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## Objectives

- Describe differences between expert and novice ways of thinking in your discipline
- Analyse problems using Polya's problem solving method and demonstrate it during in your teaching
- Identify patterns / systems of thinking that are typical to your field
- Create a lesson plan to improve representational competence

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# Novice - Expert

What differentiates a novice from an expert **in your field**?

- Write down three characteristics

Individual task
~ 2 mins

- Pair up and compare with your neighbour

Pair task
~ 2 mins

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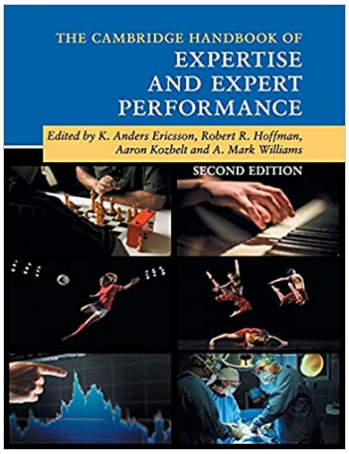
# What is expertise?




Superior reproducible performance on
**representative tasks**

Ericsson, K. A. (2018).

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## Experts behave differently

Novice Expert

What do they know? **How do they think?**

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## Experts behave differently

- Reasoning (thinking)
  - **Problem solving**

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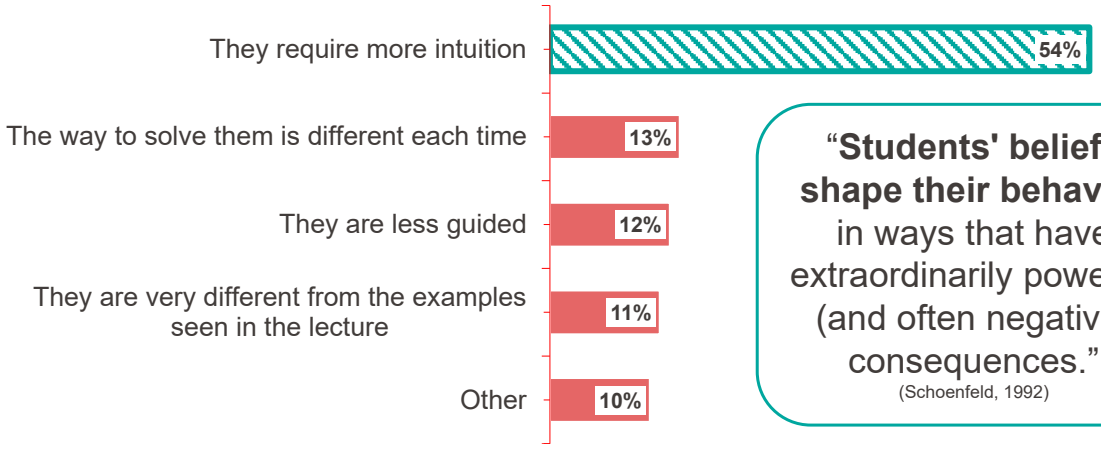
# How do students see problem solving?

**How are exercises in EPFL different from exercises in high school?**




**"Students' beliefs shape their behavior** in ways that have extraordinarily powerful (and often negative) consequences."
(Schoenfeld, 1992)

EPFL « Apprendre à étudier » session, April 2017, 223 participants

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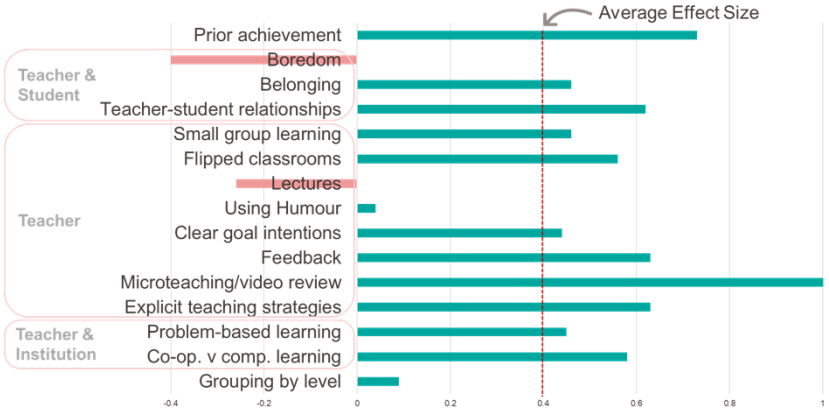
# Teaching problem solving – the data




| Aspects/Strategies | No. studies | Total no. of participants | Weighted Effect Size | Robustness |
|---|---|---|---|---|
| **Teaching problem solving** | 639 | 59305 | 0.61 | 5 |

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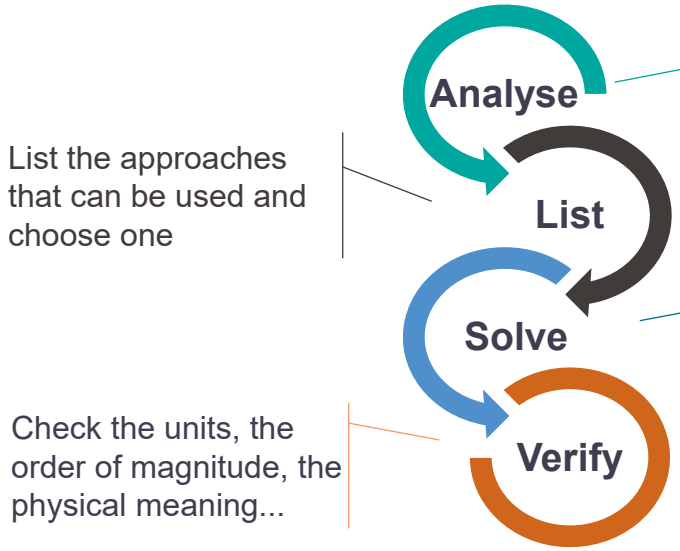
## Teaching problem solving heuristics




- List what is given/unknown
- Identify the objective
- Make a diagram…

List the approaches that can be used and choose one

- Proceed step by step
- Write clearly
- Develop algebraically

Check the units, the order of magnitude, the physical meaning...

Polya, *How to solve it*, 1945

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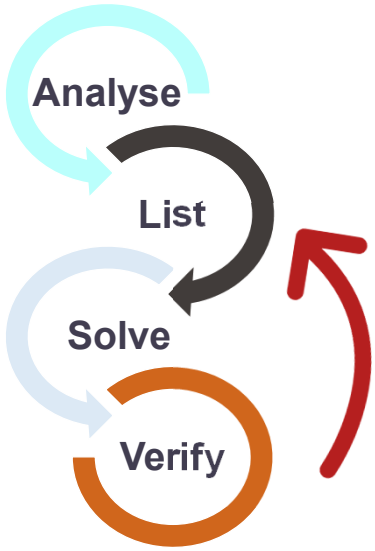
Reasoning and Representing

## Teaching problem solving heuristics




Polya, *How to solve it*, 1945

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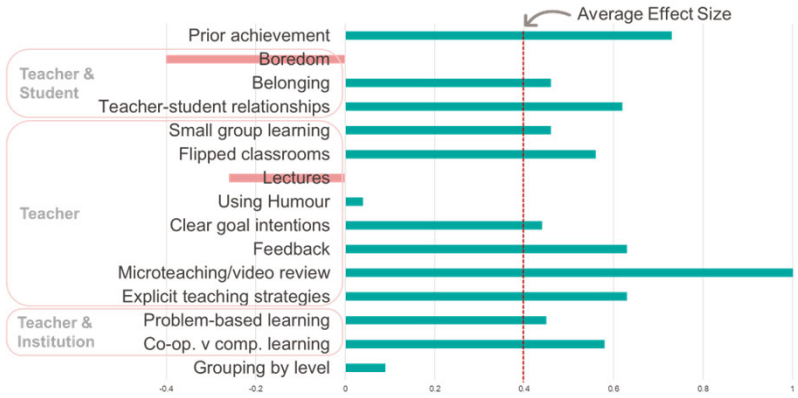
# Planning and monitoring




"Although many students are **weak at monitoring** their work, they are **not particularly aware** of this weakness"
Colussi, M., et.al., 2014

| Aspects/Strategies | No. studies | Total no. of participants | Weighted Effect Size | Robustness |
|---|---|---|---|---|
| **Planning and monitoring** | 157 | 14450 | 0.83 | 3 |

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# Teaching problem solving heuristics

Look back at your mini-lesson from Day 2 (exercise / problem solving activity):

- Are the problem-solving heuristics from your field explicit?
- How did you encourage your students to monitor their work?

Individual task
~ 3 mins

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# Experts behave differently

- Reasoning (thinking)
  - Problem solving
  - **Identifying patterns**

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# Experts identify patterns

| Type of comment | Expert | Advanced beginner | Novice |
|---|---|---|---|
| Description | 24 | 37 | 45 |
| Evaluation | 29 | 16 | 9 |

Sabers, D. S., Cushing, K. S., & Berliner, D. C. (1991)

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# Experts identify patterns

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems.

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# Experts identify patterns

| Group | n | Elements | Relationships | Function |
|---|---|---|---|---|
| Experts | 10 | 13 | 15 | 18 |
| Preservice teachers | 26 | 12 | 8 | 8 |
| Middle school students | 20 | 12 | 7 | 8 |

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems.

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## Systems thinking

- Thinking of the whole complex system as a unit
- More than the sum of the parts

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## Missing the forest for the trees

- What are some patterns in your field that novices might miss because they are focussing on the minutia?

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## Experts behave differently

- Reasoning (thinking)
  - Problem solving
  - Identifying patterns
- **Representing**

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## Common representations - 1

*IGF1* v IGF1

- Look similar
- But represent two very different concepts

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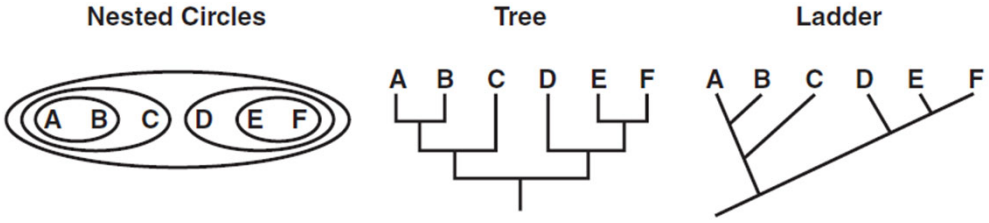
# Common representations - 2

- Look different
- But represent the same concept

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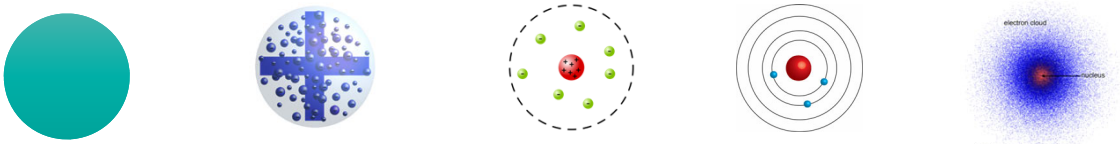
# Common representations - 3

- Historical models
- Increasing accuracy



Marble model Dalton 1803

Plum pudding model Thomson 1904

Nuclear model Rutherford 1911

Planetary model Bohr 1913

Quantum model Schrödinger 1926

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# Representational competence

- Make the conventions explicit
- Use multiple types of representations – explain contexts when one might be better than the other
- Explain difference between historical representations and current multiple representations
- Give students opportunity to interpret and construct

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# Representational competence

- What are some of the common representations in your field?
- What barriers could a novice face when using (interpreting and constructing) such representations?

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# Representing complex ideas

- Elements – Relationships – Function
- Structure – Behaviour – Function → SBF model

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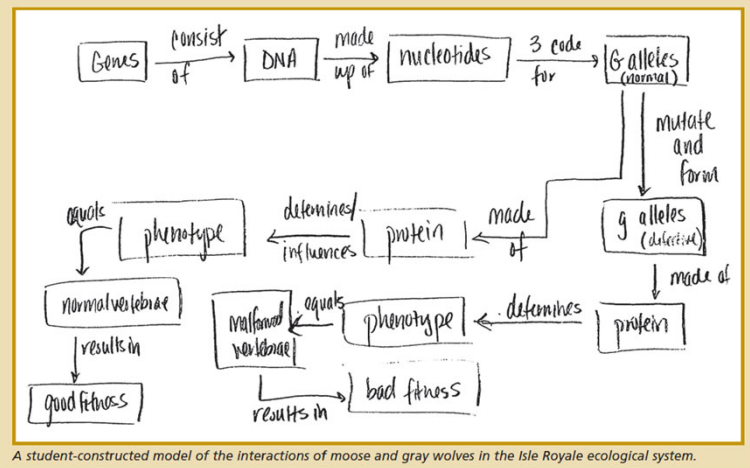
# SBF model - biology




A student-constructed model of the interactions of moose and gray wolves in the Isle Royale ecological system.

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# Experts identify patterns

| Group | n | Elements | Relationships | Function |
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Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems.

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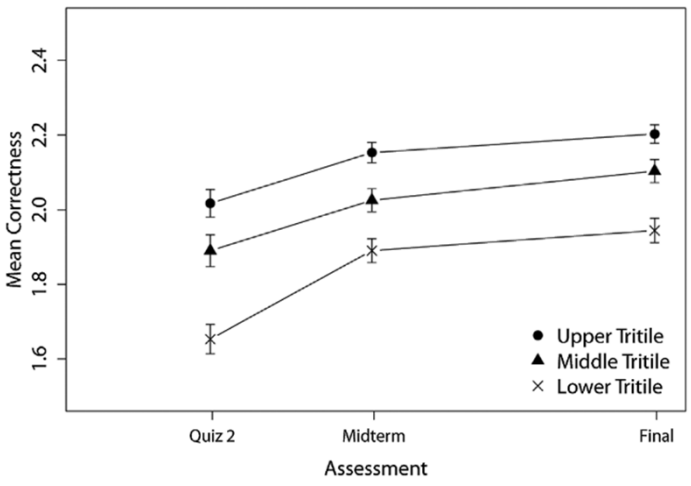
# Decrease in gap between low and high achievers




Dauer, J. T., Momsen, J. L., Speth, E. B., Makohon-Moore, S. C., & Long, T. M. (2013).

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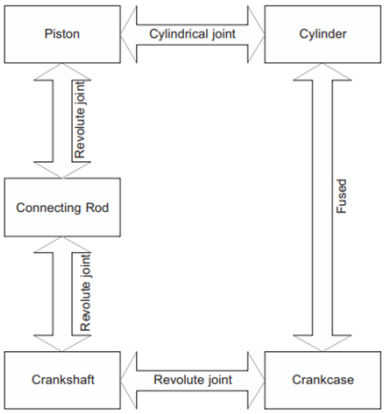
# SBF model - engineering




Yaner & Goel (2006)

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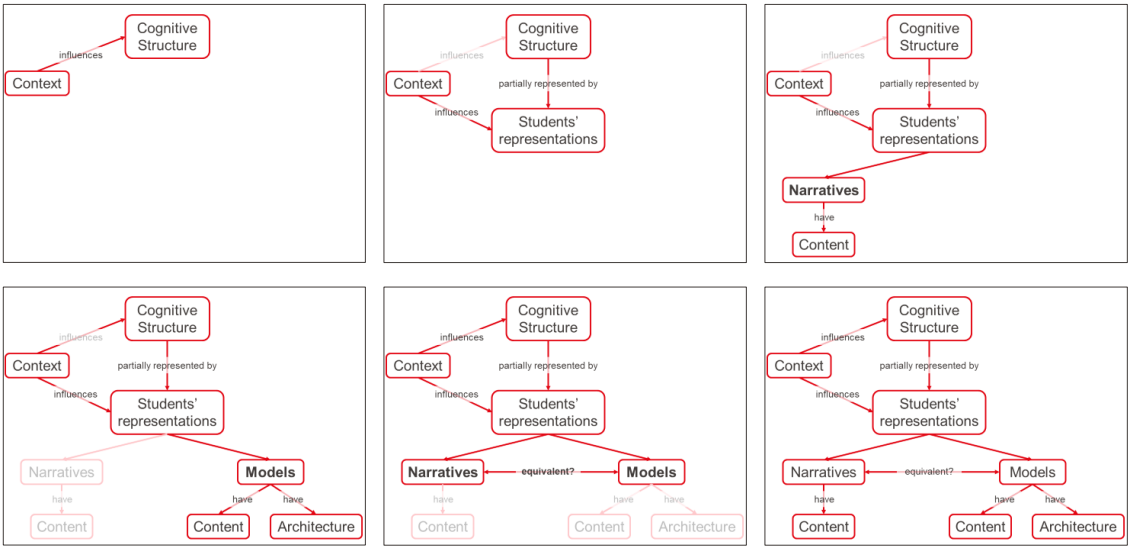
# Structure v flow

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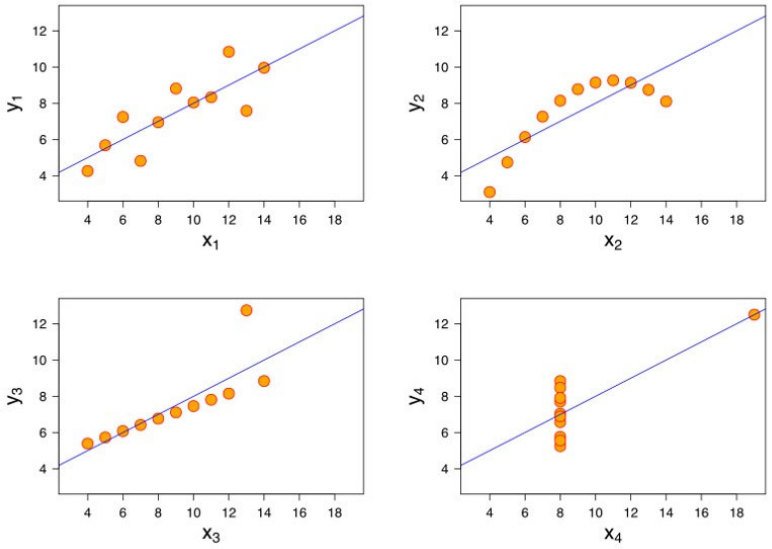
# Visualising data

This is Anscombe's quartet.

Observe it carefully.

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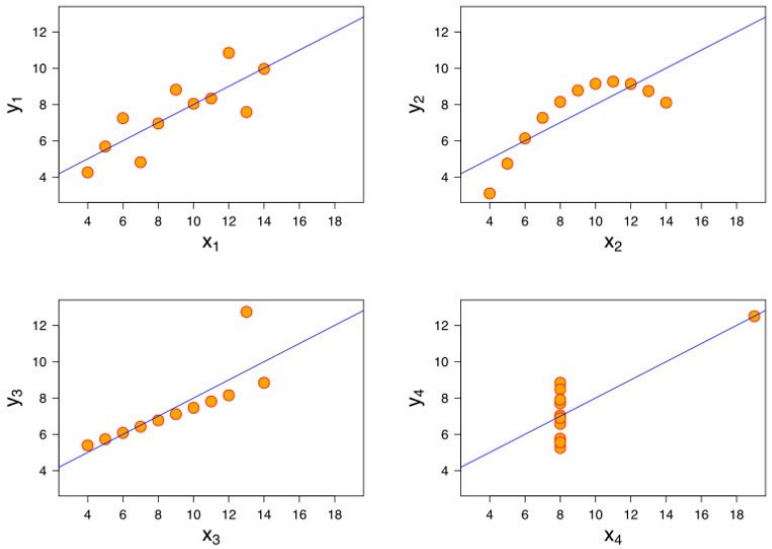
# Visualising data

These 4 plots have the same:

- mean(x)
- mean(y)
- variance(x)
- variance(y)
- x-y correlation
- Regression intercept
- Regression slope
- p-values
- $R^2$

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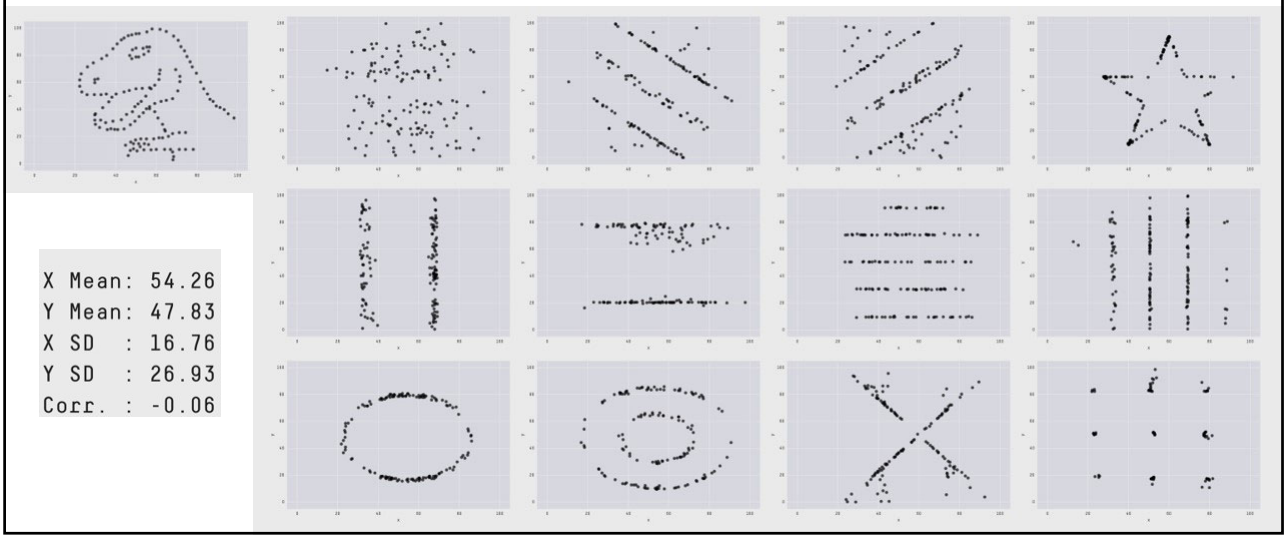
## Representations (visualisations) are important!

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## Visualising data

Next week for your mini lesson you will have to use quantitative data and use a visualisation/diagram to support student learning.

- Discuss some potential ideas with your partner.

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# Prompting students to think like experts

Experts:

- Reason and represent their reasoning in ways that are characteristic to their discipline.
- Use problem solving methods and monitor their work.
- Identify patterns and focus on the bigger picture.
- Use multiple representations fluently.

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