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Introduction to the papers of TWG07: Mathematical potential, creativity and talent

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This was the third CERME at which Thematic Working Group (TWG) “Mathematical potential, creativity and talent” took place. One of the central goals of this TWG was to raise attention of the mathematics education community to the field of mathematical potential, creativity and talent, and to promote empirical and theoretical research that will contribute to the development of our understanding in the field. In 2011, 25 participants from 14 countries discussed 15 contributions. This time (2015), 35 participants took part in the TWG discussions about 24 contributions by researchers and practitioners from 15 countries from different parts of the world. The TWG facilitated communication between educational researchers, mathematics educators and research mathematicians focusing on the nature and nurture of mathematical creativity in all students and high mathematical ability in particular individuals.

Following the debates at TWG07 at CERME7 and CERME8, we continued an international exchange of ideas related to the research into the identification of mathematical talent, the didactics of teaching highly able students as well as the promotion of creativity in all students.

Four main topics framed the TWG discussion: Topic 1: Creativity – definitions, identification, development; Topic 2: Mathematical tasks for different levels of abilities and expertise; Topic 3: High mathematical abilities: Characteristics and components; Topic 4: Teacher preparation: teaching for creativity, teaching the gifted. In order to disseminate the ideas of different participants, each session started with small group work followed by a whole group discussion. Thus, the TWG concentrated on the exchange of the ideas rather than on individual presentations.

Topic 1: Creativity – definitions, identification, development

During two sessions devoted to Topic 1, the discussion focused on the relationship between general creativity and mathematical creativity following the study of Kattou, Christou and Pitta-Pantazi. The researchers demonstrated that mathematical creativity exists as a distinct type of creativity and concluded that no predictions can be made on general creativity based on mathematical creativity and vice versa. Bronislaw Czarnocha suggested that “bisociation and simultaneity of attention” could serve a useful theoretical framework (based on Arthur Koestler’s ideas expressed in his monograph “Act of creation”) for the analysis of creativity and argued that mental flexibility is not related at all to creative processing. In contrast to this study, Rott analysed heuristics and mental flexibility in the problem solving processes of regular and gifted fifth and sixth graders. The study of Desli and Zioga directed the attention of the group’s participants to the creativity embedded in primary school mathematical tasks which are useful for educating teachers in the management of creativity in their classes. The authors argued that prospective teachers mostly connect mathematical creativity to arousing student interest whereas in-service teachers connect it to book-oriented problem posing indicating their narrow and blurred perceptions.

While Winkler and Brandl suggested process-based analysis of mathematically gifted pupils in a regular class at the primary school level, Karakok, Savic, Tang and El Turkey suggested a model for the analysis of mathematicians’ views on undergraduate students’ creativity that addresses flexibility as one of the central characteristics of creativity. They suggested the following rubric for mathematical creativity: Creative

thinking, risk-taking, innovating thinking, connecting and transforming, originality and aesthetics of the solutions. Based on the work of Monstad, participants discussed mathematical practices involved in mathematical creativity. Émin, Essonnier, Filho, Mercat and Trgalova analysed didactical contract negotiation and technology assigned to creativity. They suggested additional ways of fostering mathematical creativity through the implementation of electronic books.

Obviously the studies varied in their definitions of creativity, research methodologies, target populations and the ways in which creativity was evaluated and the proportion between cognitive and social characteristics addressed. No agreement among the researchers was achieved on the definitions of creativity and the relationships between creativity and ability grouping. This variety of views stressed the importance of further research in the field.

Topic 2: Mathematical tasks for different levels of abilities and expertise

Task design and use is a core issue in research in mathematics education. In the context of the TWG “Mathematical potential, creativity and talent” the design of mathematical tasks for the identification and development of mathematical potential and creativity attracted the attention of all participants. Leikin and Elgrably analysed integrative investigation geometry tasks as a tool for the development and evaluation of creativity for pre-service mathematics teachers. They argue that problem solving expertise influences mental flexibility which is reflected in the richness of discovered properties as well as investigation strategies. Pitta-Pantazi, Christou, Kattou, Sophocleous and Pittalis suggest a system of mathematical competences for the evaluation of the mathematical challenge embedded in the mathematical tasks: Digital, social, communication in mother tongue, learning to learn and sense of initiative. Study participants found “digital competence” and “learning to learn the most difficult aspects to incorporate in their mathematical tasks”. Palha, Schuitema, van Boxtel and Peetsma discussed the effect of high versus low guidance structured tasks on mathematical creativity. The study extended the previous research on mathematical creativity by accounting for the relationship between the learning environment and creativity and by providing a way to operationalize fluency and flexibility in conceptual mathematical terms. Safuanov, Atanasyan and Ovsyannikova argued that open-ended exploratory

learning in the mathematics classroom is an effective tool for the development of knowledge and creativity, while Schindler and Joklitschke suggested criteria for designing tasks according to students’ capabilities with special attention to mathematically talented students. Singer, Pelczer and Voica explored behaviours of 10 to 16 year old high achievers during a problem modification process. The researchers studied the relationship between students’ creative approaches and the quality of the mathematics problems they generated, and concluded that these children either show low amplitude driven creativity, or, when they try to be more creative, they fail to pose consistent problems that make use of deep structures of mathematical concepts and strategies. Mellroth presented the Kangaroo Mathematical Competition as a very effective tool for the popularisation of mathematics among students with a wide range of mathematical abilities. In turn, Bureš and Nováková explored developing students’ culture of problem solving via heuristic solving strategies. The participants discussed the construct of heuristic strategies.

Mathematical investigations, challenging problem solving and problem posing were the most common tasks considered by the TWG07 participants. The tasks were considered in different contexts: Development of creativity in students and teachers, assessing creativity, and teacher education. The participants raised the following questions for further investigation: What is done in teacher education internationally in order to assist prospective teachers to develop creativity? What are textbooks doing to develop creativity in different countries? Can “problems from the scientific studies” be used in regular classes?

Topic 3: High mathematical abilities: Characteristics and components

High abilities in mathematics is an ill-defined concept. There was no agreement between the group participants on who are the students with high ability in mathematics. Baruch-Paz, Leikin and Leikin analysed cognitive characteristics (with a focus on Speed of Information Processing) among students with superior mathematical performance. This research involved 190 students from four groups of 16–18 years old participants varying in levels of general giftedness and excellence in mathematics. The researchers demonstrated that the differences between the groups are task dependent; that is, between-group differences vary among different cognitive skills. They argued

that excellence in school mathematics differs from mathematical giftedness. In contrast to the previous study that focused on the basic cognitive traits as related to mathematical abilities, Benölken's study explored emotional factors, namely, he investigated the impact of interest in Mathematics on the identification of girls' mathematical talent. In this study, the impact of mathematical interest and attitudes were used in order to identify girls' mathematical talent. Boys showed a stronger interest in mathematics compared to girls among those who were not identified as mathematically talented. Motivational factors were shown to be critical for the identification of mathematical talent.

Nordheimer and Brandl presented challenges facing the identification of mathematical giftedness in students with hearing impairment. The researchers claimed that for teachers, it is vital to recognise their pupils' diverging abilities effectively in order to meet their respective learning requirements. They compared empirically the possibilities of identifying mathematical giftedness of 3rd/4th graders by combining written tests and by process-based analyses of lessons. Szabo examined the interaction of mathematical abilities and the role of mathematical memory in students with high achievements in mathematics. The study demonstrated that mathematical memory has a critical role in the choice of problem-solving methods. The study showed that if the initially selected methods do not lead to the desired outcome, the students find it very difficult to modify them. The study confirms some qualitative differences in problem solving between high-achievers who are not essentially mathematically gifted and mathematically gifted students. However, the inflexibility of the participants could also be explained by two main functions of the cerebral cortex, where working memory operates. Winkler and Brandl argued that with heterogeneity at schools growing, individualisation of education has become more important than ever. For teachers, it is vital to recognise their pupils' diverging abilities effectively in order to meet the pupils' respective learning requirements. The researchers presented a project aiming at showing ways to identify and characterise mathematically gifted pupils during regular lessons.

An interesting discussion developed during this session. Just as at the first two sessions devoted to the studying nature and nurture of mathematical creativity, the researchers did not agree on who the mathemati-

cally gifted are, or what are the indicators of high mathematical abilities. Moreover, one of the participants in the group argued that "such a thing as giftedness does not exist". After the discussion, it was clear that more attention should be paid, through systematic research to the following questions: Can giftedness be developed or is it an innate trait? How can mathematical giftedness be determined? Are school achievements predictors of mathematical giftedness? Is mathematical creativity a part of mathematical giftedness?

Topic 4: Teacher preparation: Teaching for creativity, teaching the gifted

It is clear to every mathematics educator that teachers' expertise, knowledge and skills determine the quality of mathematics teaching. This is equally true when teaching the gifted or when goals of teaching mathematics include the development of creativity in all students. Karp and Busev devoted their study to people who taught highly gifted schoolchildren and developed educational materials for them. They claimed that teaching the highly gifted requires the teachers' creativity the development of which can be provoked and supported by the social environment. To exemplify their ideas, researchers discussed two prominent Russian figures in the advanced course of mathematics. In contrast, Birkeland analysed mathematical reasoning of pre-service teachers through the distinction between imitative and creative reasoning. This study reveals variety of the types of students' mathematical reasoning and indicates that if their reasoning is not imitative it is perhaps not creative either. Safuanov's work is devoted to different ways of teaching students in pedagogical universities to solve various types of non-routine mathematical problems, while Sinitsky's work aimed to highlight the different aspects of promoting creativity from the point of view of an educator involved in the professional development of pre-service teachers. Challenging the prospective teachers with open-ended mathematical problems provided data on their beliefs and behaviour concerning creativity and creativity encouragement in the classroom.

Overall, participants agreed that the development of teachers' understanding of the special characteristics of gifted students is essential for teaching the gifted, and that the development of teachers' creativity in mathematics teaching is essential for the development of teachers' overall creativity.