An introduction to TWG5: Probability and statistics education

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Introduction

The working group gathered 47 participants from 17 countries, with 30 papers and 7 posters. We promoted the famous three Cs of CERME Communication, Cooperation and Collaboration creating a collaborative atmosphere that would support the discussions and feedback over the following days. We started with an ice-breaker activity "Bingo" involving all the participants. In the first session, we explained the organization of the Sessions and introduced to subthemes identified as emerging across all submissions: "Teacher education", "Reasoning about data", "Statistical and Probabilistic Thinking and Reasoning" and "Data Science". For the remainder of the conference we were divided into two groups and sessions were organised by subthemes: TWG5a with Caterina Primi, Sibel Kazak and Orlando Rafael Gonzalez and TWG5b with Aisling Leavy, Martin Andre and Daniel Frischemeier. Guiding questions were prepared to support discussions on the subthemes. However, during the group discussions throughout the week, new Cross-Cutting Themes emerged. They were: "*Developing Research Networks*", "*Task Design*", "*Curriculum*", "*Context*", "*Assessment*" and "*Affect*". At the end of each session for each group, an online shared space, called Taskcards, was created to document the content and focus of the discussion. All the contributions we collected were valuable and contributed to a successful and substantial concluding discussion on the last day of CERME-13 when we summed up our insights gathered during the CERME-13 week. In the spirit of capturing evolving research foci as they emerge, on the last day we had a culminating session with all participants with the aim being to engage in an in-depth discussion on the new Cross-Cutting Themes.

Developing research networks

TWG5 participants remarked on the valuable professional development opportunity, especially for emergent researchers, that is provided by interactions within the group at the conference. They generated ideas about opportunities to build relationships and develop collaborations between CERME conferences. Such collaborations could centre on the cross-cutting themes identified across the week and support the evolution of emerging research foci. In conversation about themes for a topic conference that would be of interest to TWG5 and other TWGs, international contexts such as climate change and sustainability were identified. Such themes resonate with our crosscutting themes, e.g., task design, curriculum, context.

Task design

Another overarching topic was *task design*. Generally, in statistics and probability education there is lack of good tasks that (1) guide students through their learning processes and (2) reveal if students developed basic understandings of concepts. In our joint work, we could identify some important aspects to consider when creating tasks:

- Tasks should make students' thinking and reasoning processes visible. Initiating group discussions in small groups, cognitive activation through controversial and surprising topics, or hands-on activities to enable engagement and communication are approaches that foster students' participation in order to reveal their thoughts.
- The context of tasks is a key component for students' involvement in learning processes. On the one hand, actual, life-changing, and authentic topics based on real data can raise students' motivation. On the other hand, it is important to balance discussions on the context and the learning of mathematics.
- Tasks have a specific role for students and teachers in different learning paradigms. In an inquiry-based, open-ended learning setting, task can provoke students to ask questions and seek for their answers, while in more teacher-centred learning settings tasks can help to explore specific learning content. Existing categorisations of tasks in German literature that distinguish whether the starting point, the path and the goal are predefined in a task or not, could be helpful for the design of tasks with a specific purpose.
- Tasks should foster informal approaches for learning and provide opportunities for the learner to reveal informal strategies and misconceptions.

In summary, we identified an urgent need to deepen research around tasks for the learning and teaching of statistics and probability on two levels. First, there is a need for more concrete tasks to be used in the field between students' learning and evaluating their thinking processes. Second, especially around learning and teaching probability and statistics, there is a need for deeper insights into general principles of task design to guide students through their learning processes and make their thinking visible.

Curriculum

In our group discussion, we identified three fundamental issues that have to be taken into account when thinking about a kind of *common curriculum*:

(a) Different educational levels: At the primary school level students should learn to collect and organize data, create data visualizations, and develop a curiosity for understanding the world through data. In addition to that they should have first experiences with the concept of probability (subjective or/and frequentist approach). At secondary school, the curriculum should evolve to include more complex statistical visualizations and concepts and students should learn about probability (theoretical approach), inferential statistics, and how to critically analyze data. Pre- and in-service teacher education programs should not only educate prospective teachers with the subject matter knowledge but also educate them in pedagogical approaches and how to use digital resources in the classroom to develop statistical thinking (for example technological pedagogical statistical knowledge).

(b) Practical challenges for implementing curricula: While the idea of a common European or "CERME" curriculum for statistics education might sound romantic, practical challenges have been raised in our group. On the one hand some countries or districts may lack permanent access to technology, which can impact the delivery of statistics education using digital resources. Therefore, curricula must be adaptable to varying technology infrastructures. On the other hand, it is evident that different countries have different school systems with sometimes unique curricular demands – therefore a *common curriculum* may seem unrealistic.

(c) Finding common ground on the content of the curricula: As we consider statistics education across different countries, it is important to identify common ground on the content and the specific learning goals. Regardless of national constraints and diverse school systems, there are several key ideas that we identified that should be considered in statistics curricula (and its realization in classrooms). Similar considerations must be made for curricula on probability:

- Emphasis on inquiry-based data exploration, embedding data exploration in a data analysis cycle
- Focus on concepts rather than procedures
- Use of real contexts and meaningful data
- Implementation of digital resources to enhance statistical thinking
- Connection of data and chance

An exemplary analysis (exploring similarities and differences, and garnering insights into international practices) of curricula for statistics at the primary school level and the comparison of the status quo of early statistical teaching and learning across different selected countries (Ireland, Cyprus, Turkey, and Germany).

Context

There is a body of literature focusing on the role of context in both statistical and probabilistic thinking. In our TWG discussions based on the papers presented, the task context appeared to be an influential factor in learning experiences in statistics and probability. On the one hand, meaningful contexts for the learners can provide motivation for engagement and help the development of informal strategies in statistical and probabilistic thinking. On the other hand, the task context can hinder learners' approaches to solving a statistical/probabilistic problem. The group discussion also referred to how context is used differently in statistics compared to mathematics. Mathematics teachers need to be aware of such a distinction and understand the different aspects of context in learning of statistics and probability.

Assessment

TWG05 participants identified four issues in relation to current *assessment* practices in statistics and probability:

- It is answer-focused, not considering process.
- Assessment frameworks do not integrate important aspects of statistical literacy (e.g., criticizing arguments made by others).

- There is not a clear transition between existing frameworks and what happens in the classroom.
- It is examination-driven.

We concluded that "considering the process" will be a fundamental step toward a better and more comprehensive *assessment* in statistics and probability. In doing so, many *assessment* indicators should be considered while assessing learners' answers:

- Categories or parameters of complexity, fluency, originality, and "out of the box" thinking should be established by the assessor.
- Categories or parameters of quality should be established by the assessor, so the quality of the claims, evidence, or arguments can be properly assessed.
- Context consideration (e.g., an answer being right in some way and wrong in another) should be made.
- Limitations of the answer should be considered.
- Consequences or implications of the answer should be considered.
- Ecological validity should be considered.
- The number of statistical and probabilistic "fundamental ideas" should be considered and how they were addressed and considered in generating the answer.
- Affective aspects of how students engaged in the activity (e.g., classroom practice) or produced the answer (e.g., in which ways?) should be considered, as they could be indicators of the level of satisfaction of learners with their own answer.

Setting and establishing statistical norms in the classroom should be also considered, in order to assess the "quality of the statistics classroom" (e.g., in the sense of the Teaching for Robust Understanding [TRU] framework).

Affect

Although we have some research in mathematics-related affect, statistics-related affect is not regarded to the same extent. However, affect is important in statistical education research since knowledge, thinking and acting in statistical situations are all influenced by people's affective worlds. Moreover, new topics appear, such as data science, that make it reasonable to consider statistics-related affect. In particularly, risk becomes a more and more prominent topic, including as a part of people's awareness about risk and other affective variables. From a research perspective, affective variables require consideration, for example cognitive variables (such as beliefs), motivational variables (such as interest), emotional variables (such as attitudes) and personality variables (such as need for cognition). Additionally, differences in individual affective worlds must be considered, such differences are dependent upon factors such as context, domains (economics, biology, ...) and culture/cultural values. An optimal way to investigate affect in statistical education could be using mixed methods research approaches. Indeed, some research questions could be better answered qualitatively and some could be better answered quantitatively.