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Typical and Atypical Mathematics Learning: What Do We Learn From Recent Studies?

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Abstract

Poor mathematical abilities have a substantial societal impact. This special issue includes contributions discussing learning of mathematics that have impact on educational policy or elementary school practice. All papers explore and illustrate recent studies and available literature in the field of understanding typical and atypical mathematics learning. They reflect on mechanisms of conceptual development, models of typical and atypical learning, individual quantitative and qualitative differences, strengths and weaknesses, factors that appear promising and positively influencing the learning process of students' learning of mathematics, and on interventions that aim to improve mathematics performance even in very young children.

Keywords:

Mathematics, Models, Differences, Interventions

Introduction

Mathematical abilities are needed in all kinds of everyday situations (e.g., understanding corona virus statistics, calculating prices, estimating amounts and many more). Although mathematical abilities seem to be learned quite effortlessly in most people, some children have persisting problems with acquiring and/or applying these abilities. This is problematic because mathematical ability is an important predictor of later academic achievement, and since poor mathematical skills may lead to decreased perceived competence and increased emotional and behavioral disengagement. In addition, poor mathematical abilities often result in gaining employment in low paid professions during adulthood and have negative consequences for mental health (Ritchie & Bates, 2013). Mathematical disabilities thus have a substantial societal impact.

Up till now research in relation to typical and atypical mathematics learning and to individuals with mathematical learning disabilities remains an underrepresented area of research. As a result of the limited studies, it remains unclear if and on which components of mathematical ability individuals show strengths or difficulties, what predicts typical and atypical achievement and how mathematical

underachievement can be detected, screened, understood, and addressed.

This special issue brings together studies and reviews about mathematical abilities that may have an impact on educational policy and/or educational school practice. In this way the issue aims to gain knowledge about the development of mathematical abilities and to map the typical and atypical development of mathematics learning. This may advance the understanding of the human abilities to perceive, represent, learn, and manipulate mathematical information.

The various contributions in this special issue

First, papers explored models of typical and atypical learning. Allen and Dowker (2022) studied the relationships between visuo-spatial working memory and different types of arithmetic in 39 children in Year 2 (6 to 7 years) and Year 4 (8 to 9 years). In addition Desoete and Baten (2022) studied the prediction of propensity (intelligence, motivation and subjective wellbeing), opportunity (years of experience of teachers and the number of hours of mathematical instruction children receive) and antecedent (gender, parental aspirations, birth order and birth weight) factors to predict mathematics in 408 children from grade 4 or 5 using the Opportunity Propensity framework (Byrnes, 2020) to prevent overestimation of the importance and unique explained variance of predicting factors. Finally, Kroesbergen (2022) proposed a multidimensional framework in which children should be regarded as individuals with unique profiles of strengths and weaknesses.

Second, papers explored mathematics learning in different age groups. Olkun (2022) reviewed studies on learning numbers with the framework of "number sense". Hartmann (2022) assessed the counting skills of 107 preschoolers (mean age 57.61 months) to focus on the conceptual understanding of "zero" as number word for an empty set emerges. Şenol (2022) examined 132 children aged 60–72 months with normal development who attend preschool education on the relationship between the academic competencies and their social information processing processes. Finally van Dijck, Abrahamse, Kesteloot, Willems and Fias (2022) focused on 438 first year bachelor students in Psychology and observed that high levels of motivation could alleviate the negative impact of statistics anxiety on statistical performance, especially when controlling for general learning abilities.

Third, contributions focused on individual differences and on the assessment of children with and without mathematical learning disabilities or dyscalculia. Martin, Mraz, and Polly (2022) studied the perceptions of 65 teachers and their use of formative assessment in mathematics, as formative assessment can be seen as a high-leverage instructional practice that has potential to support all learners. Mononen, Niemivirta and Korhonen (2022) investigated in 206 participants numeracy, cognitive, and language skills in grade 1 and arithmetic fluency and curriculum-based mathematics in grade 3. Korkmaz and Temur (2022) used electrophysiological measures in a pilot study on third and fourth graders with learning difficulties in mathematics. Finally, Lewis (2022) described how the current assessment of dyscalculia resulted in an over-representation of students of color, non-native speakers, and students from low SES backgrounds. To address this problem, they set up two studies assessing 470 grade 6-8 students and three students who demonstrated high levels of unconventional understandings.

Finally, this special issue also included interventions focusing on mathematical ability. These contributions suggest some good practices focusing on mathematical ability (or subcomponents). Diago (2022) focused on the improvement of counting skills in 14 children without special needs aged between 3 years 5 months and 4 years 4 months using special designed tasks. Akıncı-Cosgun (2022) examined the effect of a training program for 21 children between 48–65-month-old on early mathematics ability and mother-child relationship at home. Urton, Grünke and Boon (2022) studied the effect of multisensory mathematics instruction integrating a touch points strategy, performance feedback, reward system, and a reinforcing game into an instructional package on the subtraction performance of 4 children at-risk for learning disabilities aged between 6 and 7 years. Lee and Hwang (2022) explored the solving of word problems, helping 7 students to recognize multiple relationships within the context of specific problems and real-world related applications. Korkmaz and Temur (2022) examined in 4 third and fourth graders with learning difficulties in mathematics if music support enhanced calculation skills. Herzog and Casale (2022) studied the effectivity of a computer-based mathematics intervention on 11 children with and without emotional and behavioral difficulties in grades 3 and 4, pointing to different effectiveness for children with and without such additional difficulties. Finally, Alqahtani and colleagues (2022) focused on an intervention on the representational models of fractions of 46 pre-service elementary teachers.

Some preliminary observations

The papers included in this special issue demonstrate that mathematical abilities depend on multiple factors such as domain-specific knowledge and skills (e.g., magnitude processing, counting, calculation understanding 'zero', models about fractions), domain-general cognitive skills (e.g., visuospatial working memory, intelligence, non-verbal reasoning, rapid naming) and non-cognitive factors (e.g., social

information processing, affect, motivation, math anxiety) that also interact with one another.

In addition, different cut-off scores (≤ 25th percentile, ≤ 10th percentile or between 11-25th percentile) and different mathematics measures (arithmetic fluency or curriculum-based measures) seem to lead to different early domain-specific (symbolic numerical magnitude processing, verbal counting) and domain-general (nonverbal reasoning, rapid automatized naming, working memory) predictors.

In young children Şenol (2022) revealed that academic skills (numeracy, early literacy, thinking skills, and comprehension) and achievement (social-emotional competence, approaches to learning, and communication) cannot be studied as isolated phenomena, since they are related to skills to understand cues and decide about responses as subdimensions of the social information processing model.

In elementary schoolchildren, Allen and Dowker (2022) revealed a relationship between visuo-spatial working memory and verbal oral and mental written arithmetic but not with derived fact strategy use. Desoet and Baten (2022) added that intelligence was a significant predictor for math fluency and calculation accuracy, whereas positive affect influenced math fluency negative affect predicted calculation accuracy.

In older participants van Dijck and colleagues (2022) observed that high levels of motivation could alleviate the negative impact of statistics anxiety on statistical performance, especially when controlling for general learning abilities.

Finally, Alqahtani (2022) described that how teachers interpret and express fractions also might critically influence their teaching and their students' fraction knowledge, pointing to the importance of teacher training programs.

When summarizing, there are some findings on the assessment of mathematical learning (dis)abilities. Korkmaz and Temur (2022) made us reflect on the value of electrophysiological measures to assess the effect of interventions. Martin and colleagues (2022) pointed to the value of formative assessment to identify gaps and strengths of the learner, but they also revealed barriers in elementary school teachers using formative assessment. Lewis (2022) pointed to the potential of designing screeners based on the characteristics identified in adults with dyscalculia and Kroesbergen (2022) proposed to look for unique profiles of strengths and weaknesses.

Finally, this special issue also provides recommendations for interventions. Diago (2022) showed how young children can learn to master the counting principles in 16 sessions of 20 minutes, although some of the principles remain more difficult than other principles. Akıncı-Cosgun (2022) revealed that children could learn to recognized numbers and shapes and to know the total number of objects displayed in the group, while parents described better relationships and quality time with their children and increased use of mathematics in daily life. Lee and Hwang (2022) described how the retrospective analysis of class episodes offered insight into learning opportunities to support students in exploring mathematical structure and relationships while discussing and debating the word problem context. Urton and colleagues (2022) revealed that their intervention was effective to very effective to enhance the ability of students to solve subtraction problems. Students' performance improved during the course of the intervention as they learned and practiced the touch points strategy. Alqahtani and colleagues (2022) revealed the value of a measuring perspective to support pre-service teachers to shift from procedural strategies such as symbolic manipulation to more conceptual strategies to identify and represent fractions. Although most of these intervention studies are based on a very limited number of participants, most of them see to have some positive outcome. However, not every intervention was equally successful. Herzog and Casale (2022) revealed that the effectiveness of mathematics interventions might not be generalizable for children with comorbid emotional and behavioral problems, stressing the need for additional studies to address typical and atypical mathematics learning with and without comorbid disorders.

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