

## Early statistics: Introducing informal inferential reasoning through storytelling-based learning task in grades 1-3

Soledad Estrella, Alejandra Mondaca-Saavedra, Brahiam Ramírez and Maritza Méndez-Reina  
Pontificia Universidad Católica de Valparaíso, Chile  
[soledad.estrella@pucv.cl](mailto:soledad.estrella@pucv.cl)

*This study presents part of a hypothetical learning trajectory designed to introduce inferential reasoning, support, and expand emerging understanding of statistical concepts in grades 1 to 3 (n=59). Through a design-based research approach, a playful activity was designed and implemented based on a pirate story involving gold pearls, allowing children to construct, analyze, and refine data models in scenarios of uncertainty. Students worked in teams with assigned roles (counter, recorder, and shaker) to collect and record data. In whole-class dialogues guided by the teacher, students completed three dot plots, visualized sample variability, and made inferences about the distribution of the pearls. The results show that children can develop key notions such as randomness, empirical sample variation, and maximum sample frequency by interacting with data and comparisons of groups. This study provides evidence of how the children complete data modeling tasks, articulate mathematical and statistical concepts, and make informal inferences.*

### INTRODUCTION

Given the current context in which students interact daily with digital media that generate and store vast amounts of data (Nicholson et al., 2019), teaching statistics in a traditional manner appears insufficient to engage them in social life (Gal et al., 2023). Considering that data today can provide abundant information about society and the world (Engel, 2017), it is a priority to design and implement appropriate learning environments that give students the opportunity to use data critically (Gould et al., 2018), and expand their ways of thinking to work with and make sense of data (Fielding et al., 2025).

Over the past decade, the teaching of statistics in early school levels has gained importance as part of an education that responds to the demands of a data-driven society (Estrella, 2025; Estrella et al., 2024; Fielding et al., 2025). Therefore, fostering statistical literacy from an early age is essential so that students develop the tools necessary to interpret, represent, and make decisions based on empirical evidence (Bargagliotti et al., 2020) and in contexts where uncertainty is present (Estrella et al., 2023a). It thus makes sense to introduce children to the generation of informal statistical inferences in situations where only partial data are available.

Estrella et al. (2024) noted that, in the Chilean context, the primary education mathematics curriculum does not explicitly include objectives related to the development or construction of informal statistical inferences. The authors identified objectives related to making predictions in other subjects, such as language and science (Ministry of Education of Chile [MINEDUC], 2018). In contrast, they highlighted that the standards for initial teacher education in primary education do include, under the strand of Data and Probability, the competency of making informal statistical inferences in contexts of uncertainty (MINEDUC, 2022). Currently, in Chile, a proposed update to the mathematics curriculum is under development, which could help address this gap.

### CONCEPTUAL FRAMEWORK

Informal Inferential Reasoning (IIR) refers to the ability to make data-based claims that go beyond what is directly observed, considering the uncertainty inherent in sampling processes and the variability of data. From an educational perspective, IIR provides a powerful framework for introducing statistical concepts in early childhood, as it enables students to make conjectures, justify decisions, and construct arguments based on empirical evidence, without the need for formal statistical procedures (Makar & Rubin, 2009).

Several authors agree that IIR involves at least three essential components: using data as evidence, generalizing beyond the data, and expressing uncertainty (Makar & Fielding-Wells, 2011). IIR represents an emerging form of inferential thinking that allows for the integration of empirical observations, statistical representations, and early probabilistic language, even in the initial years of schooling.

According to Zieffler et al. (2008), informal statistical inference can be understood as the process through which students use their prior and informal statistical knowledge to construct data-based arguments, with the aim to support inferences about an unknown population. Its main purpose is to lay the foundation for the development of statistical inferential reasoning from data (Ben-Zvi, 2016; Makar & Rubin, 2009). Given its relevance in statistics education, IIR entails reflecting on how such reasoning is constructed from the concepts of inference and on the most effective strategies for its teaching (Garfield et al., 2015).

Given the importance of early experiences with data and uncertainty, this study explores the following research question: How does a storytelling-based learning task contribute to the development of informal inferential reasoning in grades 1 to 3?

## METHODOLOGY

Using a design-based research approach, a teaching experiment was conducted (Steffe & Thompson, 2000), during which a hypothetical learning trajectory (Simon & Tzur, 2012) was progressively established, implemented, and refined through Lesson Study cycles. This trajectory consisted of a sequence of lessons aimed at introducing and developing IIR in early childhood.

In the first lesson, students engaged in two tasks focused on using informal language to express degrees of likelihood. In the second lesson, children used concrete materials (coins and game boards) to generate and record data in the context of a game involving the comparison of three non-equiprobable events (see Estrella et al., 2024). The third and final lesson, which is the focus of this report, involved a task based on the story “The Treasure of Pearls and Pirates”; inspired by the black box experiment (Estrella et al., 2023b; Estrella & Ben-Zvi, 2025; Van Dijke-Droogers et al., 2020), chosen for its potential to introduce ideas related to informal statistical inference through repeated sampling.

The hypothetical learning trajectory in which the lesson is embedded is organized into five steps: [Step 0] Recognize uncertainty and express it using natural probabilistic language, associated with possible outcomes; [Step 1] Contrast predictions with data through repeated sampling; [Step 2] Visualize and recognize variability among samples; [Step 3] Assign likelihood levels to each event considering the regularity of the empirical sample distribution; [Step 4] Generate statements that go beyond the available data as evidence, using expressions of uncertainty (Estrella et al., 2024).

The task guided children to make a recommendation to a group of pirates seeking to discover which of three bottles was most likely to contain more gold pearls. Each bottle (B1, B2, and B3) had a different proportion of gold and purple pearls (with the purple pearls representing fake ones in the story). The unknown compositions were as follows: B1 – 25 gold and 75 purple; B2 – 15 gold and 85 purple; B3 – 35 gold and 65 purple. Working in teams of three, students took on previously assigned roles (shaker, counter, and recorder) to collect data by observing samples seen through a window in each bottle. The teacher, together with the students and in collaboration with each recorder, constructed a dot plot for each bottle based on data collected by the whole class.

The activity concluded with students being asked to make a recommendation about which bottle the pirates should choose, justifying their decision using the collected evidence. This experience was conducted in an urban Chilean school, with 59 students from first to third grade (aged 6 to 8 years) working in small teams under the guidance of their regular mathematics teacher. All sessions were video recorded with informed consent from guardians and institutional approval for research purposes. Written work, recordings, and photographs were stored on a secure private server managed by the research team.

The study’s data sources included transcripts of video recordings and students’ written productions. The analysis focused on identifying components of IIR present in students’ responses, such as comparing sample frequencies, formulating conjectures based on empirical evidence, and referencing variability in outcomes. Both individual productions and selected interactions between students and teachers were analyzed, with particular attention given to jointly constructed statements based on how the students interpreted the dot plots.

## RESULTS AND DISCUSSION

This section presents and analyzes a selection of episodes that illustrate how children from grades 1 to 3 participated throughout the final lesson. The episodes were chosen for their relevance in

exemplifying how students used data to support their claims, demonstrated generalizations beyond the data, or employed expressions of uncertainty when making decisions based on empirical samples.

The analysis considers both students' verbal productions and their use of dot plots. Teacher interventions are also considered, as they played a key role in the development of students' reasoning and in the gradual incorporation of language related to uncertainty.

#### *Episode 1. Second-Grade Students Express Their Ideas*

At the beginning of the lesson, the teacher introduced a situation based on the pirates' story, inviting students to consider which of the bottles might contain more gold pearls. Although framed within the narrative, the question was posed after students had briefly observed a few pearls visible through the windows of the three bottles. The aim was to explore how students interpreted this limited evidence to formulate initial ideas. The following excerpt illustrates how they expressed their ideas:

Teacher: ... *the [bottle] 1, why would you choose the [bottle] 1?*

Student 1: *Because there are more [gold pearls].*

Student 2: *Because there are a lot of [gold pearls] and only two [fake pearls].*

This excerpt shows how students formulated an initial conjecture based solely on the narrative context and their direct visual observation of the contents of bottles 1, 2, and 3. In this early stage, they identified the bottle that appeared to contain the highest number of gold pearls, without yet engaging in systematic data collection. This moment corresponds to Step 0 of the hypothetical learning trajectory—recognizing uncertainty and expressing it using natural probability language—and marks the emergence of reasoning based on limited, non-representative evidence.

#### *Episode 2. Third-Grade Students Generate and Record Data*

Initially, the students conducted repeated sampling by experimenting with the bottles on three occasions. In each trial, they observed, counted, and recorded the number of gold pearls (the variable of interest) and purple pearls visible through the window of each bottle. The purple pearls represented fake ones in the context of the story. These actions were carried out by the students themselves, who took on specific roles: shaker, counter, and recorder. The following episode illustrates this process:

Teacher: *without touching the [bottle], [...], ¿how many [gold pearls] are there?*

Student 1 (*counter*): *There are 3 [gold pearls].*

Teacher: *then the recorder student is going to write 3 gold pearls [on the table].*

Student 2 (*counter*): *and purple ones there are... [counts] 11 [fake pearls].*

Student 3 (*recorder*): *[On the table, she records the result of the first attempt; 3 gold pearls and 11 fake pearls were visible through the window]*

This episode highlights the importance of active participation by each trio of students in the sampling process. By repeatedly engaging in this task, students began to recognize the randomness inherent in the situation and to observe how the variability of results became evident as more samples were collected. This phase corresponds to Step 1 of the hypothetical learning trajectory—contrasting initial predictions with collected data—and lays the groundwork for developing an understanding of empirical sample variation, a key component of informal inferential reasoning.

#### *Episode 3. First-Grade Students Represent and Interpret Data in Dot Plots*

After the samples were collected, the teacher guided the representation of the data using three collectively constructed dot plots (one for each bottle), displayed in a visible place for the whole class. The following episode illustrates how the teacher facilitated the interpretation of the dot plot corresponding to Bottle 3:

Teacher: *[...] and why would you happily choose Bottle 3? Who can tell me why you would choose it?*

Student 1: *Is it bigger?*

Student 2: *Because it has more [gold pearls], because there [referring to the dot plot] the 4 is marked.*

Teacher: *Are you sure it has more [gold pearls]? Or is it...?*

Student 2: *Possible.*

This episode illustrates how students began to mobilize key components of informal inferential reasoning. In this example, students used data as evidence to justify their choice of Bottle 3, based on their observation of the dot plot, specifically highlighting that “the 4 is marked there,” which indicates a recognition of the category with the highest frequency. This justification reflects an approach toward recognizing a trend observable in the data by identifying the value “4” (representing the number of gold pearls) as the outcome with the highest frequency during the repeated samplings. In addition, prompted by the teacher’s question, “*Are you sure it has more gold pearls?*”, the student shifted from a categorical statement to an expression of uncertainty, responding with “*possible*”. This transition reflects a movement toward Step 2 of the hypothetical learning trajectory and also engages Step 3 by beginning to assign likelihood to specific outcomes.

#### *Episode 4. First-Grade Students Make a Recommendation*

The experience concluded with the analysis of the empirical sample distributions corresponding to each bottle. The task was designed for the children to make a decision by recommending to the pirates which bottle to choose, integrating all the available data evidence collected during the lesson. This moment provided an opportunity to observe how the students articulated their conclusions, interpreted the data representations, and expressed notions of possibility based on the behavior of the data.

Teacher: *Can you tell me which bottle you would recommend to the pirates?*

Student 1: *Bottle 1.*

Teacher: *Looking at what happened here [points to the dot plots of the three bottles].*

Student 1: *Oh no, [Bottle] 3!*

Teacher: *Bottle 3? Why [Student 1]?*

Student: *Because now it has 4 [points to the dot plot of Bottle 3].*

Teacher: *Okay, is it more likely to get 4 [gold pearls]? And if you had to choose one of these words [points to the printed scale of likelihood: certain, very likely, likely, unlikely, impossible], why [Bottle] 3?*

Student: *Because it would be very likely [that Bottle 3 has more gold pearls].*

This episode illustrates how two of the three components of IIR were activated. First, the use of data as evidence: the student who initially mentioned Bottle 1 reconsidered their choice after the teacher's guidance and the observation of the dot plot, ultimately selecting Bottle 3 and stating, “Now it has 4.” This justification reflects an approach toward recognizing a trend observable in the data by identifying the value “4” (representing the number of gold pearls) as the outcome with the highest frequency during the repeated samplings.

Subsequently, an emerging expression of uncertainty is observed, mediated by the teacher’s intervention. In response to the question “Is it more likely to get 4?”, the student replied, “Because it would be very likely,” indicating the beginning use of intuitive probabilistic language to describe expectations about an outcome. Although no explicit generalization beyond the collected data was made in this case, the combination of empirical evidence observation and the expression of likelihood represents a meaningful step in the development of informal inferential thinking in first-grade students.

The analyzed episodes illustrate students’ progression through the stages of the hypothetical learning trajectory (Estrella et al., 2024). In Episode 1, drawing on a brief observation and the narrative context, students formulated initial conjectures and expressed uncertainty using natural probabilistic language (Step 0). In Episode 2, through repeated sampling, they continuously compared their initial predictions with the data obtained (Step 1). In Episode 3, the construction and interpretation of dot plots supported the visualization of sample variability (Step 2). Finally, in Episode 4, students’ arguments

revealed both the assignment of likelihood levels (Step 3) and the formulation of conjectures that extended beyond the available data (Step 4).

The hypothetical learning trajectory enabled the sequenced implementation of tasks that promoted the development of students' informal inferential reasoning within a context of uncertainty, highlighting how carefully designed instructional sequences can scaffold the gradual transition from intuitive reasoning toward more evidence-based and probabilistic thinking in early grades.

## CONCLUSION

This study examined the implementation of a storytelling-based learning task, designed within a hypothetical learning trajectory (HLT) to foster informal inferential reasoning (IIR) in students from grades 1 to 3. The analysis of four classroom episodes showed how the sequenced structure of the HLT guided students through progressive stages of reasoning—from expressing uncertainty using probabilistic language to formulating evidence-based conjectures that extended beyond the observed data. The integration of a narrative context with repeated sampling, visualization of data variability, and opportunities for argumentation proved effective in engaging students while scaffolding the development of key statistical concepts.

The findings indicate that each step of the HLT played a specific role in supporting the emergence of IIR. Step 0 invited students to formulate initial conjectures and express uncertainty within a shared narrative context. Step 1 encouraged the direct comparison between predictions and empirical evidence through repeated sampling. Step 2 made variability visible by engaging students in constructing and interpreting dot plots, while Step 3 guided them toward assigning likelihood levels based on the observed data. Finally, Step 4 facilitated generalization, extending reasoning beyond the available dataset. This sequencing provided structured scaffolding consistent with previous research (Ben-Zvi, 2016; Makar & Rubin, 2009).

This study also illustrates how data use can be meaningfully integrated into primary education through intentional task design, the use of concrete and unplugged materials, and the collaborative construction of data representations in whole-class discussions. The use of dot plots as reasoning tools enabled students aged 6 to 8 to compare equally sized groups, identify patterns, discuss sample variability, and make evidence-based decisions without formal statistical methods. These results align with prior research (Fielding-Wells, 2018; Frischemeier, 2019) showing that older students can also use dot plots to reason about data comparisons.

Overall, the combination of playful narrative, empirical exploration, and collaborative knowledge construction proved to be a powerful approach for introducing young learners to statistical ideas and fostering the early development of IIR (Estrella, 2025). These findings highlight the potential of embedding inference in early statistical education and call for further reflection on how teacher preparation can better equip educators to cultivate these skills from the earliest stages of schooling

## ACKNOWLEDGEMENT

This research was conducted with financing from ANID/ FONDECYT EXPLORACIÓN 13240075; ANID/CONICYT FONDECYT 1200346; ANID/Support 2024 AFB240004; ANID/FONDEF IT23i0067; ANID Becas/ Doctorado-Nacional 21231116; 2124137, and VINCI 039.493/2024.

## REFERENCES

- Bargagliotti, A., Franklin, C., Arnold, P., Gould, R., Johnson, S., Perez, L., & Spangler, D. (2020). *The pre-K–12 guidelines for assessment and instruction in statistics education II (GAISE II)*. American Statistical Association. [https://www.amstat.org/asa/files/pdfs/GAISE/GAISEIIPreK-12\\_Full.pdf](https://www.amstat.org/asa/files/pdfs/GAISE/GAISEIIPreK-12_Full.pdf)
- Ben-Zvi, D. (2016). Three paradigms in developing student's statistical reasoning. In S. Estrella, M. Valenzuela, & J. Olfos (Eds.), *XX Jornadas Nacionales de Educación Matemática* (pp. 13–22). SOCHIEM. <https://www.sochiem.cl/documentos/actas-jnem/2016-valparaiso-xx-pucv.pdf>
- Engel, J. (2017). Statistical literacy for active citizenship: A call for data science education. *Statistics Education Research Journal*, 16(1), 44–49. <https://doi.org/10.52041/serj.v16i1.213>

- Estrella, S. (2025). What does preparing our boys and girls to interact with artificial agents mean? Perspectives from early statistical education in today's classroom. In C. Cornejo, P. Felmer, D. M. Gómez, P. Dartnell, P. Araya, A. Peri, & V. Randolph (Eds.), *Proceedings of the 48th Conference of the International Group for the Psychology of Mathematics Education: General Contributions* (pp. 55–69).
- Estrella, S., & Ben-Zvi, D. (in press). Children's emergent statistical reasoning in early childhood (ages five to eight). In J. Mulligan, C. Björklund, R. Olfos, D. Clements, and J. Sarama, *Emerging Research Dimensions of Early Mathematics Education*. Springer.
- Estrella, S., Méndez-Reina, M., & Vidal-Szabó, P. (2023a). Exploring informal statistical inference in early statistics: A learning trajectory for third-grade students. *Statistics Education Research Journal*, 22(2), Article 10. <https://doi.org/10.52041/serj.v22i2.426>
- Estrella, S., Méndez-Reina, M., Salinas, R., & Rojas, T. (2023b). The mystery of the black box: An experience of informal inferential reasoning. In G. Burrill, L. de Oliveria Souza & E. Reston (Eds.), *Research on Students' Interactions with Data in Teaching Statistics*. Springer. [https://doi.org/10.1007/978-3-031-29459-4\\_16](https://doi.org/10.1007/978-3-031-29459-4_16)
- Estrella, S., Morales, S., Méndez-Reina, M., Vidal-Szabó, P., Ramírez, B., & Mondaca-Saavedra, A. (2024). *Diseño de una trayectoria hipotética de aprendizaje para introducir la inferencia estadística informal en primaria* [Design of a hypothetical learning trajectory to introduce informal statistical inference in primary school]. *RELIME: Revista Latinoamericana de Investigación en Matemática Educativa*, 27(1), 11–42. <https://doi.org/10.12802/relime.24.2711>
- Fielding, J., Makar, K., & Ben-Zvi, D. (2025). Developing students' reasoning with data and data-ing. *ZDM—Mathematics Education*, 57(1), 1–18. <https://doi.org/10.1007/s11858-025-01671-6>
- Frischemeier, D. (2019). Primary school students' reasoning when comparing groups using modal clumps, medians, and hatplots. *Mathematics Education Research Journal*, 31(4), 485–505. <https://doi.org/10.1007/s13394-019-00261-6>
- Gal, I., Nicholson, J., & Ridgway, J. (2023). A conceptual framework for civic statistics and its educational applications. In J. Ridgway (Ed.), *Statistics for Empowerment and Social Engagement: Teaching Civic Statistics to Develop Informed Citizens* (pp. 37–66). Springer. [https://doi.org/10.1007/978-3-031-20748-8\\_3](https://doi.org/10.1007/978-3-031-20748-8_3)
- Garfield, J., & Ben-Zvi, D. (2008). Garfield, J., & Ben-Zvi, D. (2008). Preparing school teachers to develop students' statistical reasoning. In C. Batanero, G. Burrill, C. Reading, & A. Rossman (Eds.), *Joint ICMI/IASE study: Teaching statistics in school mathematics*. ICMI & IASE.
- Gould, R., Wild, C., Baglin, J., McNamara, A., Ridgway, J., & McConway, K. (2018). Revolution in teaching and learning statistics: A collection of reflections. In D. Ben-Zvi, J. Garfield & K. Makar (Eds.), *International Handbook of Research in Statistics Education* (pp. 457–472). Springer. [https://doi.org/10.1007/978-3-319-66195-7\\_15](https://doi.org/10.1007/978-3-319-66195-7_15)
- Makar, K., & Rubin, A. (2009). A framework for thinking about informal statistical inference. *Statistics Education Research Journal*, 8(1), 82–105. <https://doi.org/10.52041/serj.v8i1.457>
- Makar, K., & Fielding-Wells, J. (2011). Teaching teachers to teach statistical investigations. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching Statistics in School Mathematics: Challenges for Teaching and Teacher Education* (pp. 347–358). Springer. [https://doi.org/10.1007/978-94-007-1131-0\\_33](https://doi.org/10.1007/978-94-007-1131-0_33)
- Ministerio de Educación de Chile [MINEDUC]. (2022). *Estándares Pedagógicos y Disciplinarios para Carreras de Pedagogía en Educación General Básica* [Pedagogical and Disciplinary Standards for Primary Education Teacher Training Programs]. [https://estandaresdocentes.mineduc.cl/wp-content/uploads/2023/05/basica\\_2023\\_digital.pdf](https://estandaresdocentes.mineduc.cl/wp-content/uploads/2023/05/basica_2023_digital.pdf)
- Ministerio de Educación de Chile [MINEDUC]. (2018). *Bases Curriculares Primero a Sexto básico* [Curricular Guidelines for Grades 1 to 6]. [https://www.curriculumnacional.cl/614/articles-22394\\_bases.pdf](https://www.curriculumnacional.cl/614/articles-22394_bases.pdf)
- Nicholson, J., Gal, I., & Ridgway, J. (2018). *Understanding Civic Statistics: A Conceptual Framework and its Educational Applications*. [https://iase-web.org/islp/pes/documents/Conceptual\\_framework\\_brief.pdf?1543033023](https://iase-web.org/islp/pes/documents/Conceptual_framework_brief.pdf?1543033023)

- Steffe, L., & Thompson, P. (2000). Teaching experiment methodology: underlying principles and essential elements. In A. Kelly & R. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 267–306). Lawrence Erlbaum Associates.
- Simon, M. A., & Tzur, R. (2012). Explicating the role of mathematical tasks in conceptual learning: An elaboration of the hypothetical learning trajectory. In D. Clements & J. Sarama (Eds.), *Hypothetical learning trajectories* (pp. 91–104). Routledge.
- van Dijke-Droogers, M., Drijvers, P., & Bakker, A. (2020). Repeated sampling with a black box to make informal statistical inference accessible. *Mathematical Thinking and Learning*, 22(2), 116–138. <https://doi.org/10.1080/10986065.2019.1617025>
- Zieffler, A., Garfield, J., delMas, R., & Reading, C. (2008). A framework to support research on informal inferential reasoning. *Statistics Education Research Journal*, 7(2), 40–58. <https://doi.org/10.52041/serj.v7i2.469>