

# Quantifying students' collective creativity in designing soft matter experiments

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**Abstract.** Creativity is an important higher order skill but it is hard to measure directly. Various methods to measure students' collective creativity are compared and discussed. These methods were applied to students' design proposals for an own choice experiment in soft matter. After comparison, the most promising quantification of collective creativity was a random probability calculation of the subject distribution. By being able to distinguish smaller changes in collective creativity between years, this new measure will be very helpful in improving future implementations of lab courses to stimulate creativity in students.

## Introduction & Theoretical framework

In soft matter physics, complex problems like creating microscopic explanations for macroscopically observed behaviour of materials, and designing materials on a microscopic level to deliver specific macroscopically desired properties are creatively solved [1]. To stimulate creative problem solving by prospective researchers we have to start by stimulating creative problem solving in students. We do so by giving students scientific agency to solve soft matter problems. Next, we need to be able to measure students' creativity. Once we can measure students' creativity, investigating learning pathways to improve that creativity becomes feasible. In this research we focus on ways to measure students' creativity.

Creative thinking is part of a long list of interconnected higher order thinking skills together with problem-solving, critical thinking, and more [2]. Stimulating creativity in students is important because it will produce innovative results, stimulate other higher order thinking skills, stimulate personal growth, and asking for creativity will more closely resemble students' future workplaces.

A natural place in which students can learn to develop creativity is in lab courses in which students are given agency to make their own choices. However, defining what is creative and what is not, and measuring it have so far proven difficult [3]. Measurements of a student's creativity are mostly done indirectly via questionnaires [3], for example making use of divergent thinking tasks and personality trait assessments.

Direct measurements of a student's creativity are much harder to do [3]. It is our belief that this problem stems from the fact that individual creativity can only be stated in comparison to other people's output. An individual can only be original if no one else has done the same thing before. We therefore focus on the concept of collective creativity [4] and on ways to quantify this. Our research question became the following: "What is a valid method to quantify the creativity in experimental design of a group of students in the context of open experiments?"

## Methods and findings

To promote student agency we ask our first year bachelor students to design their own experiment in soft matter. We guide the students' experimental design process by presenting them with an inspiration matrix, where various examples of soft matter related materials are

presented on the y-axis, and examples of experimental techniques are presented on the x-axis [1]. Based on their choice, the students then write a proposal for an experiment in soft matter.

To quantify the collective creativity of this group of students we sorted the subjects of the students' experiments into the inspiration matrix and represented their choices in a heat map (fig. 1a). These heat maps already allow us to qualitatively compare the collective creativity of a group of students, e.g. the decrease in creativity during the Covid-19 '20-'21 academic year is clearly visible. However, to track finer changes in students' creativity in response to changes in the course, a further quantification is necessary.

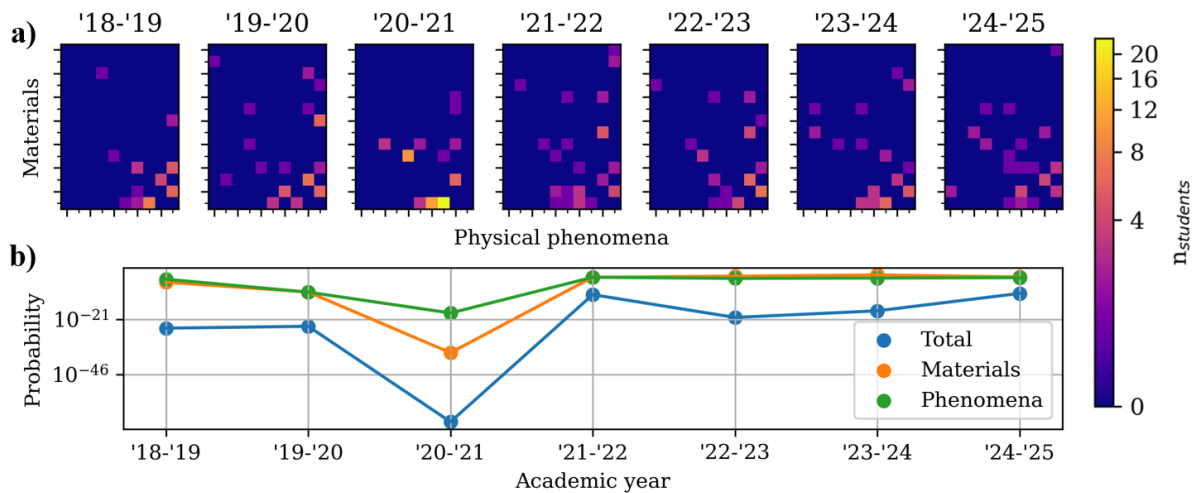


Fig. 1: a) Students' experimental subject choices since '18-'19. Note the visually observable decrease in creativity and the increase in sample size in '20-'21 due to Covid-19. b) Probability of each distribution (fig.1a) occurring randomly. A lower probability indicates low creativity in the student group. Note again the low creativity in '20-'21 and the now visible increase in creativity in '19-'20, '23-'24, and '24-'25.

To quantify collective creativity we considered the Shannon index [5], the cosine similarity [6], and a more straightforward probability calculation to come to an appropriate method. We reason that, if students creatively design their own experiments and they are not overly influenced by external sources, their subject choice should approach a random distribution. Thus, The straightforward probability calculation proved the most insightful option. This method allows us to distinguish smaller changes in collective creativity between years (fig.1b). We adopted similar ways to measure the creativity of the distribution of the students' choices in physical phenomena and in materials.

The observed positive trend in creativity matches a positive outcome of the adjustments that we have made to the course to increase creativity such as changing the way example experiments are presented in '19-'20 and more personal guidance in '24-'25.

## References

- [1] Barrat, J. L., et al. (2024). Soft matter roadmap. In *JPhys Materials* (Vol. 7, Issue 1). IOP.
- [2] Marzano, R. J., & Kendall, J. S. (2007). *The new taxonomy of educational objectives* (2nd ed.). Corwin Press.
- [3] Said-Metwaly, S., et al. (2017). Approaches to Measuring Creativity: A Systematic Literature Review. *Creativity. Theories – Research - Applications*, 4(2), 238–275.
- [4] Acar, O. A., et al. (2024). Collective Creativity and Innovation: An Interdisciplinary Review, Integration, and Research Agenda. In *Journal of Management* (Vol. 50, Issue 6, pp. 2119–2151). SAGE Publications Inc.
- [5] Krebs, C. J. (1989). *Ecological methodology*. Harper & Row.
- [6] Tan, P.-N., et al. (2014). *Introduction to Data Mining*. Pearson.