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Introduction and research interest

According to recent studies, high dropout rates in STEM subjects at university can be explained at least in part by a lack of basic knowledge and comprehension of secondary school mathematics (Blömeke, 2016), among which specific secondary arithmetic areas like fractions, and especially other areas such as powers or logarithms need to be subsumed. Therefore, many universities provide so-called "bridging courses" for students beginning a STEM subject at their institution. Sometimes, the tasks for diagnostic and supporting measures rely on theoretical frameworks outside mathematics (e.g. Bloom's taxonomy), sometimes the theoretical base is not made explicit but seems to follow expectations as expressed in local coursebooks.

Hence, for diagnosing basic knowledge and comprehension in secondary school arithmetic, a comprehensive yet concise overview of the important aspects of this area is needed. While there is extensive educational literature on the formation of basic arithmetic skills in elementary operations or fractions, we do not focus on the formative, but on a summative view on how students should master the various fields of secondary arithmetic at the transition from school to university. Thus, our research question is: *Which central aspects of knowledge and comprehension in secondary school arithmetic can be identified in relevant literature and how can these be summarized for diagnostic and supportive measures at university entry level?*

The methodological base is a systematic literature review (Durach, Kembro, & Wieland, 2017). Hereby, relevant didactic literature as well as formative literature about formation of concepts in secondary school arithmetic as mentioned above is considered. A qualitative content analysis of the literature found and subsequent clustering gives the aspects of the frame of reference.

Following Pinkernell, Düsi, & Vogel (2017) two a priori settings are given: *contents* (answering the question: Which are the basic elements of secondary school arithmetic?) and *understanding*. Understanding is subdivided into *knowing* in the sense of declarative knowledge (Anderson, 1996) and *acting*, broken down into *structuring* as a meaningful reading of area-specific expressions (Musgrave, Hatfield, & Thompson, 2015: substitutional equivalence), *transforming* as restructuring the area-specific expressions into equivalent forms (ibid: transformational equivalence) and *interpreting* as coherent change between different forms of representation or possible extra-mathematical contextualization of the same mathematical object (Duval, 2006).

A theoretical framework for analyzing and constructing tasks in secondary school arithmetic – a first draft

The outcome of this research takes on a tabular form, in which the various findings in literature have been clustered into nine aspects of knowledge and comprehension of secondary school arithmetic. Out of these we mention two here. As contents or basic elements of secondary school arithmetic *numbers and quantities* as well as *terms* arise in the frame of reference. Variables appear too, but are only used in the sense of the generalized number.

- *"to change within the same numerical representation"* – A numeric number or quantity is converted into another, equivalent numeric number or quantity.
- *"to switch between different forms of representation"* – A coherent change between numerical and other inner-mathematical forms of representation as well as verbal representations.

The model is still subject to further development. As it is planned for the German project optes+ (www.optes.de) it will – in its final stage – serve as both a reference for analyzing existing tasks and constructing new ones and a conceptual base for discussion about what is considered necessary for successful studies in STEM subjects at university entry level.

References

Anderson, J. R. (1996). *Kognitive Psychologie* (2nd ed.). Heidelberg: Spektrum Akad. Verl.

Blömeke, S. (2016). Der Übergang von der Schule in die Hochschule: Empirische Erkenntnisse zu mathematikbezogenen Studiengängen. In A. Hoppenbrock, R. Biehler, R. Hochmuth, & H.-G. Rück (Eds.), *Lehren und Lernen von Mathematik in der Studieneingangsphase: Herausforderungen und Lösungsansätze* (pp. 3–13). Wiesbaden: Springer Spektrum.

Durach, C., Kembro, J., & Wieland, A. (2017). A new paradigm for systematic literature reviews in supply chain management. *Journal of Supply Chain Management*, *53*(4), 67–85.

Duval, R. (2006). A Cognitive Analysis of Problems of Comprehension in a Learning of Mathematics. *Educational Studies in Mathematics*, *61*(1–2), 103–131.

Musgrave, S., Hatfield, N., & Thompson, P. (2015). Teachers' meanings for the substitution principle. In T. Fukawa-Connelly, N. Engelke Infante, K. Keene, & M. Zandieh (Eds.), *Proceedings of the 18th Meeting of the MAA Special Interest Group on Research in Undergraduate Mathematics Education* (pp. 801–808). Pittsburgh: Mathematical Association of America.

Pinkernell, G., Düsi, C., & Vogel, M. (2017). Aspects of proficiency in elementary algebra. In T. Dooley & G. Gueudet (Eds.), *Proceedings of the Tenth Congress of the European Mathematical Society for Research in Mathematics Education* (pp. 464–471). Dublin, DCU Institute of Education & ERME.