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Capturing flexibility in mental calculation

Timo Flückiger¹ and Elisabeth Rathgeb-Schnierer²

¹University of Kassel, Germany; flueckiger@uni-kassel.de

²University of Kassel, Germany; rathgeb-schnierer@mathematik.uni-kassel.de

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Introduction

Flexibility in mental calculation is a central goal of elementary mathematics education and there was an increasing research interest in children's approaches and flexible strategies in the last two decades (e.g. Green & Rathgeb-Schnierer, 2020). Empirical findings show that primary students rarely solve problems flexibly and adaptively, especially after learning standard written algorithm (e.g. Selter, 2001). Accordingly, students are often not capable to refer to number patterns and relationships as well as specific problem features for solving one or multi-digit problems flexibly (ibid.). Research results suggest that students' creative and flexible use and combination of different strategic means (Rathgeb-Schnierer & Green, 2013) decrease after introducing respective strategies as a sample solution in the classroom (Benz, 2005). Thus, specific approaches for learning arithmetic seem to have a negative impact on students' abilities in flexible mental calculation. On the other hand, studies show that students' flexible mental calculation can be supported by appropriate instructional approaches (e.g. Rechtsteiner & Rathgeb-Schnierer, 2017). For the development of perceiving and using number patterns and relationships as well as flexible mental calculation Schütte emphasizes the importance of the approach "Zahlenblickschulung" (2004, p. 142; see also Rechtsteiner & Rathgeb-Schnierer, 2017). In general, teaching approaches have a crucial impact on students' abilities in flexible and adaptive arithmetic. Although flexibility in mental calculation is consensually considered a relevant ability, the concept is not consistently defined and operationalized in different studies. Rechtsteiner-Merz (2013) has analyzed the existing approaches. In this study, we refer to the approach which connects the notion of flexibility to cognitive elements that sustain the solution process (e.g. Rathgeb-Schnierer & Green, 2013). Cognitive elements are defined in the context of this study according to Rathgeb-Schnierer & Green "as specific mental actions that sustain a solution process [...]. These can be learned *procedures* (such as computing algorithms) or recognition of *number characteristics* (such as number patterns and relations)" (2019, p. 5, emphasis in original). In this vein, we define flexible mental calculation according to Rathgeb-Schnierer and Green: "Only if the tools of solution are linked in a dynamic way to problem characteristics, number patterns, and relationships would we consider as evidence of flexibility in mental calculation" (2013, p. 357).

Aim of the study

There are research projects that investigate flexibility in mental arithmetic with regard to the cognitive elements that sustain the solution process (e.g. Green & Rathgeb-Schnierer, 2020; Rechtsteiner & Rathgeb-Schnierer, 2017). However, conclusions about these cognitive elements cannot be drawn directly based on manifest characteristics, such as the obtained solution or the described methods of solution. Valid conclusions can only be derived from students' explanations and justifications. So far, no standardized instrument exists for capturing the cognitive elements objectively and reliably.

Furthermore, the existing instruments are not sufficiently validated. According to this, already published research results only allow limited generalizable conclusions. Our study pursues innovative approaches: It targets to develop and evaluate a standardized, semi-structured interview for second and third graders which allows capturing abilities in flexible mental calculation by revealing the cognitive elements that sustain the solution process. Therefore, we developed a semi-structured interview guideline regarding the quality criteria of objectivity, reliability, and validity. The interview contains activities of sorting problems (prompt: “Which problem is easy/hard for you?”), reasoning about sorting as well as comparing (prompt: “Which problem is easier for you?”) and solving problems (e.g. Rathgeb-Schnierer & Green, 2013; Rechtsteiner & Rathgeb-Schnierer, 2017). For evaluation, we will conduct and videotape approx. 100 interviews with students from the end of second grade and beginning of third grade. Additionally, we survey other constructs, such as arithmetic skills and linguistic abilities. We aim to enhance existing methods to capture flexibility in mental calculation by providing an interview instrument with a different perspective that allows to be applied to a large sample. This interview offers new options regarding quantitative and qualitative analyses as well as triangulation analysis. We completed the pilot run of the semi-structured interview guideline with eleven second graders. Some of the interviews were also conducted by an assistant to see how well the semi-structured guideline worked.

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