Measuring collective creativity in first-year physics students

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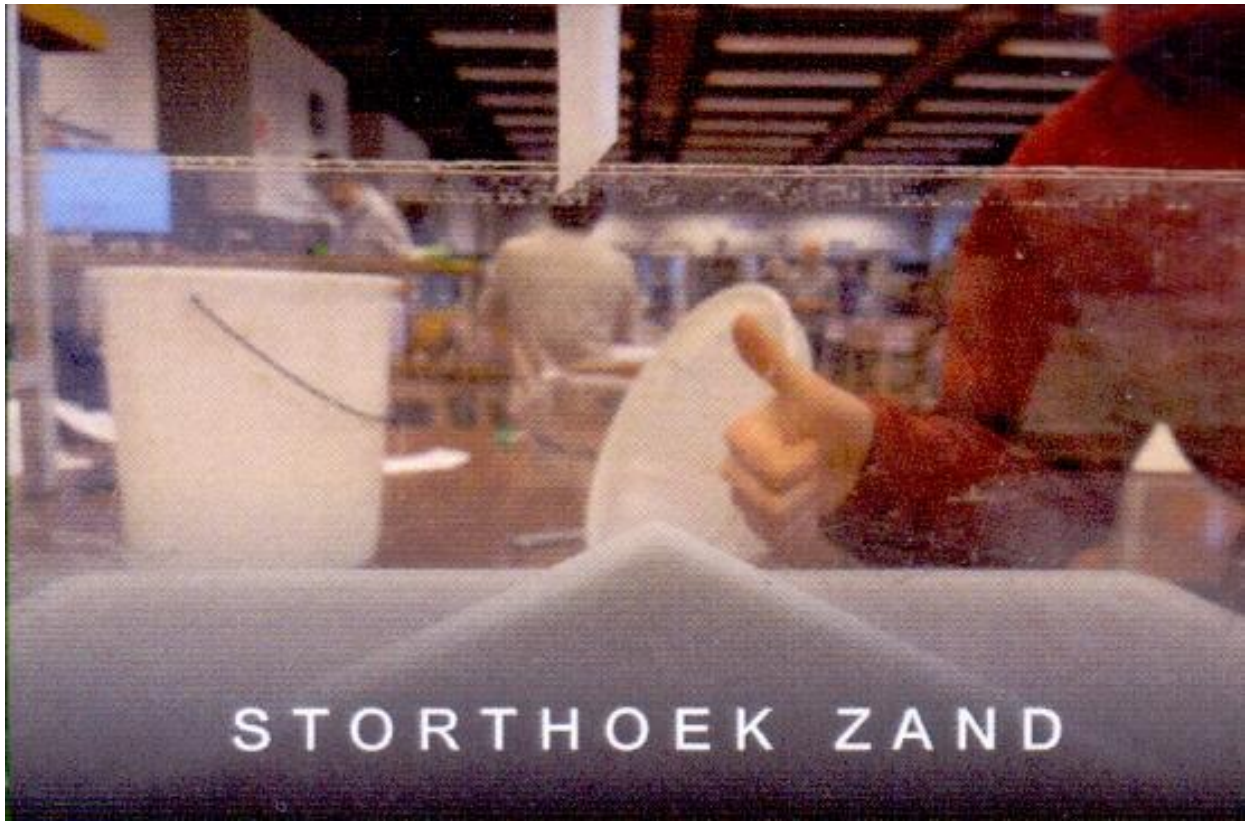
“*Experimentele Natuurkunde*” 2

Soft and biomatter

- First **open** experiment for first year students.
- Simple materials and measuring devices.

Why do open experiments?

- Approximates later research practice.
- Allow students to follow own interests within limits.



“*Experimentele Natuurkunde*” 2

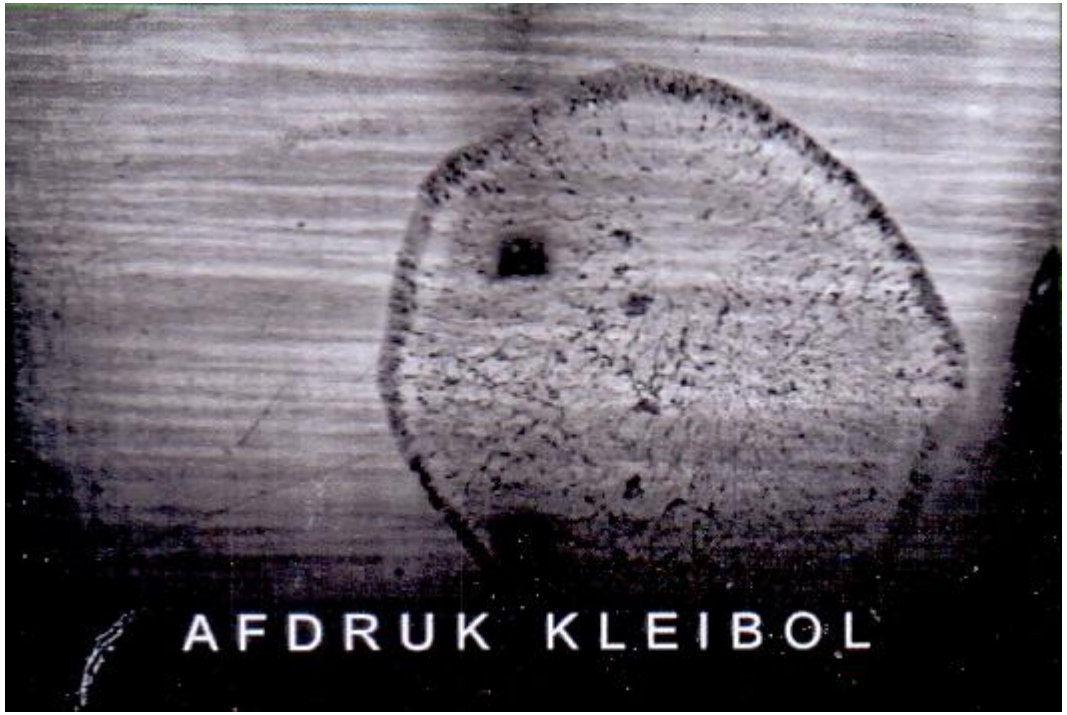
Soft and biomatter

- First **open** experiment for first year students.
- Simple materials and measuring devices.

Problems:

- 16.4% of students measure viscosity.
- 16.4% of students measure sand crater size.

Question: How can we encourage more creative experiment design?



Quick poll: Can creativity be taught?

Yes! → Raise your hand

No → Don’t raise your hand

To know if we are ***teaching*** creativity, we have to ***measure*** it.

Defining creativity

Not creative

- Copying research subject from syllabus examples
- Using the first research idea Google suggests
- Copying a suggestion from chatGPT

Creative

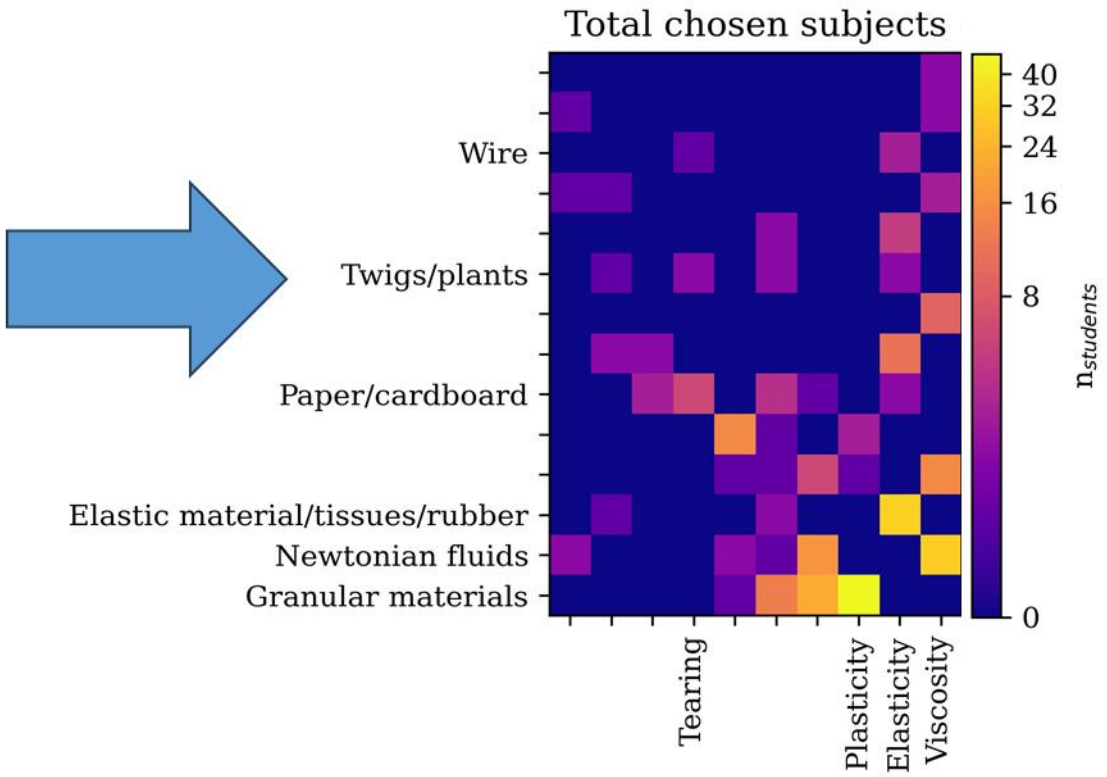
- Elaborating on a syllabus example
- Targeted Google search based on own idea
- Brainstorm session with chatGPT based on own idea

Conclusion: A creative group comes up with ***varied*** research ideas.

Categorizing students' research ideas

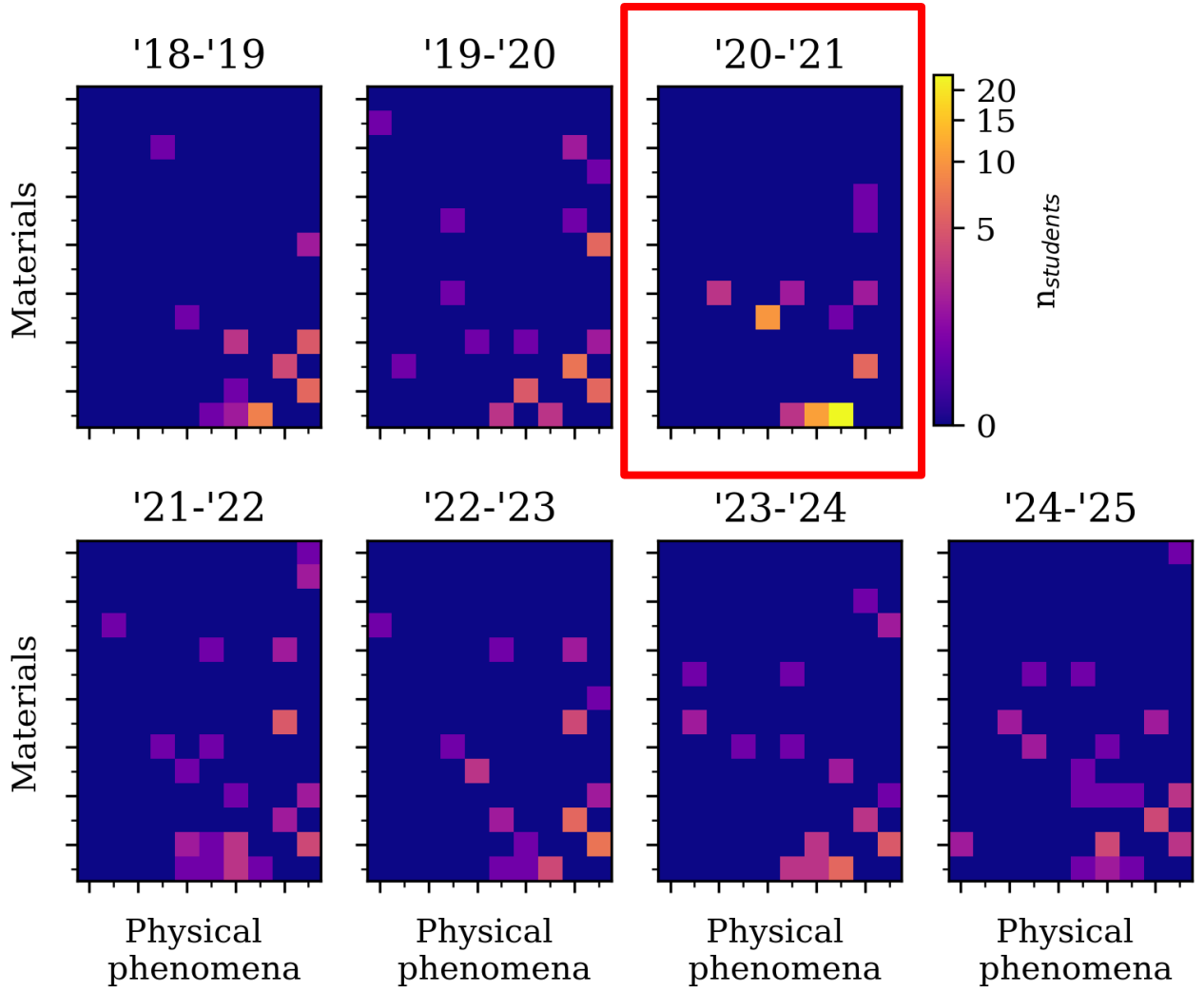
Total chosen subjects

	0	0	0	0	0	0	0	0	0	2
	1	0	0	0	0	0	0	0	0	2
Wire	0	0	0	1	0	0	0	0	3	0
	1	1	0	0	0	0	0	0	0	3
	0	0	0	0	0	2	0	0	5	0
Twigs/plants	0	1	0	2	0	2	0	0	2	0
	0	0	0	0	0	0	0	0	0	9
	0	2	2	0	0	0	0	0	11	0
Paper/cardboard	0	0	3	6	0	4	1	0	2	0
	0	0	0	0	15	1	0	3	0	0
	0	0	0	0	1	1	6	1	0	15
Elastic material/tissues/ rubber	0	1	0	0	0	2	0	0	32	0
Newtonian Fluids	2	0	0	0	2	1	17	0	0	31
Granular materials	0	0	0	0	1	13	22	46	0	0
				Tearing				Plasticity	Elasticity	Viscosity



Students' research ideas per year

- Decrease in creativity during Covid visible.
- Finer changes in creativity invisible.
- No quantification yet!



Quantification methods

- Cosine similarity
- Shannon index
- Probability calculation

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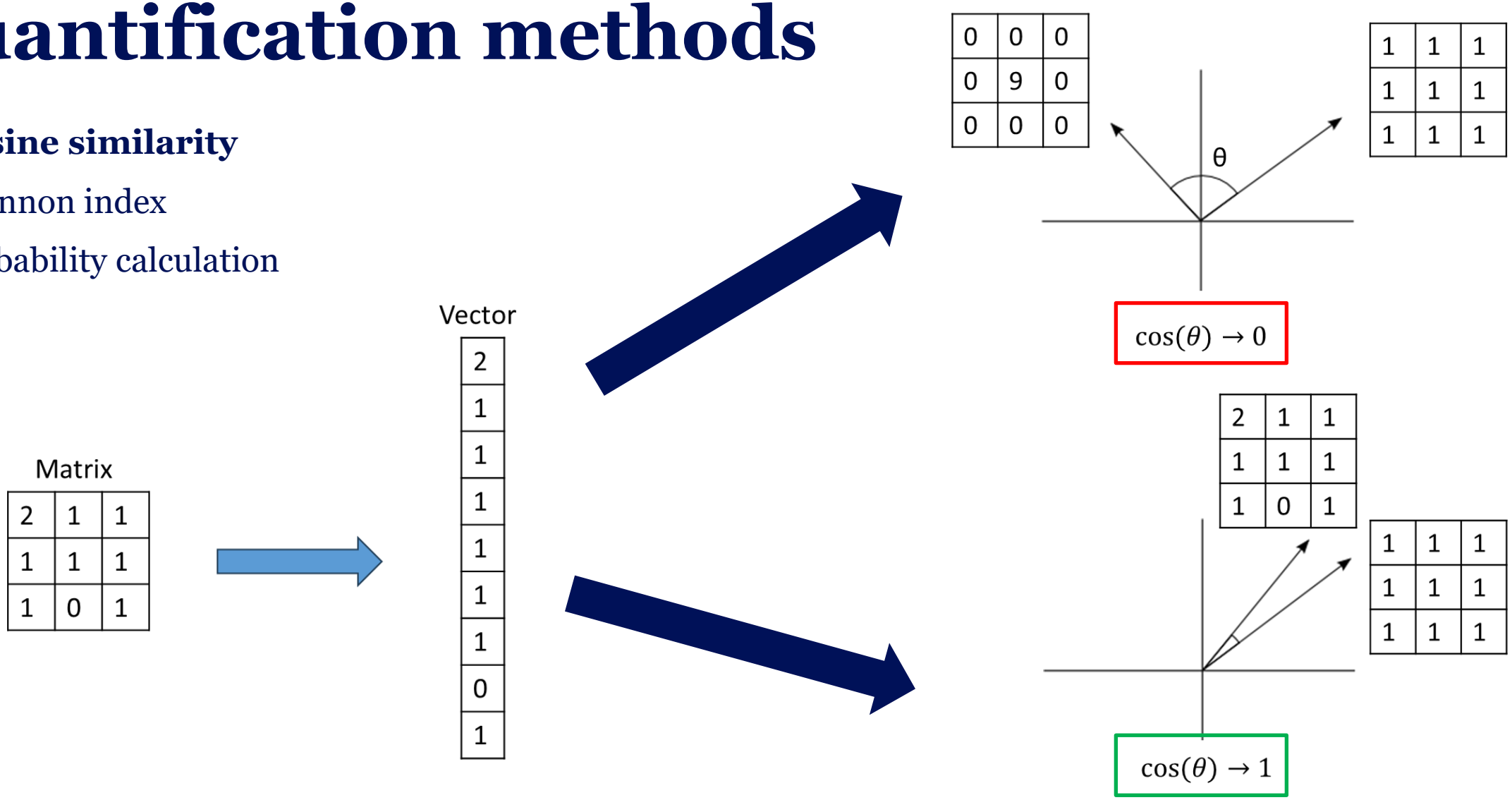
- Shannon index
- Probability calculation



Quantification methods

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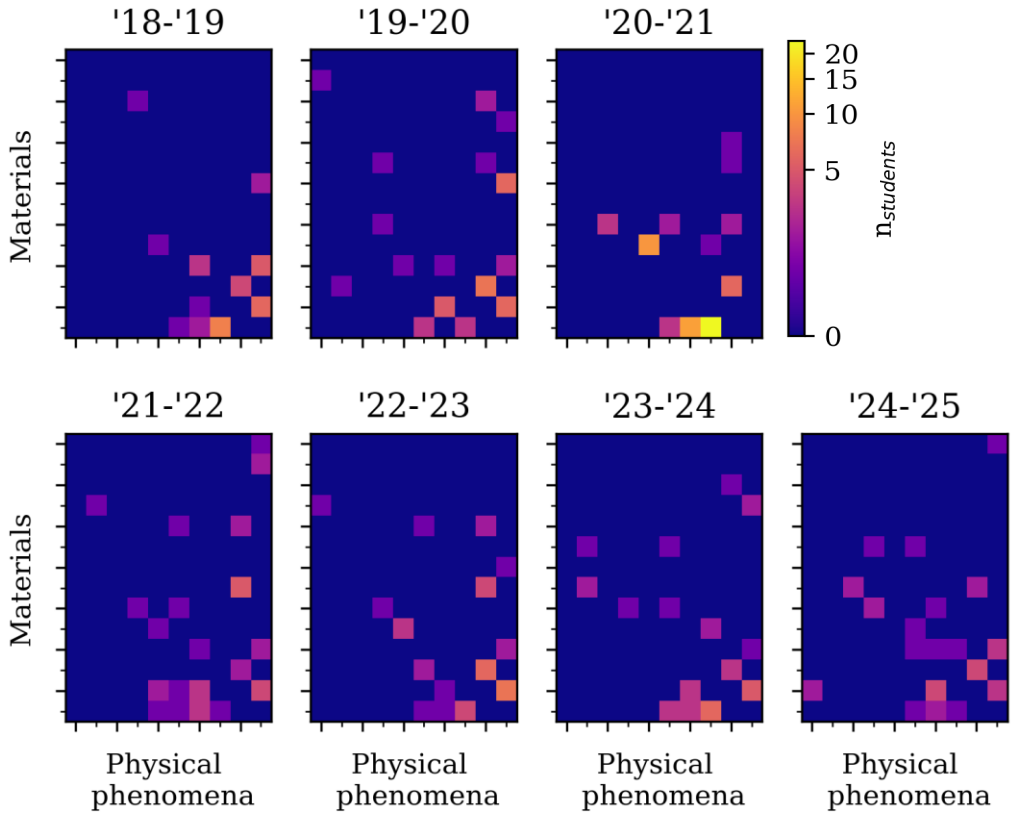

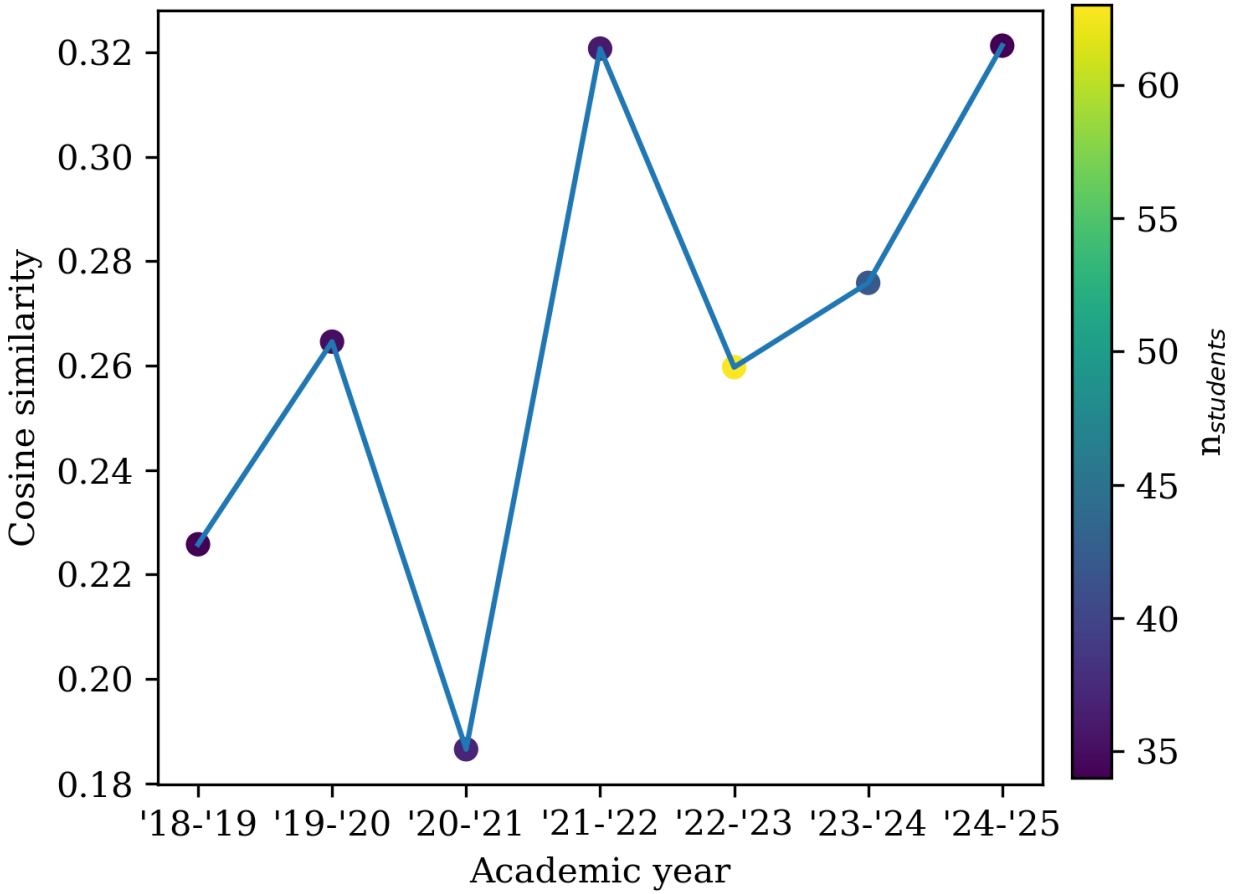

Quantification methods

- Cosine similarity
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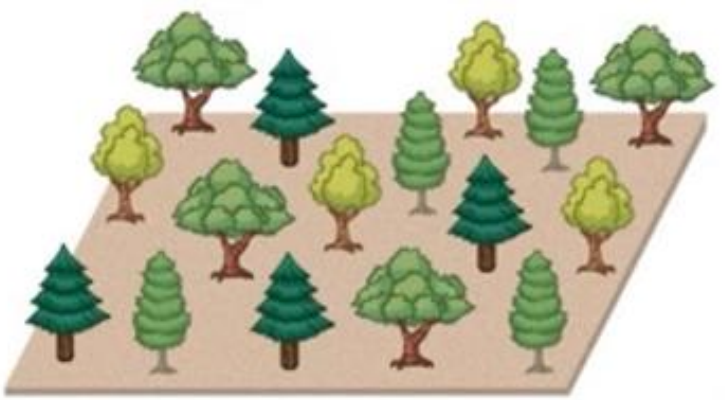

https://www.youtube.com/watch?v=lbnXPI05qNI

Amount of different subjects chosen

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Equal distribution over subjects: $H' \rightarrow large$
Unequal distribution: $H' \rightarrow small$

Relative prevalence of every subject: $\frac{amount\ of\ times\ a\ subject\ is\ chosen}{number\ of\ students}$

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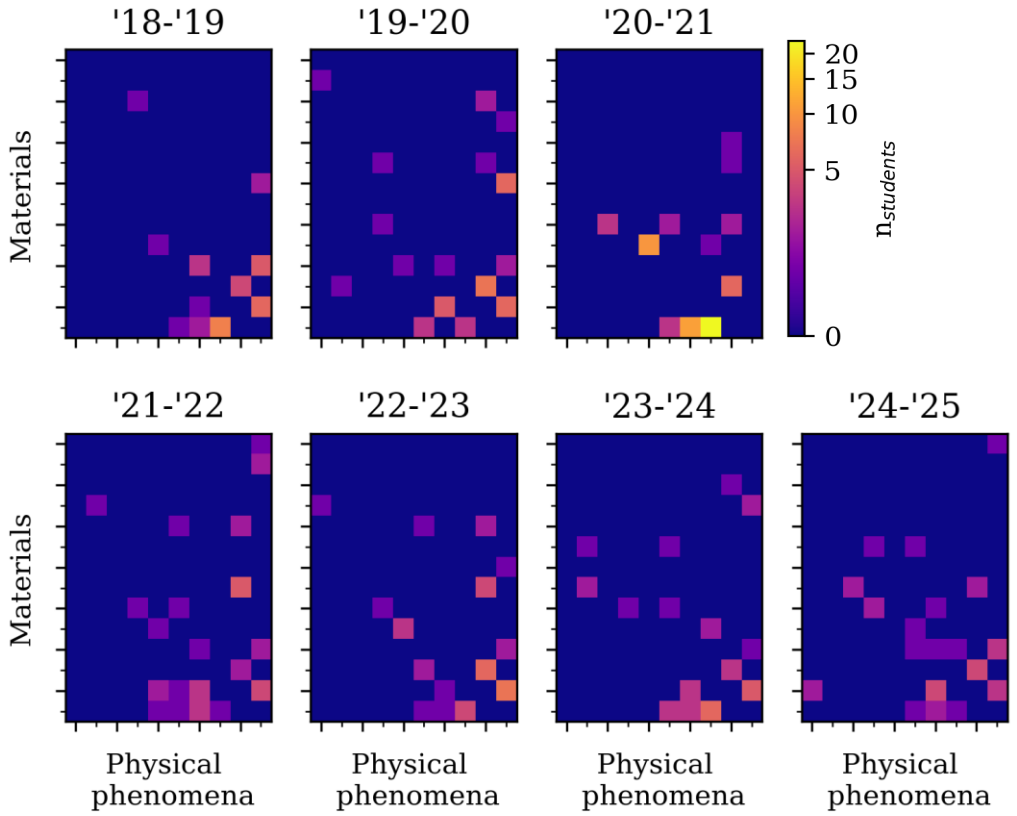
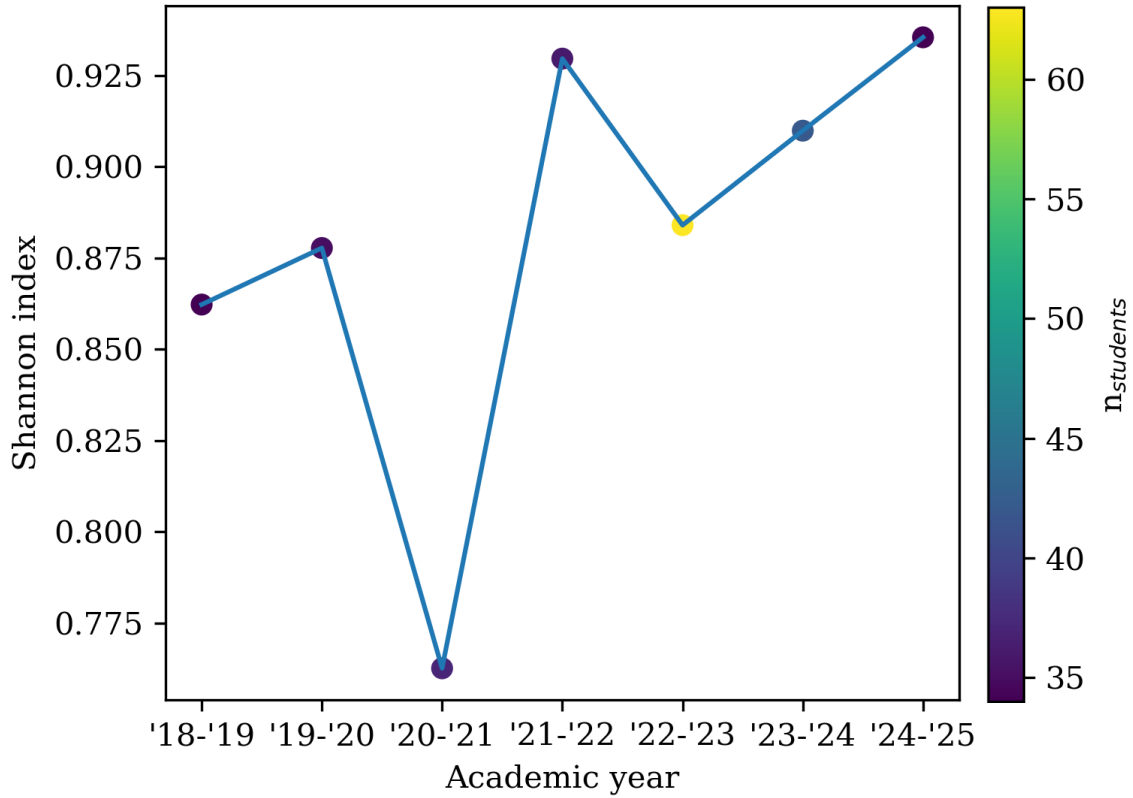




Quantification methods: Shortcomings

- **Cosine similarity**
- **Shannon index**
- Probability calculation

Results for different $n_{students}$ do not match with intuition

1	0	0
0	1	0
0	0	1

Cosine similarity = 1.10
Shannon index = 0.58

2	0	0
0	2	0
0	0	2

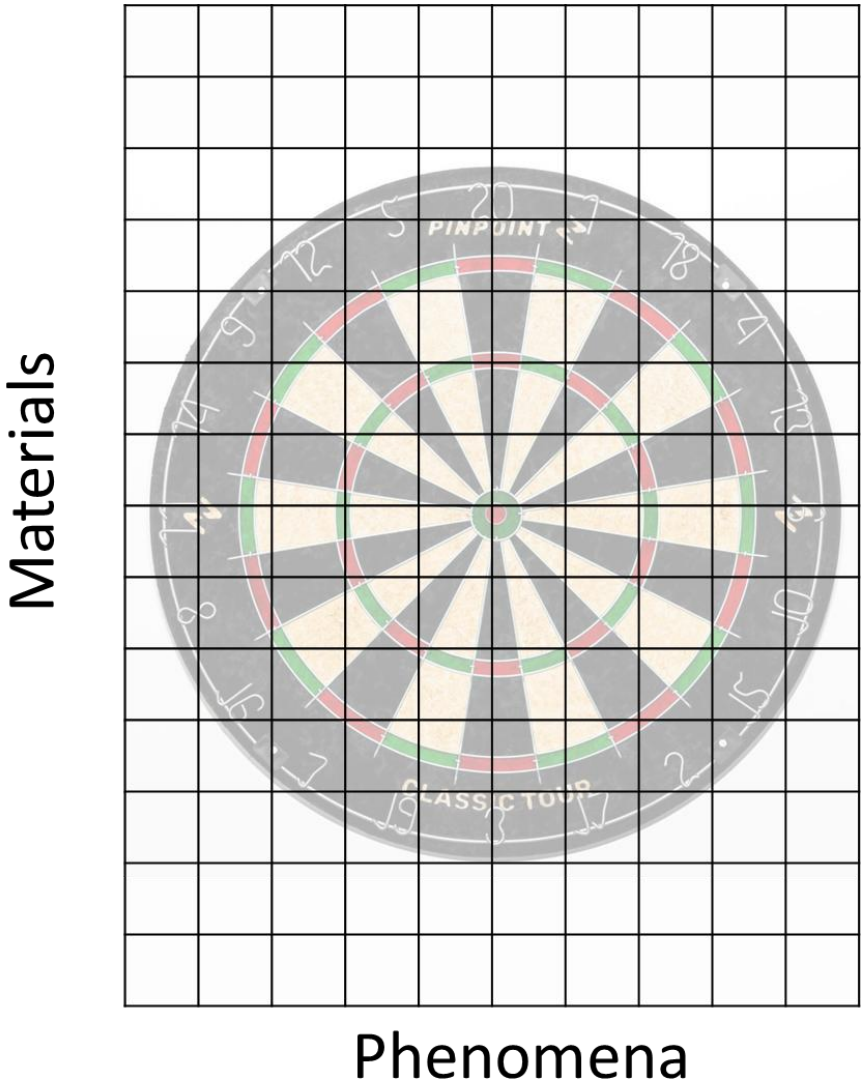
Cosine similarity = 1.10
Shannon index = 0.58

Quantification methods

- ~~Cosine similarity~~
- ~~Shannon index~~
- **Probability calculation**

Probability of a “collection of research ideas” randomly occuring for a group

- Independent (creative) heuristics → random distribution



Quantification methods

- ~~Cosine similarity~~
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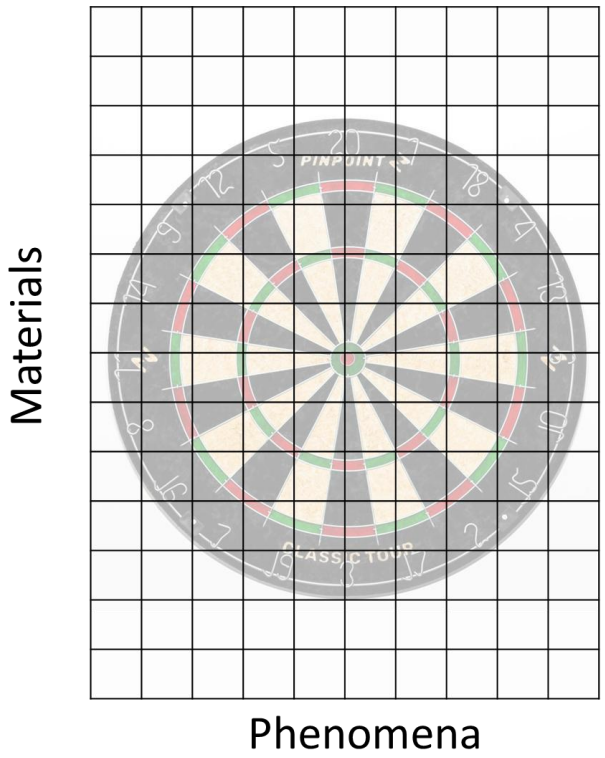
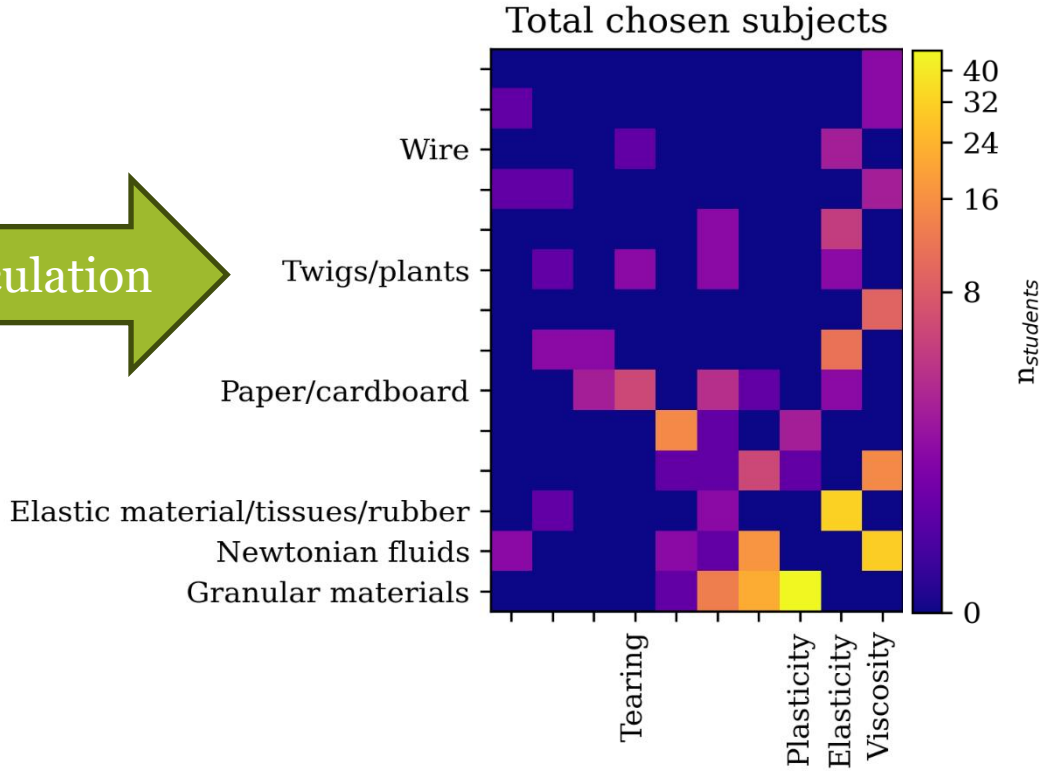
- **Probability calculation**



Probability calculation



Quantification methods

- ~~Cosine similarity~~
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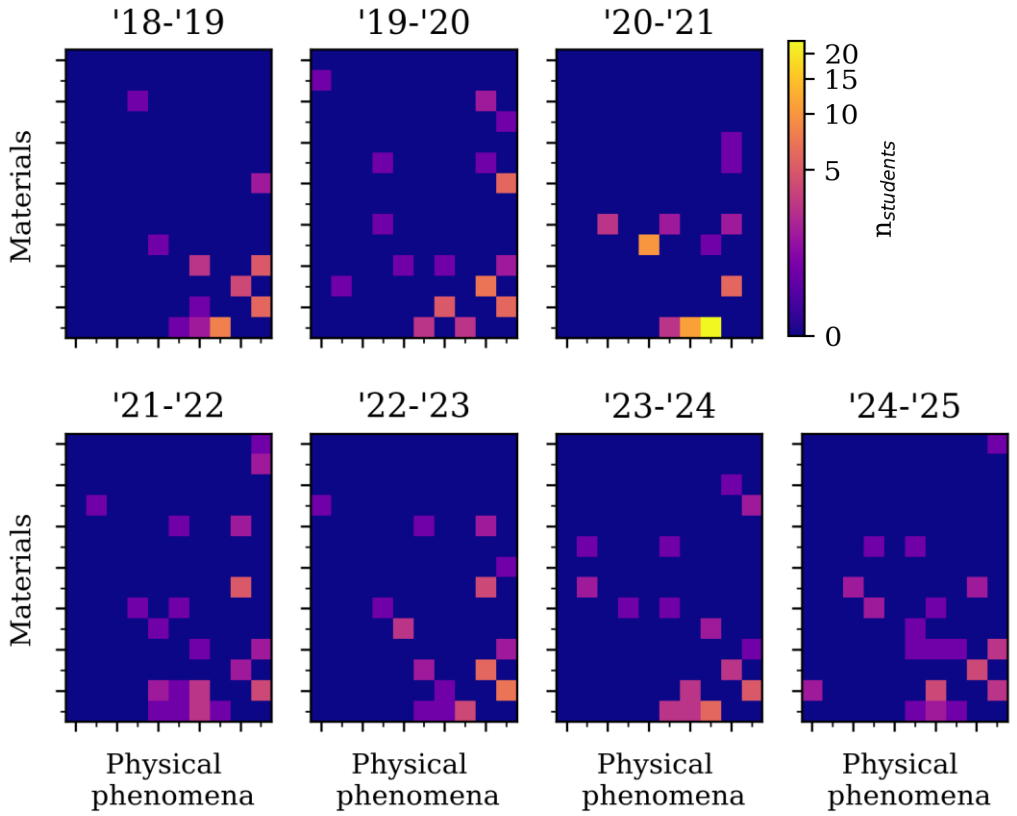

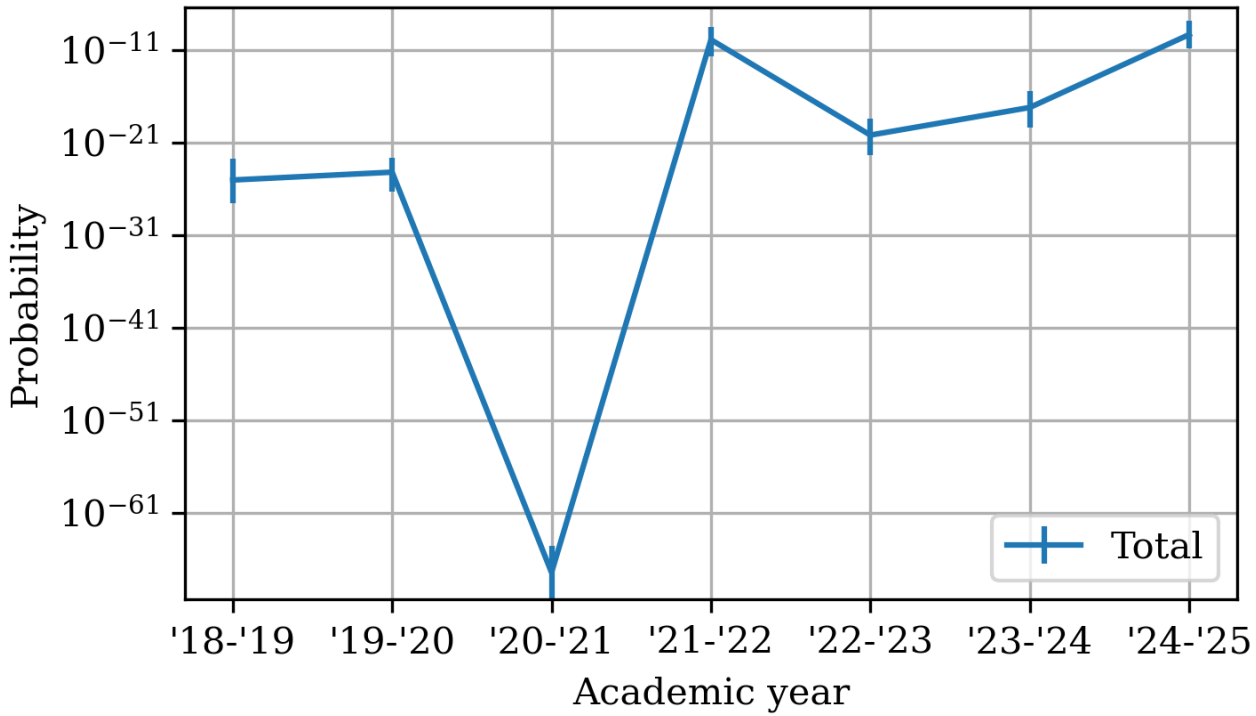

Quantification methods

- ~~Cosine similarity~~
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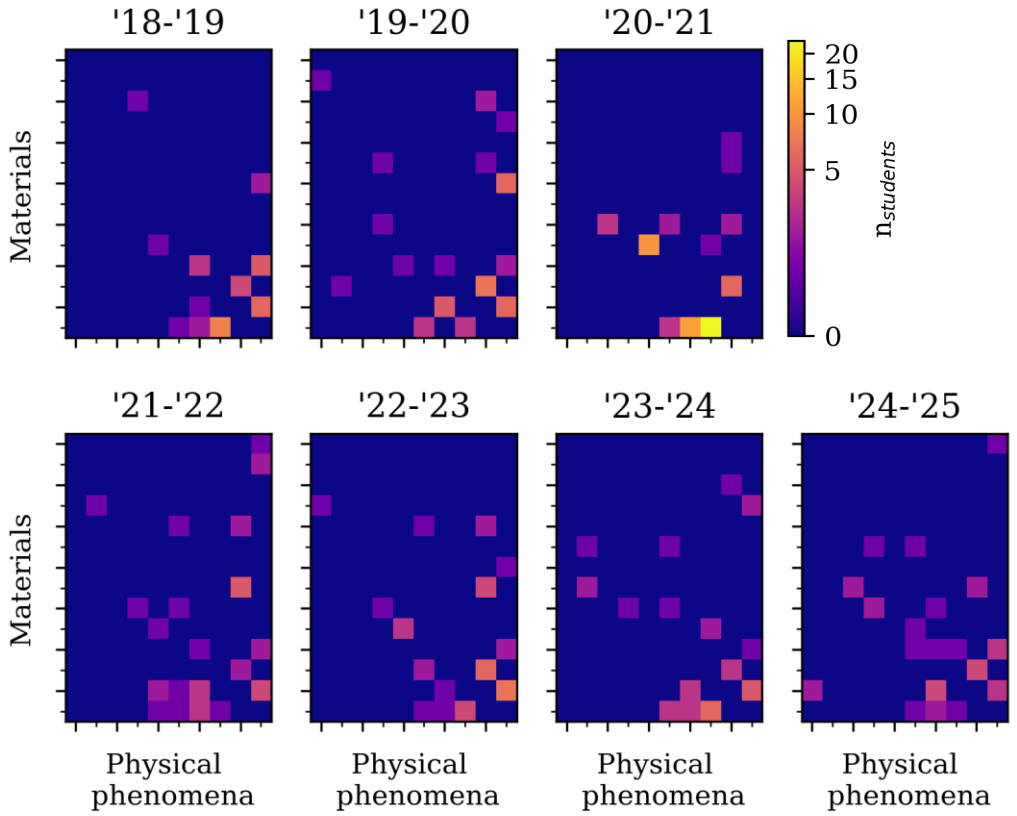
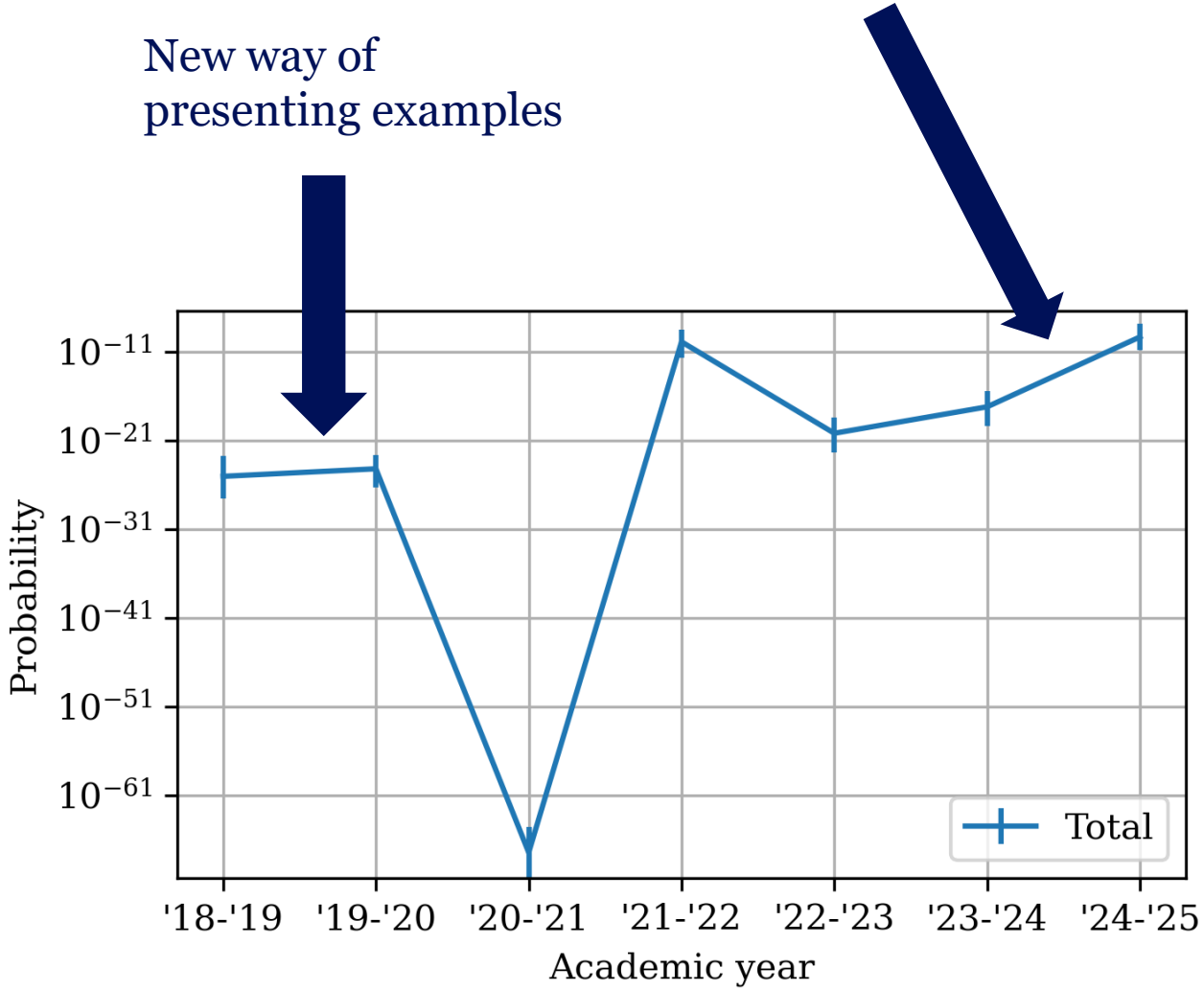


More personal guidance

New way of presenting examples



Quantification methods

- ~~Cosine similarity~~
- ~~Shannon index~~
- **Probability calculation**
  - Expected handling of different $n_{students}$

1	0	0
0	1	0
0	0	1

Probability = 0.69

2	0	0
0	2	0
0	0	2

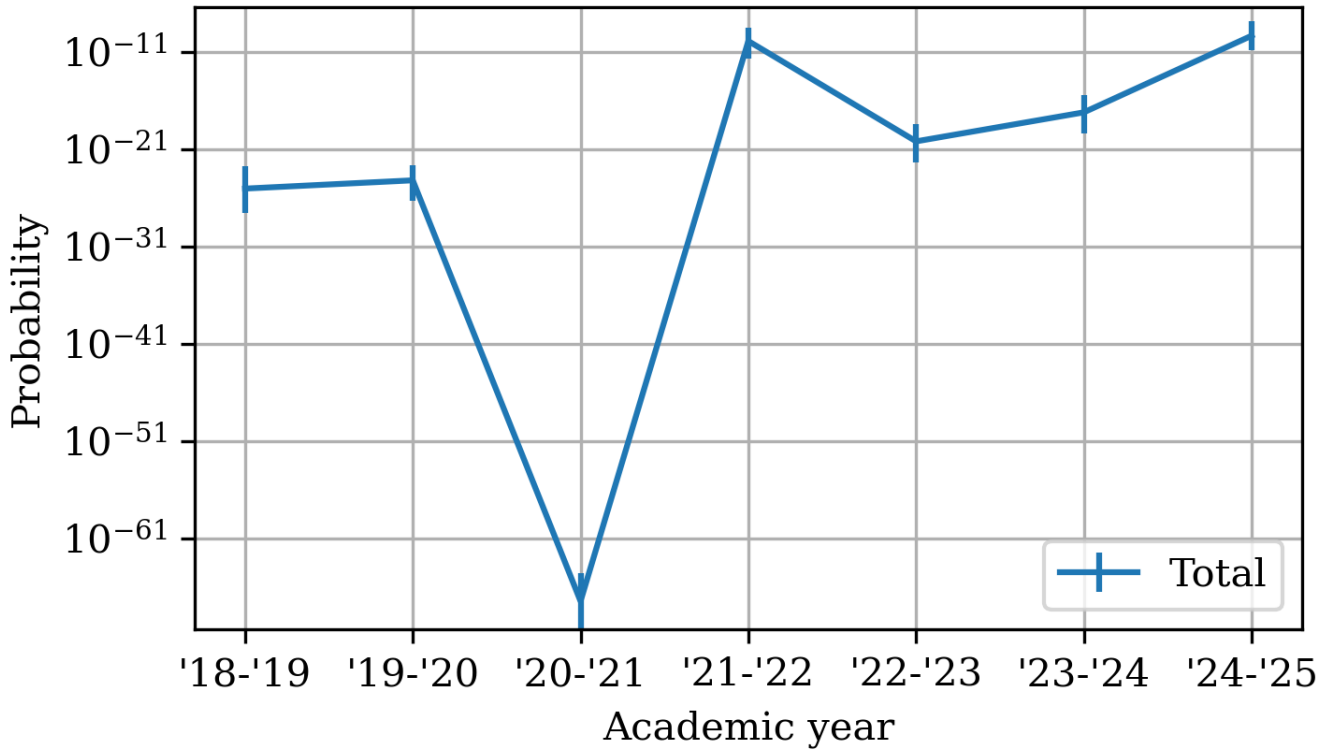
Probability = 0.01

Conclusion

- The **probability calculation** is a feasable method to measure **group creativity**
- Cannot be used for individual creativity.

Next steps:

- Track a student group's creativity **through time**
- Measure improvements in creativity!
- Matrix set-up allows us to look at phenomena and materials seperately.



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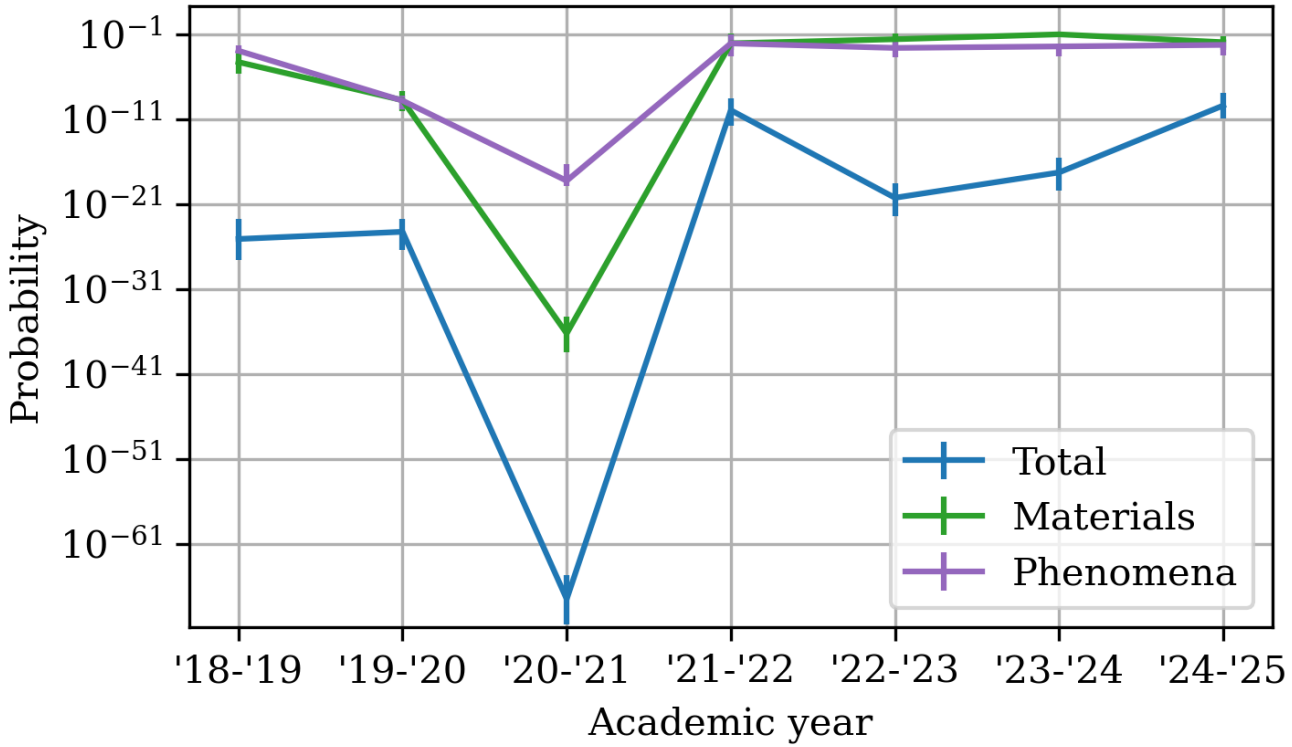
Materials and phenomena

- Sum along axis
- Probability calculation on summed array.

3	1	2
1	0	5
1	0	1

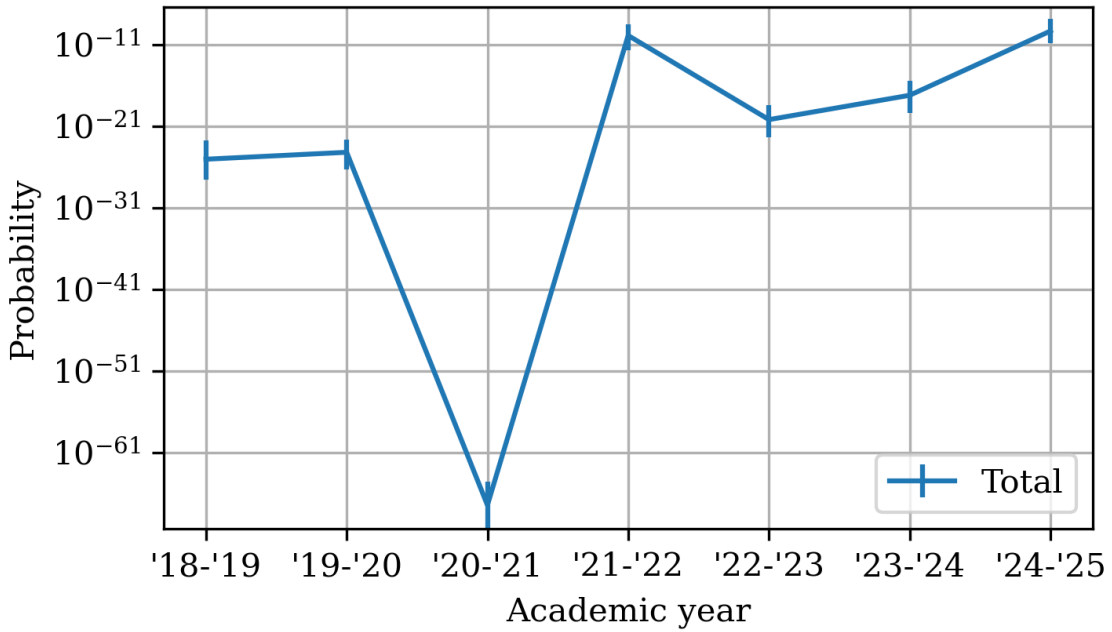
5	1	8

6
6
2



Probability calculation

- Compare “one step” more creative and “one step” less creative



Upper bound probability

3	1	2
1	1	4
1	0	1

Original matrix

3	1	2
1	0	5
1	0	1

Lower bound probability

3	0	2
1	0	6
1	0	1