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Tangible statistics: cutting and weaving through data

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Experience data like never before! Use kirigami and participatory statistics to create low-cost, hands-on multisensory visualizations to engage and inspire.

Data has become a powerful tool in our lives, helping us understand the world beyond biases and misinformation. But without engaging communication, this wealth of information and its analysis often goes untapped. Enter data physicalization – the ultimate approach that transforms data into multisensory experiences, enabling you to hear, touch, and interact with information. This method complements traditional analytical approaches in statistical education, serves as a playful introduction to the topic for younger students, and enhances communication whenever data is used, regardless of the subject.

In this first article of a series on tangible statistics,[1,2] we dive into the world of kiristats and participatory statistics. These accessible, low-cost, and creative activities bring data to life, making them perfect for any classroom.
Using kirigami, an ancient Japanese paper-cutting technique, students can transform simple cardboard sheets into outstanding representations of complex data, while having fun and sparking creativity.[3] Here, we'll guide you through creating kirigami age pyramids, opening up discussions on demographics and migration.

With participatory statistics, students and communities can engage directly in data collection and visualization, making learning a truly collaborative experience. In the proposed activities, participants shape the data landscape themselves, using colourful wires and simple tools to build visualizations that tell compelling stories.

The hands-on approach not only makes data more inclusive, but also encourages a deeper understanding and critical thinking. These dynamic activities are not just educational but transformative, making any subject, like history or social studies, come alive with interactive data exploration.

Activity 1: Slices of life: kirigami age pyramids

Imagine having a snapshot of the world's population at your fingertips, revealing the secrets of past events and future trends. An age pyramid is just that – a fascinating tool that lets us peek into the demographic shifts shaping our world. By analyzing age pyramids, students can uncover the social and economic implications of demographic events, sparking discussions about future challenges and opportunities, to reflect on how a youthful boom or an aging wave can shape a country's needs and dreams as well as those of its neighbours. It's more than just data – it's a way to connect history, society, and the choices we make today, helping students see the bigger picture and think critically about our shared future.

Kirigami three-dimensional (3D) age pyramids are very easy to make and can be explored and manipulated for a deeper understanding and engagement. With an added touch of colour, multiple data layers can be visualized, offering a richer food-for-thought experience for the simple cost of scissors, paper, pencils, and creativity!

In this activity, we compare the age pyramids of higher- and lower-income nations to forecast social and economic changes over the next 20 years and beyond. We explore migration trends, policies, and strategies to ensure sustainable and equitable development. This activity is suitable for students aged 11–19. The activity itself takes an hour and is followed by 20 minutes of discussion.

Safety notes

Remind students to always keep the cutter in safety mode when not in use: blade cap on or in the safe position. Metal rulers and cutting boards are recommended.

Materials

- Device with internet access
- Cutter (with safety blade/cap)
- Metal ruler
- Cutting board
- Colourful heavy paper (suggested >140 g)
- Activity sheet 1
- Optional: Population Pyramid template for drawing the pyramids by hand instead of printing them

Procedure

Exploring the data

1. Introduce the concept of demographics and age pyramids, and come up with some questions that can be explored to find the answers using age pyramids. Questions can be agreed upon as a class or groups of students can formulate their own research questions. Activity sheet 1 can be used to either introduce the activity or aid the discussion.
2. Divide students into small groups (of around three or four) and have them visit the Population Pyramid website and choose the age pyramids that align with the thesis or discussion. They can explore data globally, by continent, or by country, spanning from 1950 to projections for 2100 (figure 1).

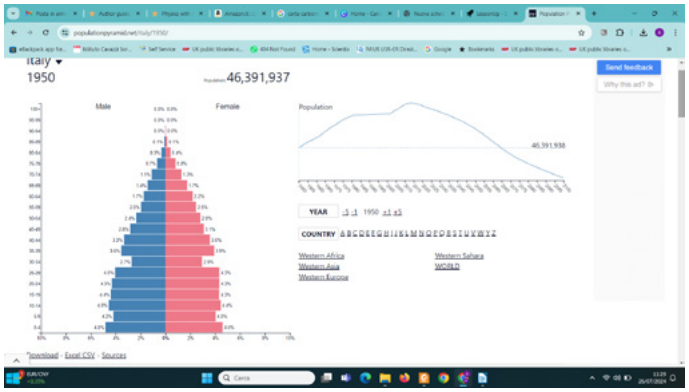

Figure 1: The Population Pyramid website may be browsed by either location or time. It highlights both pyramids and a graph of population versus time.

Image courtesy of the author

3. Encourage students to reflect on demographic changes and their implications, focusing on a topic of their choice, such as healthcare needs for aging populations or job creation for youthful booms. They can also explore how surrounding regions' demographics might present challenges or opportunities for a specific country.
4. Students should choose the age pyramids that illustrate their thesis or question (see activity sheet 1) and then follow the model building instructions below.

Building 3D kirigami models

5. Click on the "Download" option, then right click and select "Save picture as" to save it to the device. Alternatively, the students can hand draw the pyramid by filling in the population pyramid template.
6. **Transfer the pyramid:** resize the image as needed, and transfer the pyramid onto a sheet of coloured cardboard (print and photocopy or use carbon paper).
7. **Cut and fold:** using a cutter, slice along all the horizontal continuous lines. Gently push the strips outwards, then fold the cardboard along the dotted vertical lines (sides and central axis; figure 2).

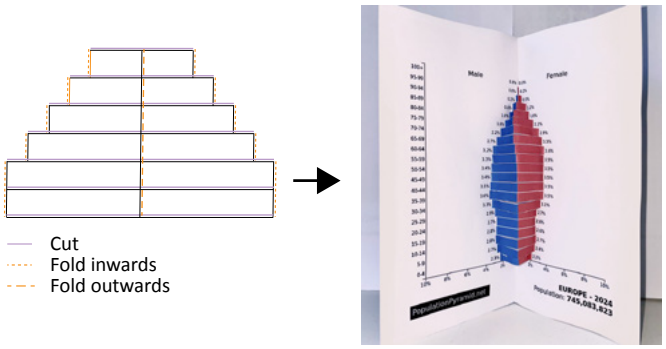

Figure 2: Cut along the continuous blue lines, fold, and push outward along the red dotted line.

Image courtesy of Maria Paola Pisano

8. Add details: label the model with the country, year, legend and data source. Add a catchy caption.

Extension activity

To include more data layers[4] for each cohort, work on white cardboard and colour the strips, highlighting new pyramids within the main one. Be sure to add a legend. In the example in figure 3, we embedded data about education levels.

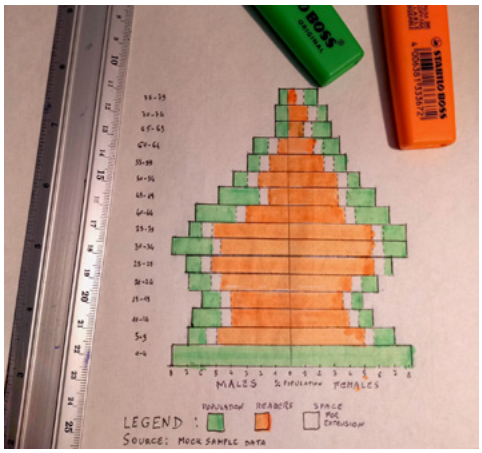

Figure 3: You may embed additional information by building new pyramids within pyramids. Here, the education level of each cohort is reported.
Image courtesy of the author

Discussion

Here are some tips and suitable questions for the classroom discussion/debate. The teacher may choose to start simply, limiting the analysis to a single country, or dig deeper by embracing a global view.

Focus on one country: if the group chose to focus on a specific country, which years are particularly significant to illustrate its demographic evolution? Is it possible to glimpse the future from the pyramid data of a specific year? Which age groups should be carefully considered for future projections? Are there noticeable differences between males and females, or do both trends appear to be similar? Can you find clues for impactful past events?

Priorities and challenges: reflect on the priorities and challenges faced by previous generations, such as your parents and grandparents. Consider the new and specific issues your generation will need to address. Which areas should be prioritized – education, healthcare for an aging population, job creation, and so forth? Why?

An interconnected world: in our increasingly interconnected world, we cannot view ourselves as isolated, self-sufficient systems. Consider how demographic developments in surrounding regions might serve as both challenges and resources. Can you support your insights with additional age pyramids from other areas? Regarding migration, which countries exhibit unstable or rapidly expanding population pyramids? Why do countries like Qatar and the Emirates have uniquely shaped pyramids?

Acting for change: finally, consider the factors that could alter the model predictions. How might these changes unfold and over what timeframe? Understanding the factors influencing a population's age structure is crucial for making informed decisions today that will shape the future.

Activity 2: Statistics that care: enhancing student wellbeing with a participatory approach

Sometimes it's good to get quick feedback from students about their day/lesson in an engaging hands-on way with a tangible eye-catching visualization. Results are immediately and easily shared with colleagues and the whole class as food for thought for a better school experience. Figure 4 shows a poster with a whirlwind of tiny paper planes of all shapes and colours. Each student chooses one and pins it in position, according to their mood. There are three parameters: colour (ranging from red to blue, corresponding to mood), dimension (intensity of the feeling), and position (up in the sky for an outstanding experience, at the bottom for total failure). This simple, yet effective, method allows students to freely express their feelings and engage in data visualization, fostering a sense of belonging and empowerment.

Figure 4: Participatory statistics activity to gauge student wellbeing. The positions, colours, and sizes of paper planes stuck onto the poster reveal how students feel.
Image courtesy of the author

The sample encompasses all the key elements of a successful participatory statistics activity: it is visually appealing (featuring bright colours and evocative images), quick and easy to complete, actively engaging, and incorporates a few functional parameters to encode multiple layers of information. As data is collected, the visualization naturally emerges, making the resulting pattern instantly visible and understandable.

For a complete and meaningful learning experience, students should, after testing the method themselves, design and set up their own participatory statistics projects. They should also include a short report on their design process, explaining the parameter choices and the implicit meanings. The main activity should only take around 20 minutes if the teacher sets it up before class and the students just add the data points and discuss the outcome. However, additional lessons will be required if the students then design and run their own surveys (extension activity).

Materials

- A1 cardboard
- Markers
- Colourful paper (> 140 grams)
- Double-sided tape
- Scissors
- Activity sheet 2

Procedure

Preparation before the lesson

1. Prepare the poster with the whirlwind trace.

Image courtesy of the author

2. Prepare a legend with the model parameters (plane colour, size, and position):
   a. colour – ranges from red to blue, corresponding to mood. Students can get involved in the planning and discuss and choose their own moods as a class or use the following legend: red = enthusiasm, pink = desire to act, orange = fun, yellow = curiosity, green = indifference, blue = boredom
   b. size – several sizes to indicate intensity of feeling
   c. position – up in the sky for an outstanding experience, at the bottom for total failure.

Image courtesy of the author

3. Add brief instructions, for example, choose the plane colour that matches how you feel and choose a size that matches the intensity of the feeling, and then stick it at the top or bottom of the poster, according to whether you feel the lesson went well or badly, respectively.
4. Cut out paper planes: cut triangles out of the colourful paper sheets. There should be several sizes in each colour. Fold each triangle along the middle axis and stick a piece of double-sided tape to the outside of one wing.

Image courtesy of the author

End-of-lesson survey

5. At the end of the lesson, students choose a plane, remove the protective backing from the tape and stick the plane onto the poster to represent their feelings about the lesson.
6. Discussion can follow in the next lesson to plan wellbeing improvements.

Extension activity

Inspired by the plane posters, students should design their own 'wellbeing feedback' activity (activity sheet 2). Divide students into small groups of three or four. They should consider the significance of colours, shapes, and sizes because evoking emotions through aesthetics is crucial for gaining public commitment. It's important they ensure responses are fast and straightforward, keeping the public engaged and encouraging them to take action. This process fosters creativity and encourages students to engage deeply with the data. The steps that they should follow are outlined below.

Design

Discuss and decide on the following elements, ensuring that every detail has a meaningful purpose:

- **Visual appeal:** incorporate bright colours and evocative images to capture attention.
- **Parameters and data layer:** take care that all parameters are associated with data.
- **Aesthetic appeal:** design elements should be harmonious and attractive.
- **Quick and easy to complete:** the activity should be straightforward, allowing participants to engage without confusion and complete it in a few minutes.
- **Actively engaging:** include interactive components that encourage active participation.
- **Functional:** consider practical aspects, such as usability and accessibility.
- **Emerging visualization:** as data is collected, the visualization should naturally and clearly develop, making the results easy to understand.
- **Calls to action:** clearly communicate what participants should do during and after the activity.
- **Cost efficiency:** design the activity to be low cost, using readily available materials and resources.

Reflect and report

Add a short accompanying report describing your design process and detailing the meaning of each of your above choices. Remember: nothing is left to chance; everything is carefully planned with a meaning and a purpose. Peer review among groups may be a brilliant add on to the activity!

Go and do it

Ideally, give students the opportunity to build their boards and run their survey. This can be done in class (e.g., a different student group every day) or somewhere in the school, or after a school event like an assembly.

Activity 3: Don't get tangled up! Weave your way through data into understanding

This activity involves using coloured wires to create visual data representations on a board.[5] Students design a questionnaire and use knobs and wires to depict different answers, creating a visual pattern that reveals insights. This activity takes 60 minutes to design the board, 10 minutes to run the activity, and 20 minutes for the evaluation. It is suitable for students aged 11–19.

Safety notes

Predrilled reusable boards may be safer and quicker (i.e., 8 columns with 4 holes each). Students can then decide how many to use.

Materials

- A3 or larger thick cardboard or plywood (3 mm)
- Coloured string or wool
- Nylon or polypropylene bolts and nuts: at least 1 cm longer than the board thickness; if you go for the more rigid plywood, you may use knobs instead of bolts
- Colours pencil/pens/paint/paper, scissors, and glue to decorate the board
- Survey structure template

Procedure

1. Preparation: introduce the task as a physical questionnaire that visually shows the results. Show students a picture of the final result,[5] or have them run through a test session with a premade example.
2. Plan the questionnaire: divide the students into groups of three of four. In their groups, they decide on the topic and select questions and answers (how many? in which order?). They should choose just a few questions, but these should be impactful and significant.

3. Design the board: the students choose the accompanying graphics. It should be somehow connected to the questionnaire topic. Questions to answer:
   a. Soothing colours or vibrant ones?
   b. Which fonts? (Of course, without forgetting the right size for readability.)
   c. Which symbols or images? (This will be guided by the impression we want to convey, and the emotions we would like to stir in the public.)
4. All details should consider both aesthetic and functional aspects to create an enthralling, immersive experience. The students may use the survey structure template structure the task.
5. Then create a captivating title, a legend for the string colours, and simple and clear instructions on how to interact with the board and answer the questionnaire.
6. Run the activity: put the balls of coloured string next to the assembled board with a pair of round-edged scissors for cutting. Each participant wraps the string around the knobs to answer the questions. As people keep answering, a visual representation of data will clearly emerge.

Discussion

Students reflect on the results, exploring new insights, and discussing possible actions based on the collected data. Are the answers what they expected, or do they reveal aspects the students had not been aware of? Is there some area of interest on which they may follow up? Participants in the questionnaire may have declared themselves as being in favour of being further engaged in conversation with the community, or they may be asked for more information.

Summary

These activities offer a cost-effective way for students to engage with data in a multisensory, inclusive, and creative manner, all within an interdisciplinary framework. They promote critical thinking and creativity, making data analysis an interactive and enjoyable experience with a focus on communication. Additionally, they also offer the opportunity to reach out to and engage with the surrounding community. «

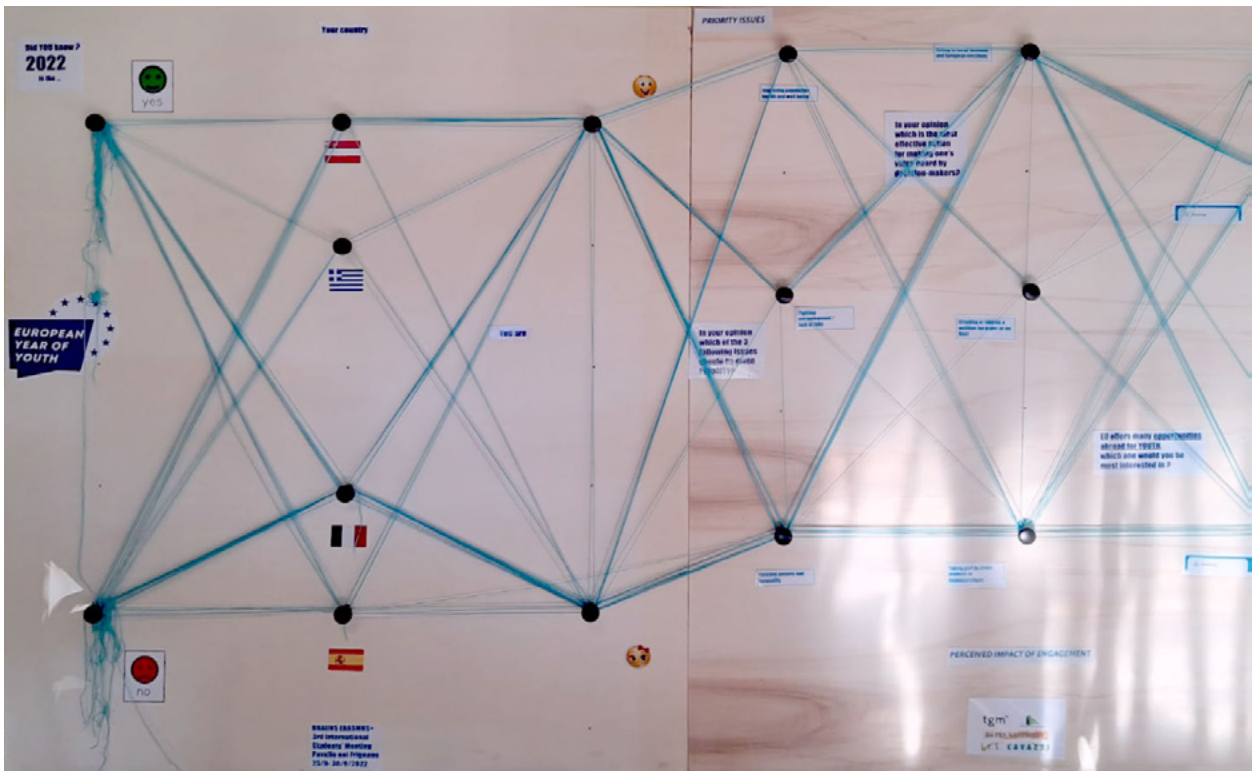

Figure 5: Participatory live questionnaire with the string-and-knobs board. You may go for a smaller version in cardboard with plastic bolts.
Image courtesy of the author

References

[1] Lisotti A, Vicini L (2023) Tangible statistics. *IASE 2023 Satellite Paper* **36–41**.

[2] Lisotti A, BeReady pilot activity: https://www.beready.pw.edu.pl/doc/IO3-summary.pdf

[3] Daneshzand F, Perin C, Carpendale S (2022) KiriPhys: exploring new data physicalization opportunities. *IEEE Xplore* **29**: 225–235. doi: 10.1109/TVCG.2022.3209365

[4] Reiter C (2021) Population pyramids by skills-adjusted education: estimates for 45 countries. Submission for the International Population Conference 2021.

[5] Moretti M (2018) Participatory data physicalization. *Free University of Bozen-Bolzano*.

Resources

- Browse worldwide demographic data spanning over 150 years.
- Delve deeper in age pyramids in the classroom using worldwide and European data.
- Kirigami templates for statistics and guidelines to make your own.
- Download customizable models for 3D printed nuts and bolts.
- Build participatory statistics activities based on maps that are free download at Free World Maps and Geointeractiva.
- Sketch graphs from 'story' videos of everyday events to boostunderstanding of data visualization: Reuterswärd E (2022) Graphing stories. *Science in School* **58**.
- Explore the science behind anamorphosis: Liang Y (2024) Exploring anamorphosis: revealing hidden images with mirrors. *Science in School* **68**.
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- Explain exponential growth to your students through these simple activities involving confetti: Vieser W (2021) Exponential growth 1: learn the basics from confetti to understand pandemics. *Science in School* **53**.
- Learn about exponential growth and how it relates to real-world problems like the spread of infectious diseases: Vieser W (2021) Exponential growth 2: real-life lessons from the COVID-19 pandemic. *Science in School* **53**.
- Teach your students about binary code with this fun challenge: Estudante A, Lourenço JP (2021) Teaching binary code with a secret word challenge. *Science in School* **52**.
- Help your students to explore the concepts of area and volume: Gallo MT (2021) Maths with fruit. *Science in School* **52**.
- Discover the Education corner on the Eurostat website to teach your students about statistics: Brondino R, Macchia G (2023) Eurostat's Education corner: your key to European statistics. *Science in School* **65**.

AUTHOR BIOGRAPHY

Annamaria Lisotti is a high school maths and physics teacher with a knack for making science exciting and accessible. She's all about sustainability, bringing AI into the classroom, and making data come alive. Whether she's diving into Erasmus adventures or rocking Science on Stage, she loves getting involved in international projects and EU initiatives, always aiming to inspire and energize her students with a passion for learning.