Guest Editors' Introduction

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In recent years, much discussion has been devoted to the relations between cognition and mathematical practice, thanks to the work of cognitive scientists, philosophers and historians of mathematics dedicated to this topic. Initially, the investigation focused in particular on the question which 'core' cognitive systems might ground several mathematical notions and results —especially the number concept. More recently it has moved towards discussion of mathematics as a product of embodied cognition, evaluating the role of conceptual metaphors, bodily experience, and external representations in mathematical practice and mathematical understanding.

Some of these proposals claim that mathematics is a unique type of human conceptual system, sustained by specific neural activity and bodily functions, and brought forth via the recruitment of everyday cognitive mechanisms that make human imagination, abstraction, and semiotic processes (work on notations) possible. The question of the nature of mathematics has been addressed as an empirical issue subject to methodological investigations of an interdisciplinary nature, involving hypothesis testing.

At the same time, however, such claims have been received with skepticism, be it that they are considered premature or because their actual links with mathematical knowledge, properly speaking, are found wanting.

This Special Issue addresses the question, what brings us humans from basic cognition to the practice of mathematics, gathering together scholars from different disciplines with the aim to develop common points of view. The focus is, primarily, on what separates mathematics properly speaking from basic cognition, and which cognitive ingredients may act as bridges between both. The idea of the Issue came out of the Workshop "From basic cognition to mathematical practice" (https://gecomat12.wordpress.com/) that took place at the Institute of Mathematics of the Universidad de Sevilla (IMUS) in September 2016. However we are not publishing the proceedings of the workshop. The editors have selected some of the most interesting talks and asked their authors to further elaborate on the ideas presented then.

The result, as the reader will find below, is a varied approach to several questions on mathematical practice, mathematical cognition, and specific issues in mathematics. The approach is obviously multidisciplinary, featuring elements from cognitive science, history, philosophy, semiotics, or even archaeology. The topics discussed include cognition of

number, proto-arithmetic, geometric cognition and proto-geometry, but also the concept of infinity, cognition of time, dynamic elements in mathematical concepts, and quite importantly the cognitive role and functioning of semiotic tools. All authors seem to agree on some version of embodied cognition, yet there are big differences as to specific characteristics of the cognitive approach adopted or supported.

Three of the papers bear relations with the cognitive theory of conceptual metaphors, put forward by Lakoff and applied to mathematics jointly with Núñez. Rafael Núñez reflects on the kind of cognition that makes mathematical practice possible. From a multidisciplinary approach which includes linguistics, ethnography, and of course mathematics, he analyses cognitive mechanisms which seem fundamental in the practice of abstracting and imagining. The notion of conceptual metaphor is combined with gesture studies in order to apply it to specific issues such as motion-based representations in mathematics or the conception of time. The second text, by Markus Pantsar, considers numerical cognition in the light of a newly proposed basic metaphor, the Process → Object Metaphor, trying to overcome some gaps between experimental research on numerical cognition and arithmetic properly. Roy Wagner proposes a refreshing view in favor of fallibilism in mathematics. Confronting two different cognitive stories (as he refers to them), he considers the image of mathematics emerging from them by contrast with conservative or absolutist views about mathematics.

José Ferreirós and Manuel García-Pérez question recent cognitive approaches, especially by Spelke and collaborators, who identify what they call 'natural geometry' with Euclidean geometry, presenting this as 'the' universal geometry. They consider several experimental results in cognitive science, together with data from comparative history of science in different cultures and archeological records, in order to discuss the role of material culture in the development of geometry. They present so-called 'basic geometry' as significantly different from the Euclidean theoretical framework.

Starting with a semiotic approach to embodied mathematics, Valeria Giardino reflects on the role of notation, formulas or diagrams, as cognitive tools for mathematical practice. She explores a particular theoretical framework to situate the role of these tools: Kendal Walton's theory of representation as games of make-believe combined with the notion of affordance introduced by James Gibson. Finally, Sorin Costreie presents an original combination of Frege's late conception of arithmetic as geometrically based with Stanislas Dehaene's cognitive intuitionism (the "number sense" in its relation with spatial representations), arguing for their compatibility.

It is our belief that all of these papers introduce relevant contributions to important questions about the specificity of mathematical knowledge and its production, cognitive ingredients that mediate between basic cognition and intellectual practices, how innovation becomes possible in mathematics, etc. As editors, we would like to thank the authors and the referees for their good work, and the journal *Theoria* for the availability to publish the issue. Special thanks go to María José García-Encinas for her help and patience in the editorial process.

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