THE DEVELOPMENT OF A STATISTICAL RESEARCH PROJECT IN CHILDHOOD: INTERFACES WITH LIFE SCIENCES

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ABSTRACT

The objective of this article is to discuss the development of statistical and probabilistic reasoning in childhood as a result of an interdisciplinary project, involving the fields of mathematics, statistics, and life sciences. This is a case study with three 10-year-old students from a Brazilian school. The children's oral and written narratives are used as a methodological path. It is an investigation process that examines human actions and considers social practices, subjective experience, identity, beliefs, emotions, values, context, and complexity. The results show that an interdisciplinary study involving life sciences, mathematics and statistics promoted the development of statistical and probabilistic reasoning, appropriate to the age group, enabling the children to positively rescale their eating habits.

Keywords: *Statistics education research; Childhood education; Statistics education; Interdisciplinarity; Statistical and probabilistic reasoning.*

1. INTRODUCTION

The aim of this paper is to discuss the development of statistical and probabilistic reasoning during childhood through the development of an interdisciplinary project entitled, "Healthy Eating." The research presented in the paper is a case study with three 10-year-old students from a Brazilian school. The problematization of aspects regarding children's culture, as well as the context in which they live, are considered as theoretical and methodological bases for learning mathematics and statistics. Signs of the constitution of different forms of combinatoric, probabilistic and statistical reasoning displayed by the children throughout the project are discussed.

We consider that statistics and mathematics are two different disciplines as they have different epistemologies. The reasoning behind these disciplines is not the same. While statistics focuses on interpretative reasoning that depends on variability, mathematics focuses on deterministic reasoning (Cobb & Moore, 1997). However, the interconnection between the two sciences occurs via statistical and probabilistic reasoning. Statistical reasoning requires the conceptual comprehension of important statistical ideas (delMas, 2004; Garfield, 2002) and probabilistic reasoning uses logic and probability to manage uncertain situations and express uncertainty, often derived from representative statistics (Biehler, 1994).

Teaching probability promotes the development of probabilistic reasoning, which leads to the understanding that "chance is not magic but computable - at least to a certain extent, namely regarding long-run behavior. Risks become calculable and, under uncertainty, decisions can be rationalized." (Biehler, 1994, p. 7). Gal and Garfield (1997) consider that the ultimate goal of teaching statistics is to promote understanding and proficiency in relation to uncertainty, variability, and statistical information so that individuals can "participate effectively in an information-laden society" (p. 2). To assist in the elaboration of pedagogical proposals in statistics education, the authors list eight instructional goals that go beyond mastering statistical processes and help paint a larger picture of how, when, and why use statistics and probability:

1. Understand the purpose and logic of statistical investigations.
2. Understand the process of statistical investigations.
3. Master procedural skills.
4. Understand mathematical relationships.
5. Understand probability and chance.
6. Develop interpretive skills and statistical literacy.
7. Develop the ability to communicate statistically.
8. Develop useful statistical dispositions.

These recommendations were considered during the development of the "Healthy Eating" project, which discusses the interdisciplinary intersection among natural sciences, mathematics, and statistics, in the pursuit of the goals for teaching statistics. Also, the project considers the fact that critical thinking is an important aspect to be developed in statistics education. Proposing probability and statistics activities linked to another field of knowledge enables students to develop a critical attitude, which leads to willingness to plan, flexibility to consider new options and reexamine previous problems, determination, and drive to self-correct and learn from mistakes (Lopes, 2021). This enables students to develop relevant skills for properly understanding and analyzing reasons, statements, and arguments regarding topics which are relevant to their lives.

It is worth mentioning that achieving such objectives requires a teaching practice guided by problematizing and raising issues related to themes that refer to statistical investigation. In this sense, Savard and Manuel (2016) mentioned that, in order to promote the development of statistical reasoning, teachers must ask questions about "how" and "why." For those authors, students must explain their reasoning and justify the use of statistical concepts while in a statistics class, which promotes the interdisciplinary intersection between mathematical and statistical contexts.

2. THEORETICAL BACKGROUND

2.1. STATISTICS EDUCATION IN CHILDHOOD

When contemplating education in childhood, and statistics education in particular, it seems impossible not to consider the culture of the children. It is necessary to develop a respectful attitude towards the knowledge that children bring to school, acquired in their cultural environment, which often involves the discussion of topics such as the city and country where they live, the environment, pollution of rivers and seas, among others. Statistics education in childhood should consider these factors and focus on more than algorithms, rules, and statistical conventions. Children are entitled to mathematical and statistical knowledge which is present in both their imaginary and real worlds. They have the right to contemplate and establish relationships between mathematics and their lives as they unfold. Children see the world, and question what they see. We need educational spaces where they can express their doubts and socialize their hypotheses and answers.

To educate statistically one must be guided by the spell of childhood. Children must not be robbed of their right to play and banter, of their different forms of expression, multiple languages, the relationships they establish in the construction and creation of games, the way they play and their meaning. In this context, statistical education has been justified by the needs of children themselves to build and recreate knowledge, develop their imagination and creativity; and, by social imperative, use them as instruments for living in the world. According to Lopes and Cox (2018, p. 76), children need to experience problem-solving activities involving different events related to possibility, random ideas, data collection, tabulation, and representation processes, so that their observations may lead to the inception of probabilistic reasoning. The experience of collecting, representing, and analyzing data, which is significant and pertinent in their environment, can expand the scope of their competences and enhance their creative potential.

2.2. PROBABILISTIC AND STATISTICAL REASONING

Garfield et al. (2003) defined statistical reasoning "as the way people reason with statistical ideas and make sense of statistical information" (p. 7), in particular ideas such as "distribution, center, spread, association, uncertainty, randomness, and sampling" (Garfield, 2002, p. 1). Bennett (2003) believes that, although probabilistic reasoning can often be considered part of statistical reasoning, it is the way people think about probability (of outcomes), and uncertainty.

We consider that the key concept of statistics is variability, which entails the ability to perceive the existence of variation. Variability is at the center of the statistical reasoning process of making relationships about the problem investigated and elaborating the construction and analysis of data. The variability present in the data determines a way of thinking that requires a combination of ideas, which leads us to an intersection between combinatorial, probabilistic, and statistical reasoning. In order to understand this interface, it is worth discussing these three different forms of reasoning. Combinatorial reasoning refers to combinatorics, which can be defined as a principle of calculation that involves the selection and arrangement of objects in a finite set. Combinatorics is not simply a tool for calculating probability, however, there is a close relationship between these two subjects, which is why Heitele (1975) included combinatorics in his list of ten fundamental stochastic ideas that should be part of the process of teaching and learning mathematics.

Probabilistic reasoning is tied to combinatorial reasoning, that is, after enumerating possibilities, one can analyze chance and make predictions. This form of reasoning is essential for analyzing data obtained from a problem, which leads to statistical reasoning; and enables the understanding of statistical information which involves linking one concept to another, for instance, median and average, or allows combining ideas about data and facts.

Reasoning statistically enables us to comprehend statistical processes, which means being fully able to interpret the results of these processes, referring to statistical thinking, which requires an understanding of why and how statistical investigations are conducted. This includes recognizing and understanding the entire investigative process, from the elaboration of the question, the choice of instruments for data collection, to the processes of analysis and interpretation.

When interconnected, these different forms of reasoning constitute stochastic reasoning, which allows us to understand how models are used to simulate random phenomena; comprehend how data is produced to estimate probabilities; recognize how, when, and with what tools inferences can be made; as well as understand and use the context of a problem to plan investigations, evaluate them and draw conclusions.

2.3. INTERDISCIPLINARITY

In this study, we sought to promote the connection between contents, procedures and practices of life sciences, statistics, and mathematics, in an approach that explores interdisciplinarity not as a mere combination of disciplines, but as a bold attitude and a quest for knowledge. Fazenda (1991) considered interdisciplinarity under a point of view that affords an in-depth and critical reflection about the function of education. For that author, interdisciplinarity can be used as a means for achieving a better general education, as only an interdisciplinary approach can establish the link between what is experienced and what is studied. Under this perspective, such an approach fosters the development of new cognitive abilities and the attribution of new meanings, as it is possible to extract content constituted from the intersection of knowledge, which translates dialogues, divergences, confluences, and boundaries of different disciplines from interdisciplinarity. Given their problematizing nature, studying through projects favors interdisciplinarity.

While discussing creativity and interdisciplinarity, Plucker (2008) considered that the ability to apply information from a distinct field of knowledge towards the solution of a problem, frequently mentioned as a key component of insight and flexibility, seems to be teachable. Therefore, when considering the interdisciplinary nature of statistics and the possibilities which it affords for analyzing information from different areas, we can infer that learning statistics contributes to flexibility of thought, which is paramount for the development of creativity.

Thus, we consider that solving problems in statistics which involve other areas of knowledge significantly contributes to students' development. It is possible for students to work with projects in elementary school because the organization of work projects is based on a concept of globalization understood as "a more internal than external process, in which the relationships between content and fields of knowledge are effected according to inherent needs that solve a series of problems that underlie learning" (Hernández & Ventura, 1998, p. 63).

From the same perspective, we have the example of Savard and Manuel (2016) who developed three case studies in which middle school mathematics teachers used different tasks in lessons on pie charts. For the authors, the use of rich tasks in statistics classes can develop statistical reasoning and create intra and interdisciplinary links in students, allowing them to develop statistical reasoning. The students must be exposed to both intradisciplinary links between mathematical ideas, including probability and chance, and interdisciplinary links between mathematics, statistics, and the sociocultural context involved.

In this research, we propose the perspective of working with interdisciplinary projects in the final years of elementary school, with statistical education at its core. Lopes (1998) pondered about statistics as a science with interdisciplinary roots ingrained in different fields of knowledge. Such perception points to interdisciplinarity enable a process of statistical education that becomes an integration hub among disciplines. This does not mean favoring one area of knowledge to the detriment of another, quite the contrary, the expansion of learning should occur when considering the specificities, multiple concepts, and procedures of each discipline in the development of projects. Therefore, the concept of statistical education adopted in this project does not dialogue with a positivist view of science and, much less, of education.

3. METHOD

3.1. RESEARCH SETTING

We developed a qualitative case study, which is considered by Stake (1994) not as a methodological choice, but as a choice of the object of study. The knowledge generated by case studies is different from other types of research because it is more concrete, more contextualized, and more geared towards readers' interpretation. For the construction of data, we considered the process of hermeneutic listening to children, through which "teachers listen to the students' voices, believing that the teachers themselves, can learn something new" (D'Ambrosio, 2013, p. 251). Therefore, the children's oral and written narratives are used as a methodological path; a methodological dimension that can generate a wealth of details and lead to the elaboration of data through different methods, in which it is essential to listen to the other, who willingly express their ways of thinking. It is an investigation process that examines human action and considers social practices, subjective experiences, identity, beliefs, emotions, values, context, and complexity.

To outline the analysis process, we connected the activities developed with the pedagogical objectives and the eight objectives pointed out by Gal and Garfield (1997), as shown in Table 1. This outline provided clarity and focus for the discussion of students' results in relation to the objectives.

Table 1. Relationships among activities developed, and intended learning and instructional objectives

Activity	Teacher's instructions	Instructional goals
Activity 1 – The Questionnaire	Answer the food questionnaire and compare it with the food pyramid.	Understand the purpose and logic of statistical investigations. Understand the process of statistical investigations.
Activity 2 – Combinatorial problems	Solve combinatorics problems.	Understand mathematical relationships.
Activity 3 – Possibilities	Observe events. Analyze possibilities.	Understand mathematical relationships.
Activity 4 – Survey	Perform data collection, organization, and representation. Write conclusions about statistical research.	Understand the process of statistical. investigations. Develop the ability to communicate statistically. Master procedural skills.
Activity 5 – Uncertainty	Classify probabilistic event.	Understand probability and chance. Master procedural skills.
Activity 6 – Probability	Notice randomness and draw conclusions.	Understand probability and chance.

3.2. CONTEXT OF THE STUDY AND PARTICIPANTS

This discussion stems from a survey with 10-year-old students, at a public school, in the interior of the state of São Paulo. Due to the COVID-19 pandemic, in-person attendance became non-compulsory. This meant that, in fifth grade, the class was reduced to a group of six students, who felt safe enough to attend in person, while the rest participated remotely. However, of these six students, only three attended all meetings. The students were assigned pseudonyms to safeguard their privacy and ensure anonymity. Data from audio recordings of classroom discussions, students' written work and individual student interviews from a total of four 180-minute classes were collected and analyzed.

A teacher called Adriana, who had a degree in mathematics, worked as a trainer for early childhood educators, had been teaching mathematics for 20 years, had taken several specialization courses, and held a master's degree in education, created the activities developed within the "Healthy Eating" project. She coordinated and supervised the implementation of the activities with students. The development of the project was not limited to an analysis and discussion of the food pyramid but sought to trigger a reflective study through statistical investigation.

The case study examined the eating habits of Bruno, Nicolas and Ruan, through the "Healthy Eating" project, which included interdisciplinary work in the areas of life sciences and mathematics. Nicolas was a student with good performance and was a bit of a perfectionist. He was always very involved with the activities implemented. Ruan stood out for his language skills but had difficulties in Mathematics. He did not, however, show much effort to overcome difficulties, settling for minimum results. Bruno had many difficulties in mathematics, but he was always very involved with the proposals, showing a lot of commitment, and striving to overcome difficulties. Nicolas, Ruan and Bruno had similar socioeconomic conditions, with family income that linked them to a low social class.

3.3. DATA ANALYSIS

The activities conducted were transcribed and that corpus of data used to analyze and interpret what the three students had learned during the lessons. At each step, we interviewed the students regarding their insights concerning the activities conducted.

Within the children's narratives, we sought to identify relationships with the eight instructional objectives identified by Gal and Garfield (1997) as described in the introduction. In addition, we looked for evidence of how an interdisciplinary proposal with health and food content, particularly a food pyramid, led to the development of statistical and probabilistic reasoning. In view of the objectives, we observed an approximation towards those objectives, considering that the students had not worked with statistical education before.

4. ACTIVITIES, RESULTS AND RECOMMENDATIONS

The research was developed through the conduction of activities with the participating students. For that, Adriana introduced the students to the food pyramid, which is conceptual content of natural sciences. Mathematics activities related to combinatorics, probability and statistics were proposed so that the children could learn, from an early age, to compare possibilities in a deliberate manner, and opt for the most correct or fair according to their values, thus making better judgments.

4.1. ACTIVITY 1 – THE QUESTIONNAIRE

Initially, the students answered the food questionnaire, registering their names, ages and eating habits for six daily meals (breakfast, morning snack, lunch, afternoon snack, dinner, and evening snack). They were also asked about fruit, carbohydrates, and protein consumption, as well as the amount of water ingested.

- Bruno declared that he ate fruit, salads and drank plenty of water and that his favorite foods were banana, apple, and passion fruit juice.
- Nicolas wrote that he did not eat salads, vegetables or fruits and only drank a glass of water a day and that his favorite foods were eggs, soda, chocolate cake and chocolate.
- Ruan stated that he ate one piece of fruit a day and that he ate junk food and sweets before bed.

Adriana noted that the diversity of responses indicated a few healthy eating habits, while others were not so much, so she decided to work with the food pyramid. She conducted the reading of the science textbook (Figure 1).

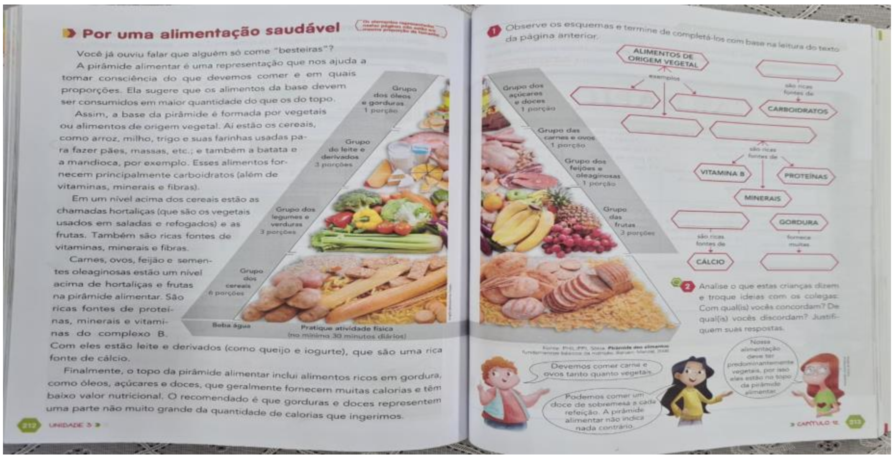

Figure 1. Food pyramid (Simielli et al., 2017, pp. 212–213).

After reading, they discussed the types of foods at the base of the food pyramid, which are the ones that should be consumed in greater quantities and the foods at the top of the pyramid, occupying a smaller space in it, as they should be consumed in lesser quantities. Then, the teacher built a food pyramid with pictures cut from magazines of food consumed by the students (Figure 2). After finishing the food pyramid, Nicolas asked, "Can I exclude the category of fruits and vegetables?" In the initial survey, he had already declared that he did not consume such foods. The teacher talked with the students about the importance of all foods included in the food pyramid.

Figure 2. Constructing a food pyramid

4.2. ACTIVITY 2 – COMBINATORIAL PROBLEMS

Activity 2 included combination problems in which the participants could put together dishes for each of the meals they were going to have, so that students could reflect on their eating habits after studying the food pyramid (Figure 3).

Let's create a tasty breakfast. Choose one option from each box. Which and how many possibilities are there?

Milk Juice Yogurt	Packed bread Fresh bread	Margarine Cheese

Let's create a dish for lunch. Choose one option from each box. What and how many possibilities are there?

Pasta Rice and beans	Beef Pork	Lettuce Tomato

Let's create a delicious snack. Choose one option from each box. Which and how many possibilities are there?

Biscuits Crackers Orange cake	Apple Banana Watermelon

Let's create a soup for dinner. Choose one option from each box. What and how many possibilities are there?

Pasta Potato Carrot	Beef Pork

Figure 3. Combination problems

4.3. ACTIVITY 3 – POSSIBILITIES

After reflecting about other eating possibilities, the students conducted an activity which entailed casting fruit dice (Figure 4). Three different dice were used, die number 1 bore faces with drawings of a strawberry, banana, bunches of grapes, watermelon, apple, and orange; die number 2 bore four faces with pineapple and two with strawberry, and dice number 3 bore three faces with oranges and three with strawberry.

Figure 4. Fruit dice

For completing this activity, students had a form in which they had to register their bets on the dice. Whoever got it right scored one point and whoever got it wrong scored zero. In each round, Adriana and the students analyzed the roll of the dice, and the chances of a certain fruit coming up.

The students were excited about rolling, but at times it was possible to see that they were betting on their preferred fruit, not on the fruit with the best chance of coming up. This situation was discussed with them; then they moved on to the card drawing activity.

Three different bags were organized, the first contained three strawberry cards, and seven orange cards. The second bag contained three cards with bunches of grapes, two with strawberry, one with an apple. The third bag contained three strawberry, three orange, and three grape cards (Figure 5).

Figure 5. Materials created for the fruit draw

During the fruit draw, the students also took notes as they had done during the rolling of the dice. The teacher described the faces of the dice on the blackboard to define the sampling space and discuss the chances of the fruits in each of the bags.

In the last meeting, the teacher revised with the students all the steps of the “Healthy Eating” project. She explained to them that they were conducting interdisciplinary work linking life sciences and mathematics, and that they had worked on content regarding life sciences, with the Food Pyramid and Healthy Eating, and mathematics, with statistics, combinatorics, and probability. She highlighted the results of the survey conducted so that students could observe that the individuals interviewed ate little fruit. Then, the teacher prepared the following activities to encourage fruit consumption, as it is healthier compared to other types of desserts and sweets.

4.4. ACTIVITY 4 – POLL

To complete the project, in the last meeting with the students, Adriana worked on statistics, probability, and combinatorics activities. On this day, six students were present. In statistics, they developed a poll about their favorite fruit. Adriana explained to the students that, similarly to an election for mayor, they would vote for the fruit that they would eat during the break and that only one fruit could be the winner. Of the six students participating in the poll, three chose strawberries and three chose bunches of grapes. As the vote was a tie, she informed them that they would have a "second round" (a second tiebreaker vote) as they needed to decide on just one fruit. She suggested they discussed and tried to reach a consensus, then vote again. To her surprise, all the students changed their votes from grapes and strawberries and chose pineapple! In Figure 6, they represented the results of the first vote in the first two columns, and in the last column the second vote.

Adriana took fruit and juice for the students to try. She intended to encourage fruit consumption. Nicolas was the only student who refused to try either juice or fruit.

Figure 6. Graph showing the favorite fruit

4.5. ACTIVITY 5 – UNCERTAINTY

Next, students worked on probability. In order to familiarize themselves with the terms "unlikely," "very likely," "impossible" and "certainly," students received the four printed phrases and a set of pictures of food, cut out of supermarket discount inserts, to be classified, according to their willingness to eat each of them (Figure 7).

Figure 7. Grouping possibilities

Ruan’s ranking displayed kale, soda, gnocchi, ketchup, chocolate cake, peanuts, pineapple, lasagna, strawberry yogurt, ice cream for “certainly;” pancetta and cake for “very likely;” cake and Danonino™ for “unlikely;” and cheese, cream cheese, avocado and margarine as “impossible.” Bruno listed sweets, cakes, lemon, fruit, pizza, cocoa powder, ice-cream, condensed milk, Doritos™, and soda pop, for “certainly;” he listed eggs, bread, pudding, butter, and meatballs as “very likely;” kale, cheese bread, and lettuce were listed as “unlikely,” and onions, milk, and vegetable puree as “impossible.” Nicolas listed eggs as well as rolls, cookies, Danonino™, margarine, bread, ice-cream carton, and soda pop as “certainly.” In the “very likely” category he listed eggs; he listed carrots, potatoes, beef, and fruit as “unlikely;” and chicken, fish, and onion as “impossible.” Through the ranking of the foods, Adriana realized that students still mistook “very likely” for “certainly,” but, due to the nature of the activity, involving food, also might mistake “unlikely” and “impossible.” This is clear in the ranking presented by Nicolas, as he listed eggs as both “very likely” and “certainly.” One of the foods listed in the rankings was onions, about which the unanimous opinion was that onions were “impossible” to eat. Sweets, cakes, and ice-cream, on the other hand, were all marked as “certainly.”

4.6. ACTIVITY 6 – PROBABILITY

Subsequently, Adriana worked with images of “fruit roulettes.” She taped three images on the blackboard for the students to imagine that they were roulette wheels. Roulette 1 displayed three oranges and three pineapples, Roulette 2 displayed four pineapples and two bunches of grapes, and Roulette 3 had six different fruits. The intention was for the students to observe the roulette wheels and answer a quiz to assess if they had acquired any knowledge of probability.

Figure 8. Fruit roulettes

Initially, Adriana asked Bruno, Ruan, and Nicolas to observe Roulette 1 and answer some questions, which are labelled here as Questions 1, 2 and 3:

Teacher:	If Nicolas bet on orange and Ruan on strawberry, who would be more likely to win and why? (Question 1)
Bruno:	Both are equally likely to win because the odds are equal.
Ruan:	The strawberry because the strawberry is on top.
Nicholas:	Both have the same chance
Teacher:	Murilo drew a strawberry and in the second draw he got strawberry again. If he draws again, do you think strawberry will come up again? Why? (Question 2)
Bruno:	In the next draw another one might come up.
Ruan:	The strawberry because the strawberry is on top.
Nicholas:	You can't know because the odds are the same.
Teacher:	If I spin the wheel first and you spin it later, who has the best chance of drawing an orange? Why? (Question 3)
Bruno:	Whoever goes after, in this case, can get strawberries and someone else can get oranges
Ruan:	Orange and strawberry have the same chance.
Nicholas:	You can’t tell.

After that, the students observed Roulette 2 to answer Questions 4 and 5.

Teacher:	Who has a better chance of winning the game; a person who bets on pineapple or grapes? Why? (Question 4)
Bruno:	Whoever bet on pineapple because pineapple has a better chance.
Ruan:	Pineapple because of the quantity.
Nicholas:	The pineapple has a better chance.
Teacher:	Bruno bet on grapes. Does he have a high, little, or no chance of winning? Why? (Question 5)
Bruno:	Little chance because he chose the fruit with the least chance.
Ruan:	Because of the amount of grapes???
Nicholas:	Why did the "pudding head" bet on the one with the least chance?

The students proceeded to the next questions, observing Roulette 3 to answer Questions 6 and 7.

Teacher:	Vitor bet on the banana. Will he be the winner? Why? (Question 6)
Bruno:	No; because there is no banana.
Ruan:	No; because there is no banana.
Nicholas:	There's no chance because there's no banana on roulette number three.
Teacher:	If we spin roulette number three, which fruit will likely come up? Why? (Question7)
Bruno:	Grapes because the arrow can go back to the grape.
Ruan:	Grapes because it is underneath.
Nicholas:	The odds are equal.

In Question 1, Bruno and Nicolas realized that the chance was equal. Ruan did not realize that the odds were equal and focused on the fact that the strawberry appeared at the top of the roulette wheel. The teacher inferred that Ruan imagined it was similar to the draw of the chips made in the previous class and concluded that whatever is on top has a better chance of coming up. Another factor that influenced the answers was the fact that the roulettes were pasted onto the blackboard, as they were not actual roulette wheels, just circles divided into six parts.

In responses to Question 2, Bruno and Nicolas realized that the chance was equal. Similarly, to the previous question, Ruan did not recognize that the odds were equal and focused on the strawberry appearing on top. For Question 3, the three students realized that each roll was independent. In relation to Question 4, the three students realized that the chances for pineapple were greater, due to the greater quantity. For Question 5, Bruno and Nicolas, realized that those who bet on grapes had little chance of winning. Ruan's answer for that question was unclear. For Question 6, the three students realized that it was impossible to draw a banana, as there is no banana on the roulette. Nicolas answered Question 7 correctly, realizing that all fruits had an equal chance of coming up. Bruno and Ruan said that the grapes were easier to come up, perhaps because they noticed that the grapes were at the bottom. Bruno even asked: "So, where are we going to spin this roulette?" We suppose he figured that if there was a pointer on the roulette wheel taped to the board, it would certainly point downwards.

At the end of the project, Adriana assigned the following task:

> Comment on the Friday classes in which we developed the "Healthy Eating" project. Try to remember all the stages of the project. Write about what you think of all the work. Write about what you learned and also if any of your knowledge has changed during this time.

Bruno wrote:

> We learned how to survey water and fruit, we asked students, coordinators, and teachers. There was a draw for the fruits. The opposite of what I had bet on came up every time. When I bet the opposite, the fruit I had chosen before came up. Seriously, I got really mad. We made a chart that showed the amount of fruit people ate. Someone stated that they did not drink water. We made the combinations of food and fruit. We made the pyramid of fruits and sweets.

Verbally, Bruno stated that it was appalling that someone had said they did not drink water: "I don't know how they are still alive!!!" This was an inference made by Bruno in relation to the survey findings. This was remarkable for him, as he made the comment verbally one month after the survey. It was satisfying that in his text Bruno said, "We did it ..." thus demonstrating his involvement and "firsthand experience" instead of something like "The teacher said, ..." or "The teacher did ..." Ruan wrote:

> One of the lessons I liked most was the probability part. I learned many things and, on the first day, we did a survey on how many pieces of fruit people ate and how many glasses of water they drank. I changed; I used to do things differently than I do now. I changed my eating habits.

It is interesting for Ruan to comment that he changed his eating patterns. In the interview he said he was eating better, eating less "junk." Nicolas wrote:

> I enjoyed all the classes. My knowledge has increased. My favorite class was the roulette class, the combination class, the dice class, the draw, the food pyramid class, water, and fruit survey. Now, I can figure it out faster.

Most striking was that Nicolas wrote that he could figure it out faster, as when solving combinatorics problems, when he had to describe all the possibilities, he would sometimes get confused. The guidance of the teacher who told them to fix one element first, and then combine the others, helped them realize the importance of having an organized procedure to solve problems. They worked with the tree of possibilities, and this enabled them to achieve greater mental agility. While solving the last combinatorics problems proposed, Nicolas managed to make the combinations mentally, as he had realized that to find the result, he simply had to multiply the items in each list.

To complete the work, Adriana conducted an interview with the three students, who gave the following answers regarding the learning achieved throughout the development of the project:

> Ruan: I'm really enjoying the classes; I'm learning more than at my old school. I learned more about food. Before, I ate too much, now I'm eating less. I got into better eating habits after I took the class. Before, I ate a lot of things that were not very good, very fatty; I have stopped eating those. The second time I did the combination problems it was easier, the first time I was in doubt, but the second time I picked up the pace.
>
> Nicolas: I remember you gave us plates and we put little pictures of things and we made different combinations with them. First, we did it fixing one thing to the other, and we fixed them until we knew the total number of things we had done. The first day was more difficult because it is a lesson I had not seen. On the second day I already knew what to do and I found it much easier. We researched whether other people ate fruit and the number glasses of water they drank a day. Then we made a chart and put the number of votes each food received on the survey, and we figured out how many people had voted. We took little pictures and put them on the pyramid. At the base, we put the healthiest things, then fruits and vegetables, then fats, then fried foods, and then things that we should eat very little of, which were sweets. I learned that we could combine several options to make at home, like food combinations that you can make.
>
> Bruno: I remember that we asked people about fruit and water. As far as I remember we saw who drank more water.

Bruno was quite shy during the interview; missing the second meeting might have hindered his learning. We noticed that the students got involved with the proposed activities and displayed the development of different skills which enabled statistical and probabilistic reasoning.

Regarding the first research objective, from the students' narratives, we observed that they understood there is a logic in statistical investigations which requires problematizing a given topic, collecting data through an instrument, tabulating, representing, and interpreting the data. It is that movement that will yield a conclusion. This understanding demonstrated by the children also indicates a degree of clarity about the process of a statistical investigation. Even if students have no proficiency regarding statistical structures, and the link between context and statistical structures, "their reasoning about the context paralleled more formal statistical reasoning that would be developed over time" (Makar, 2018, p. 18).

To get to this point, students treaded a pedagogical path that required learning about procedural skills and certain mathematical relationships, particularly between the survey of possibilities provided by combinatorial analysis and the probability of occurrence of a given event. As the project evolved, the students displayed approximation to interpretative skills and statistical literacy, as they were able to draw conclusions about the didactic path they had followed. By systematizing their interpretation of the statistical study conducted, they developed a certain ability to communicate statistically and realized how useful statistical arrangements can be.

In the introduction, we considered that the objective of this article was discussing the development of statistical and probabilistic reasoning during childhood, as result of an interdisciplinary project. The activities conducted involved combinatorial, probabilistic, and statistical problems. Table 2 shows that the students partially achieved the objectives outlined by Gal and Garfield (1997) as they were studying combinatorics, statistics, and probability for the first time. In the previous academic years, they had never experienced a survey and analysis of possibilities, nor had they conducted statistical investigations.

Table 2. Students' results in view of instructional goals (Font: the authors)

Instruction goals	Results
Understand the purpose and logic of statistical investigations	We observed that the goals were partially achieved, since it was the students' first experience with statistical investigation, and that they achieved an approximation with the idea of variation.
Understand the process of statistical investigations	We observed that this goal was achieved due to the possibilities generated by the teacher, through problematization, which prompted students to collect, organize and represent relevant data, and then conclude that some of them did not eat fruit or drink water.
Master procedural skills	In relation to this goal, we observed that the students were able to create a table and a graph. After creating the final graph, the fruit chosen would be enjoyed by the class, and, although some had not personally voted for pineapple, they understood that the fruit served was the most voted.
Understand mathematical relationships	Regarding this goal, the students developed activities with combinatorics and probability. They surveyed the possibilities, approaching the intuitive idea of sample space. It was not possible to approach the idea of statistical measures.
Understand probability and chance	During the development of the activities with dice, roulette, card draw and analysis of unlikely, very likely, certain, and impossible events, the students were able to contemplate the chance of a given event occurring.
Develop interpretive skills and statistical literacy	Even at their stage of cognitive development, and despite the fact that this was their first experience with statistics, the students were able to interpret data based on the organization and representation they had created.
Develop the ability to communicate statistically	Regarding this goal, the students were able to adequately approach probabilistic and statistical terminology.
Develop useful statistical dispositions	The students were able to develop an appreciation of chance and randomness, as well as realize that statistical investigations give access to information on various topics.

The participants of the study demonstrated their learning through oral and written narratives, registered by their teacher, Adriana. However, it is worth pointing out that one of the limitations of the present study is that it was conducted with only three male students due to the restrictions imposed by the COVID-19 pandemic. The results obtained show that the opportunities to develop statistical and probabilistic reasoning in childhood, by relating contents and procedures from social science, mathematics, and statistics, provided students with an approximation to statistical and probabilistic ideas that enabled them to rethink their eating habits. The results of this study suggest that the most common instructional objectives for teaching statistics are those that focus preferentially on the processing aspects of statistics, more specifically on data representation. The graphical display of the survey enabled the development of a certain statistical reasoning, which should deepen throughout the schooling process.

It is also worth noting that Adriana's training contributed to the results obtained, as she was an experienced teacher of mathematics and had extended teacher qualifications, including a master's degree in education. There is evidence that students demonstrated an approximation to the idea of chance through the activities developed by Adriana on the topic of food. The teaching proposal she prepared, using materials that students could manipulate, was essential for their understanding of probabilistic ideas. The adaptation made in the roulettes and dice, to link to the topic studied, helped the children attribute meaning to the random process inherent to those objects. The work done by Adriana, gathering information, organizing data, creating ways to represent data, by means of tables and charts, and conducting data analyses shows that through statistical projects, students take charge of their learning process (Grando & Lopes, 2020).

Savard and Manuel (2016) also considered the eight instructional goals for teaching statistics, pointed out by Gal and Garfield (1997), to discuss the data from their case studies and highlight the importance of treating statistics as an interdisciplinary subject. The study reported herein allows us to corroborate this consideration and highlight that, as statistics is a data analysis science that has interdisciplinarity at epistemological roots, it favors the understanding of topics that are ingrained in students' social context.

Figure 9 shows the interdisciplinary intersection developed in this project among mathematics, life sciences, and statistics. While working with the students, Adriana addressed combinatorics and probability, which are themes linked to the study of mathematics, statistics, and science.

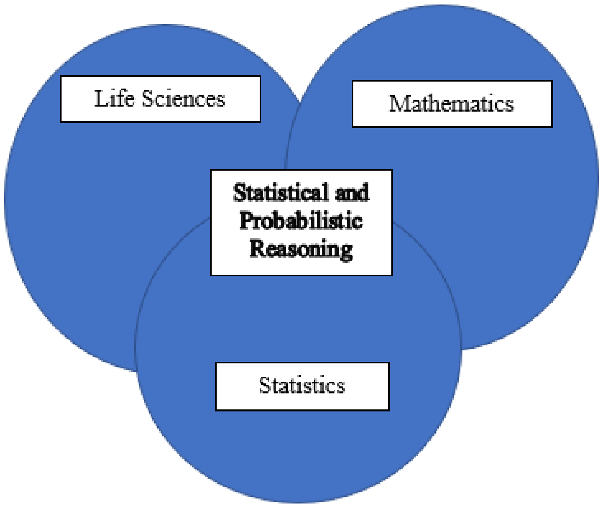

Figure 9. Interdisciplinary intersection of mathematics, life sciences and statistics

The development of the project proved to be effective in interconnecting mathematical and statistical contexts with the contents for life sciences, without abrupt cutoffs among fields. Thus, we can observe a propinquity towards the development of the eight instructional objectives, which must certainly be considered within the scope of childhood, by adapting pedagogical proposals to children's level and understanding. We must also point out the need to investigate topics that generate possibilities for students to understand and rescale their attitudes as well as improve their quality of life. Thus, statistical and probabilistic reasoning contributes to improving students' skills as members of society.

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