a variable or the criterion analysed. Thus, classifying data is an important ability in the development of statistical literacy.

As previously mentioned, the ability to interpret a graph depends on understanding the categories involved. In this sense, categorizing data is an important ability for the development of statistical literacy. If interpreting a graph or table requires a significant level of understanding, representing statistical data is even more complex. According to the type of data obtained from a classification, students may choose various types of representation: a hierarchical classifications tree, sets, tables, and graphs.

8.4 Errors in Classification Carried Out by Children

Piaget and Inhelder (1983) identify that people present different understandings in their attempts to learn the ability to classify: figure collections, grouping elements in pairs, not classifying every element, dichotomous forms of classification, classifying without specifying the criteria, and adequate classification. We point out that these performances do not take place in any given order, since the same subject may try to organize the elements in pairs and later classify them dichotomously.

Collections of figures are when the student puts together a triangle and a square to draw a house. When a student groups elements in pairs, he/she is seeking a relation of resemblance, but is not relating these elements to the whole group.

Another type of strategy used by the student is not exhausting all the elements to classify, since they used criteria that did not involve all the elements. In a dichotomous classification, the subject chooses a property and analyses whether the element has that property or not. For example, he/she may classify the ones that are blue and those that are not. This type of classification is also called a binary classification. Some subjects are able to classify, but not to specify the criteria. They classify their toys as wooden, plastic, or metal, but are unable to explain that the criterion chosen was the type of material the toys are made of. Lastly, subjects classify by anticipation, explicitly stating a criterion (such as size) and using said criterion to classify.

According to Gitirana (2014), classifying must follow well-defined criteria, as well as keep in mind that every object can belong to one or various classes. Every concept, in and of itself, is a class, and once we define it, we have one of the necessary characteristics for an element to be part of that class (concept). It is exactly the use of these characteristics that allows us to decide whether a given object is part of a given class or not.

Thus, the importance of classification work reinforces the need for systematic work, with interesting, challenging activities that encourage students to think for themselves. In this sense, it is essential to discuss which abilities related to classification children need to develop.

8.5 Research on the Ability to Classify

In general, we have found several studies that investigate how adults and children build concepts based on classifications (Deák & Bauer, 1995; Nguyen & Murphy, 2003; among others), as well as studies with very young children or babies on the relation between thought and language (Mareschal & French 2000; Vieillard & Guidetti 2009; among others).

Besides these, Clements (2003) and Rodrigues (2016), among others, state that most of the studies of children's mathematical classification concern geometric shapes, progressively making possible their access to the process of shape classification based on the characteristics and properties of the simple geometric shapes, which allows them to identify and recognize inclusive types of classifications.

In this same sense, Amorim and Guimarães (2017), upon analysing Brazilian math textbooks for students aged 6–8, observed an almost complete lack of activities that involve classification, and when such activities were proposed, they also involved teaching geometric concepts. In these situations, students are not led to create classification criteria. The objective is to see whether students are able to classify the shapes based on defined criteria for existing categories. According to Gitirana

(2014), although essential to the development of concepts, schools have given little importance to the logical procedure of building criteria.

Other research suggests that reasoning about data classification is encouraged when students are invited to invent and revise models (Hancock, Kaput, & Goldsmith, 1992). Thus, teachers need to know how to propose situations that develop creation, critique, and revision of data classification.

The objective of this chapter is to analyse what students between 5 and 9 years old and teachers of those grades know and can learn about activities involving classification.

In the following section, we present, in detail, three studies carried out in Brazil involving students and/or teachers of the earliest school years. The first study was done with 20 kindergarten children (age 5); the second, with 48 third-grade children (age 8) and 16 early grade teachers; and the third, with 72 fourth-grade children (age 8–9).

8.6 Method and Data Analysis

This chapter presents the outcomes of three different studies. The results were obtained from the three studies conducted by the GREF team—*Grupo de Estudo em Educação Estatística no Ensino Fundamental* (Study Group on Statistical Education in Elementary Education). The first two (diagnostic) studies were carried out based on an individual Piagetian clinical interview, in which the researcher has a script that is modified depending on the student's answers, in order to allow the researcher to investigate how the student is thinking about the question. The third study is an experimental study, in which a pretest, two different intervention situations, and a post-test were performed to verify the learning from the interventions.

From the students' answers during the interviews, a qualitative and quantitative analysis was carried out in order to identify the students' understanding of classification, considering the types of answers identified by Piaget and Inhelder (1983). Thus, a hit-and-error analysis was initially performed. Then, a qualitative analysis of the types of errors and hits was performed. The categorization of strategies was performed according to the types of responses observed by Piaget and Inhelder (1983) and in the studies previously presented in this chapter.

In the following sections, we will present each of the studies that have contributed to our reflection on the understanding that kindergarten and elementary school students have about classification.

Study 1—What do kindergarten students understand about classification?

In this study, Barreto and Guimarães (2016), upon identifying the scarcity of activities that request that children create classification criteria, both in textbooks and in classrooms, decided to investigate what students understand about classification. To this end, they carried out Piagetian clinical interviews with 20 children (age 5) from three schools in Recife, Brazil. The authors chose to work with different schools to

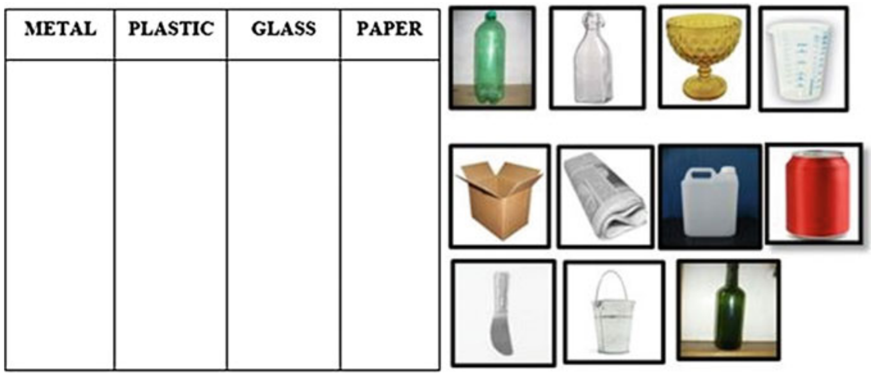

Fig. 8.3 Activity based on a given criterion

avoid similar results due to teaching methods or curricular organization of a given school.

Each child was asked, individually, to respond to three types of activities involving different classification situations. The order in which the activities were presented was established based on how familiar the children were with the activities. They began with the most common activities in school and in textbooks, followed by an activity that was done rarely, and finally an activity which requested them to create criteria. The interviews were conducted in a support room in the school and lasted approximately half an hour. The activities were:

Based on a given criterion

In this type of activity, the criterion is presented and the student must identify which objects belong in each group. This activity used 11 cutout pictures and a sheet of paper (Fig. 8.3).

Each child was told: "*I'd like you to organize these pictures based on what they're made of. Here are objects made of metal, plastic, glass, and paper*." The researcher always asked the student to justify their answer.

Identifying the classification criterion

In this activity (Fig. 8.4), the children had to do the inverse operation of the previous activity, since in this one the groups are already formed. Students had to discover which criterion was used for the classification. The researcher reads the statement presented in the activity.

When a child did not understand the command, the researcher would explain, "*A boy organized his books in these two baskets because he thought not all the books were the same. So I want to know what he might have thought to organize them this way; why did he put these here and these here?*" (pointing while giving this explanation).

Fig. 8.4 Activity for identifying the classification criterion. (Observe the images below, and discover the criteria used to organize children's books in each basket.)

Fig. 8.5 Activity for creating a classification criterion. (It is time to pack the toys. Cut out the toys from the next page. Stick on the same shelf the toys that you think should stick together)

<u>Creating a classification criterion</u>

In this type of activity (Fig. 8.5), the objects are presented and the child is asked to create a criterion to classify the elements in the way they think best. For this activity, the children received eight cutout pictures to come up with an organization criterion to divide the pictures into three groups. The children would then glue the pictures on the three shelves. "*These objects need to be organized. You will see which ones are similar and that belong together. You are going to organize these toys in three groups and put them on the shelves*".

Once again, as the child was doing the activity, the researchers asked questions, trying to understand what the child was thinking upon gluing each picture. The children were asked: "*Why are you putting these pictures together? Could this picture go somewhere else?*"

Table 8.1 Percentage of correct answers in each activity

Activity	Quantitative of successful students (%)
Classify from a given criterion	95
Identify classification criteria	20
Create classification criteria	35

8.7 Results Study 1

Table 8.1 represents the percentage of correct answers the children gave in each activity. We see great variety in the percentage of correct answers. This result shows that the activity of classifying based on a given criterion had a high percentage of correct answers, as was expected, since this activity is frequently found in textbooks and classrooms. On the other hand, few children were able to identify or create classification criteria, activities that are less frequent in textbooks.

In the activity of identifying classification criteria, we found students gave different types of answers: they either identified correctly the classification criteria; or described the themes of the books; or used more than one criterion in their attempts to classify. In these cases, the children would group the books as this example: giraffe and dragon books/family, dolls, and fairy tale or horror books (theme)/"girl" books (gender). We point out the difficulty, but not impossibility, of early schoolchildren doing this task, since four children were able to answer adequately. They classified the books as animal books/fairy tale books, dinosaur books/princess books.

In the activity to create classification criteria, seven children were able to classify correctly, but only three were able to explain the criteria (dolls, musical instruments, games). The others distributed the pictures randomly among the shelves. We always asked the students to explain how they had made their classifications, just as Lehrer and Schauble (2000) did in their study. We considered it important to investigate students' metacognitive ability to explain how they classified.

However, based on this study, we can conclude that children from early childhood education have shown that they understand classification activities, and in the first place, they are capable of creating certain sorts of classification. Thus, if they are able to create criteria to classify, they will be able to conduct research, collect data, and classify responses so that conclusions can be drawn.

Study 2—How elementary school students and their teachers created classification criteria.

Guimarães, Luz, and Ruesga (2011) investigated how elementary school students' and their teachers created classification criteria. Forty-eight students (aged 8) in the third grade of elementary school and 16 teachers of this same level of education participated in the research.

The author carried out Piagetian clinical interviews, during which they handed subjects nine cutout pictures and asked the students/teachers to create a criterion to classify them. Half of the participants were asked to create two groups, and the other half three groups.

Since context has been shown to be a determining factor in classification, the authors used two groups of pictures (toys and cartoons) which were familiar to the participants. Although the pictures were familiar, there is no type of classification commonly used neither in everyday life nor in school.

8.8 Results Study 2

The results show that most of participants performed poorly on this task (only 33% of the students and 44% of the teachers succeeded in the task). This result is very important because it shows that the teachers present a difficulty similar to that of their students. In this way, two points should be taken into account: how can teachers lead their students' learning about creating classification criteria if they themselves do not know how to do it? Second, it is evident that the life experience of adult teachers participating in this study has not been enough to lead all of them to learn how to classify in some situations.

In face of the importance of knowing how to classify, it is fundamental that teachers learn to create classification criteria and that they provide their students with activities that will guide them to learn it also.

Once again, in their attempts to classify, the participants (56% of students and teachers) would use more than one criteria when asked to create a criterion to classify a group of figures (Fig. 8.6). In this example, the teacher does not seem to realize that all the pictures have shapes (which can be the same or different) and that a game always leads to a competition.

However, it is important to point out that some children carried out this activity successfully, both in two groups and in three, showing once again that children can create classification criteria correctly.

In Fig. 8.7, we present an example of a student who appropriately classifies into three groups. Although he wrote the name of the first figure in each group, when he was asked how he had classified it, he explained that "*these* (referring to the Shrek group) *I watch a lot, these* (referring to the Garfield group) *I sometimes watch, and these* (referring to the Monica group) *I don't watch*".

Few participants wrote the name of the criterion (29% of students and 44% of teachers). Furthermore, in several cases where the participants wrote the name of the criterion, they do not fit into the classification used. Vieillard and Guidetti (2009) had already observed that adults and children would name the groups and not the criterion they had used.

Fig. 8.6 Response of a teacher upon request to classify into three groups (shapes/games/competition)

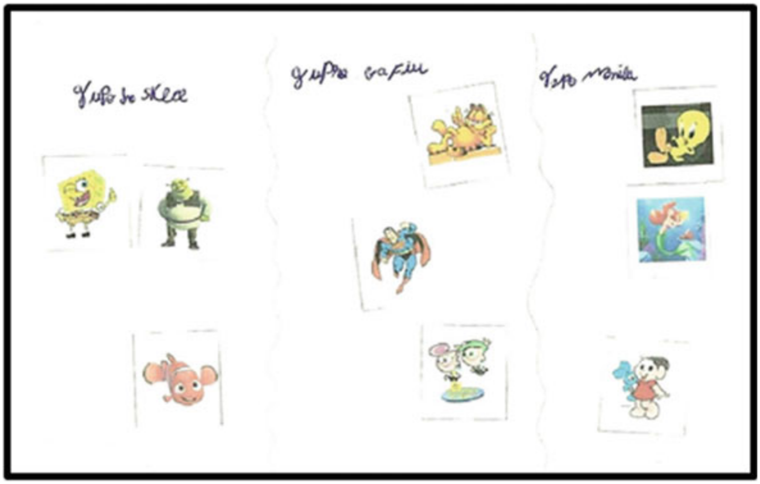

Fig. 8.7 Example of a correct classification of a child in three groups

The results obtained on this type of activity are similar to those found by other authors (Leite, Cabral, Guimarães & Luz, 2013; Lehrer & Schauble, 2000; Guimarães, Gitirana, & Roazzi, 2003), in which they identified the difficulty experienced by children and adults present when classifying.

For example, Lehrer and Schauble (2000) researched classrooms of students and their teachers (first, second, fourth, and fifth grades) in the task of classification. The authors observed that the youngest children evolved systems of attributes that described their categories in a post hoc fashion, but failed to regard those rules as a model to guide classification. In contrast, fourth and fifth graders considered their category systems as models that logically constrained the members admitted into categories, although many continued to include redundant or foreign information. They incorporated and discussed a variety of kinds of decision rules, and they had the opportunity to see the intellectual work performed by practices of data modelling. Also, Guimarães and Oliveira (2014) investigated how 113 future teachers in Recife, Brazil; Quebec, Canada; and Burgos, Spain, created criteria to classify and used these criteria in a free classification activity. Although most students managed to reach a correct classification in two groups, when the activity required three groups, the performance was significantly weaker ($x^2 = 13.717$, gl 1, $p \leq .000$). Only those who defined a descriptor were successful in their classification. Thus, knowing how to classify appears not to be an ability learned solely through life experience. This difficulty faced by both students and teachers can be partially explained by the absence of any systematic schoolwork on classification.

In this way, we can conclude that some elementary school students and their teachers have difficulties in creating classification criterion. This conclusion needs to be drawn very carefully, since, despite the difficulty of some, others are able to create criteria to classify. More than that, some children are able to create classification criteria in an appropriate way since kindergarten, as evidenced by Barreto and Guimarães (2016). Thus, we believe that the difficulties we met can be explained by an absence of reflections from teachers and students on how to create classification criteria. Thus, we believe it is essential that teachers understand the importance of knowing how to classify and how to propose that kind of learning for their students.

Study 3—Learning about classification

Since studies have found that children can create classification criteria since kindergarten, we present a study in which the researchers sought to work with classes of students that were expected to learn to create classification criteria.

Cabral (2016) investigated 72 students (9 years) of six classes of fourth-grade students from three different schools. This study involved three phases: a pretest, sequences of activities, and a post-test. During the pretest phase, each student was asked, individually, to classify nine pictures, with the purpose of determining if they were capable of creating an adequate criterion for classification.

To carry out the intervention processes, different types of activities were used involving the ability to classify proposals in textbooks and previous research: (1) classifying based on a given criterion, (2) discovering the criterion used in a classification, (3) presenting the criterion and asking students to analyse the pertinence of the classes, (4) listing properties of the elements, (5) analysing whether elements in a class belong or not, (6) identifying classes based on a criterion, and (7) creating a classification criterion. For the accomplishment of the sequence of activities, the students were divided into three groups. Two classes (G1) participated in a sequence of teaching activities that involved understanding only one criterion, based on situations 1, 2, and 3. Another two classes (G2) participated in a sequence of teaching activities that involved an understanding of element, class, and criteria, based on situations 4, 5, and 6. Two classes (G3) had no teaching activities, thus serving as control group. The sequences of activities were carried out in class during regular class time, involving all the students, over 2 days, for approximately two hours each

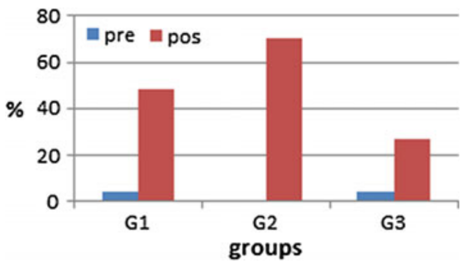

Fig. 8.8 Percentage of correct answers in each group in the pre- and post-tests

day. After students had done the activities, they were organized in pairs, and together with the teacher, the whole groups would once again analyse their answers, reflecting on how appropriate they were.

During the post-test, the students were asked once again to classify another nine pictures that did not present an explicit or common criterion. The purpose was to identify whether the students had learned to create a criterion and classify correctly.

8.9 Results

In the pretest, the performance of students in all three groups when creating a classification criterion was very weak, and no group presented significantly different performance from the others $F[(2.71) = 0.419,\ p = 0.659]$ through an analysis of variance.

In Fig. 8.8, we present the percentage of correct answers in each group in the pre- and post-tests. We can see that the performance of groups G1 and G2, which took part in the sequences of learning activities, improved quite a bit between the pre- and post-tests. Albeit much lower, G3 also presented improvement $F[(2.71) = 4.702,$ $p = \leq 0.012]$. We believe these results to be quite important, since they show how easy it seems for children to learn how to classify when they are systematically stimulated to do so.

In this way, the two sequences of activities allowed learning, emphasizing that systematic work with students on what it means to classify is possible and fundamental. It is also possible to affirm that the two intervention proposals led to learning and that there is no significant difference between them; that is, both types of activity allowed an advancement in understanding what it is to create classification criteria.

The variety of criteria used by students in the post-test is also interesting (Fig. 8.9). We stress that it is our intent that students create criteria and not use the habitual classifications. Why is this so important? If we want students to be able to research, collecting data to answer their questions, it is fundamental that they know how to organize the information they collect. Knowing how to create classification criteria will allow them to group answers according to their objectives and thus develop answers.

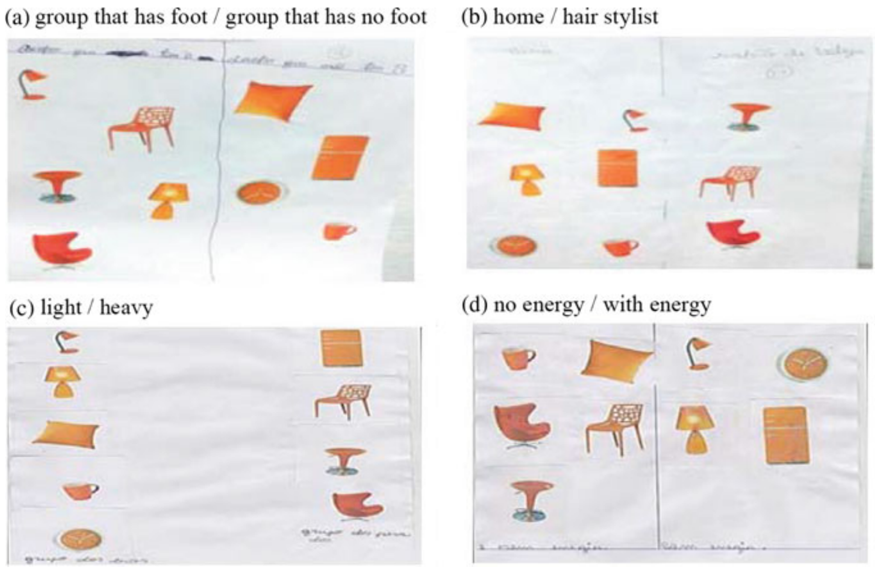

Fig. 8.9 Variety of criteria used by students in the same task (**a** group that has foot/group that has no foot; **b** home/hair stylist; **c** light/heavy; **d** no energy/with energy)

In this type of activity, the majority of the students (83%) presented an excellent performance.

In another study, Leite et al. (2013) investigated the knowledge of 30 third (aged 8) and fifth (aged 10) grade elementary school students creating categories to classify, and a potential improvement in performance based on a teaching intervention. This intervention was carried out over 2 days, during which it was proposed that students, in pairs, classify groups of pictures, then present these to the class, and, together with the teacher, reflect on the criteria used. The results show that students in both grades had difficulty classifying; however, the reflections in class allowed significant improvement in their understanding of classifying, showing the possibility of quick learning.

Thus, we observe the importance of proposing trajectory of work to promote the understanding of classification through different activities. We can also say that the activities imply different abilities, since the performance was different for the students. However, it is the set of them that supports the development of students' knowledge of classification. For the construction of knowledge, a variety of situations involving different skills is necessary. Finally, it is important to mention that the work of the teacher plays a fundamental role in understanding the classification of students.

8.10 Conclusions

In this chapter, our aim was to analyse what students between 5 and 9 years old and teachers of those school years know and can learn about activities involving classification. For this, we present three research studies our research group published.

These studies demonstrate the difficulty people with different educational backgrounds have in creating criteria to carry out a classification. We believe this difficulty can be explained, at least partially, by the lack of familiarity with this type of ability, both in everyday life and at school, since students are generally asked to classify from pre-defined criteria, instead of creating the criteria themselves. However, from a very young age, people interact with a world that is organized hierarchically in classes and subclasses.

From kindergarten, some children are already able to classify into different situations (Barreto and Guimarães, 2016; Guimarães et al., 2011) and, most importantly, they are able to learn with ease (Cabral, 2016). However, some teachers we investigated presented difficulties in solving these same tasks. This result needs to be studied carefully because it is rather surprising that young children show better results than adults do. Perhaps, children are more likely to create criteria because they feel freer to create categories that are not standardized. Adults, in some situations, use common categories in schools and textbooks. Guimarães and Gitirana (unpublished) observed that some graduate students in mathematics education also presented difficulties in creating classification criteria. Thus, studies on how to promote adult learning (teachers or others) need to be carried out so that this issue can be better analysed. Probably, if children and adults have opportunities that lead them to think about the classification, they learn easily, thereby showing the important role of the school.

Thus, the results provide evidence of the possibility of stimulating the learning of students when encouraged to reflect on classification. In addition, we believe that the different types of activities presented here will allow teachers to diversify classroom work by seeking to develop their students' ability to classify.

If current teachers have difficulty classifying, how will they be able to teach their students? The process of training teachers needs to lead them to systematic reflection that allows them to learn to create criteria to classify a given group of objects, respecting both exhaustiveness and exclusiveness. It needs to go beyond activities in which classes are already defined and where the student is only expected to distribute the elements. Developing students' independence in creating classifications will allow them to classify and analyse whatever data they wish, be it in school or in their daily lives, in a relevant manner.

It is fundamental to citizenship that everybody knows how to analyse the criteria chosen for a classification and how to create criteria to classify a set of data they wish to analyse. Knowing to create classification criteria will allow the children to participate in the universe of research, making it possible for them to become autonomous decision makers.

References

Amorim, N., & Guimarães (2017). Statistics education in textbooks: Brazil's National Textbook Program and the Teachers' Manuals. In *Proceedings of International Conference on Mathematics Textbook research and development—ICMT*, Rio de Janeiro.

Barreto, M., & Guimarães, G. (2016). Estratégias utilizadas por crianças da educação infantil para classificar. *Revista Iberoamericana de Educação Matemática e Tecnológica EM TEIA, v7*(1).

Batanero, C., & Diaz, C. (2005). El papel de los proyectos en la enseñanza y aprendizaje de la estadística. *Anais do I Congresso de Estatística e Investigação Operacional da Galiza e Norte de Portugal*.

Ben-Zvi, D., & Amir, Y. (2005). How do primary school students begin to reason about distributions? In K. Makar (Ed.), Reasoning about distribution: A collection of current research studies. *Proceedings of the Fourth International Research Forum on Statistical Reasoning, Thinking, and Literacy (SRTL-4)*, University of Auckland, New Zealand, 2–7 July, 2005. Brisbane, University of Queensland.

Bonthoux, F., & Kalénine, S. (2007). Preschoolers' superordinate taxonomic categorization as a function of individual processing of visual vs. contextual/functional information and object domain. *Cognitie Creier Comportament, 11,* 713–731.

Cabral, P. (2016). *A classificação nos anos iniciais do ensino fundamental*. Dissertação (mestrado) - Programa de Pós-graduação em Educação Matemática e Tecnológica - Universidade Federal de Pernambuco.

Clements, D. H. (2003). Teaching and learning geometry. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.), *Research companion to principles and standards for school mathematics*. NCTM: Reston, VA.

Deák, G., & Bauer, P. J. (1995). The effects of task comprehension on preschoolers' and adults' categorization choices. *Journal of Experimental Child Psychology, 60,* 393–427.

Fielding-Wells, J. (2010). Linking problems, conclusions and evidence: Primary students' early experiences of planning statistical investigations. In *Proceedings of the Seventh International Conference on Teachings Statistics—ICOTS 8*, Slovenia.

Gal, I., & Garfield, J. (Eds.). (1997). *The assessment challenge in statistics education*. International Statistical Institute: Amsterdam.

Gattuso, L. (2011). L'enseignement de la statistique: où, quand, comment, pourquoi pas? *Statistique et Enseignement, 2*(1), 5–30.

Gitirana, V. (2014). A pesquisa como eixo estruturador da educação estatística. In: *Pacto Nacional pela Alfabetização na Idade Certa: Educação Estatística*/Ministério da Educação, Secretaria de Educação Básica, Diretoria de Apoio à Gestão Educacional. Brasília: MEC, SEB.

Guimarães, G., & Borba, R. (2007). Professores e graduandos de pedagogia valorizam e vivenciam processos investigativos? *Revista Tópicos Educacionais, 17,* 61–90.

Guimarães, G., & Oliveira, I. (2014). Does future teachers of primary school know how to classify? In *Proceeding of 38th Psychology of Mathematics Education (PME 38*), Vancouver, Canada from July 15 to July 20.

Guimarães, G., Gitirana, V., & Roazzi, A. (2003). Interpretar e construir gráficos de barras: o que sabem os alunos de 3ª série do ensino fundamental. *Anais do XI Congresso Interamericano de Educação Matemática—CIAEM*, Blumenau.

Guimarães, G., Luz, P., & Ruesga, P. (2011). Classificar: uma atividade difícil para alunos e professores dos anos iniciais do Ensino Fundamental? *Anais do XIII Conferência Interamericana de Educação Matemática—CIAEM*, Recife/ Brasil.

Hancock, C., Kaput, J., & Goldsmith, L. (1992). Authentic inquiry with data: critical barriers to classroom implementation. *Educational Psychologist, 27*(3), 337–364. (Lawrence Erlbaum associates, Inc.).

Kalénine, S., & Bonthoux, F. (2006). The formation of living and non-living superordinate concepts as a function of individual differences. *Current Psychology Letters: Behaviour, Brain, & Cognition, 19*(2).

Leavy, A. & Sloane, F. (2017). Insights into the approaches of young children when making informal inferences about data. In *Proceedings of 10th Congress of European research in Mathematics Education—CERME 10*, Dublin.

Lecointre, G. (Ed.). (2004). *Comprendre et enseigner la classification du vivant*. Paris: Belin.

Lehrer, R., & Schauble, L. (2000). Inventing data structures for representational purposes: Elementary grade students' classification models. *Mathematical Thinking and Learning, 2*(1&2), 51–74.

Leite, M., Cabral, P., Guimarães, G., & Luz, P. (2013). *O ensino de classificações e o uso de tabelas.* Trabalho de Conclusão do Curso de Pedagogia na Universidade Federal de Pernambuco.

Makar, K., & Rubin, A. (2009). A framework for thinking about informal statistical inference. *Statistics Education Research Journal, 8*(1), 82–105.

Mareschal, D., & French, R. (2000). Mechanisms of categorization in infancy. *Infancy, 1*(1993), 59–76.

Nguyen, S. P., & Murphy, G. L. (2003). An apple is more than a fruit: Cross-classification in children's concepts. *Child Development, 74,* 1–24.

Piaget, J., & Inhelder, B. (1983). *Gênese das Estruturas Lógicas Elementares.* 3ª Ed. Rio de Janeiro: Zahar Editores.

Ponte, J. P., Brocardo, J., & Oliveira, H. (2003). *Investigações Matemáticas na sala de aula*. Autêntica: Belo Horizonte.

Rodrigues, M. P. (2016). *Identificar propriedades em quadriláteros – um caminho para a classificação inclusiva*. Porto, Portugal: Anais do Seminário de Investigação em Educação Matemática - XXVII SIEM.

Silva, E., & Guimarães, G. (2013). *Perspectivas para o ensino da Educação Estatística*. Curitiba: XI ENEM—Encontro Nacional de Educação Matemática—Anais.

Vergnaud, G. (1991). *El Niño, Las Matemáticas y La Realidad: Problemas de La enseñanza de Las Matemáticas en La Escuela Primaria*. México Trillas.

Vieillard, S. & Guidetti, M. (2009). Children's perception and understanding of (dis)similarities among dynamic bodily/facial expressions of happiness, pleasure, anger, and irritation. *Journal of Experimental Child Psychology*, 102, 78–95.

Ware, E. (2017). Individual and developmental differences in preschoolers' categorization biases and vocabulary across tasks. *Journal of Experimental Child Psychology, 153,* 35–56.

Wild, C., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. *International Statistical Review, 67*(3), 223–265.