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Using tangible technology to multimodally support algebra learning: The MAL project

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Scope and objective of the presented project

Based on the assumption that activity (as opposed to the passive consumption of verbal instruction) supports learning, and accompanying the rise of learning theories that take into account the bodily grounding of the brain and its development, the usage of *manipulatives* – tangible learning materials – enjoys widespread trust among algebra teachers. Over the last two decades a variety of virtual adaptations of such manipulatives on personal computers and touch devices has been developed. The potential of such programs lies in the possibility to discover a range of configurations that would not be feasible in the real world, and to get automatic feedback about the correctness of the chosen manipulations. However, these qualities come at the price of abandoning the materiality of the manipulatives. The miniaturization of existing technologies and the creation of new input and output channels raise the question if and how manipulatives in mathematics education could be conceptualized as *smart objects* or *tangibles* – manipulatives that have the ability to interact with its users. Such objects have already been designed for learning purposes in other domains (Marshall, 2007). For the field of school algebra, the possibilities and challenges of their implementation is to be investigated in the MAL (*Multimodal Algebra Learning*) project, a collaboration between mathematics education and digital media researchers, experts in data collection and evaluation, and commercial enterprises. This contribution focuses on the didactical conceptualization that underlies the work of the consortium.

Theoretical framework

Many theoretical approaches assume bodily action to be beneficial or even defining for learning processes. Bruner's well-known model proposing the distinction between enactive, iconic and symbolic action offers a starting point. Following Nakahara (2008), a distinction can be made at the enactive level (between hands-on manipulation and other real(istic) settings) and at the symbolic level (between natural and mathematical symbolic language). Although neither Bruner's nor Nakahara's terminology implies a strict proceeding order, the progression from concrete action with the smart objects to symbolic algebraic language follows from the pedagogical setting at hand.

Design ideas and questions for investigation

Because research regarding traditional manipulatives suggests that only prolonged engagement with such objects reliably supports learning (Sowell, 1989), the MAL project wants to design *one* set of smart objects that can be used for a whole range of topics (e.g., for the generation of algebraic expression from pattern sequences, for transforming expressions, building relations, and for solving

equations). To achieve this, we turn to *algebra tiles*, which are already integrated in some North American algebra textbooks (e.g., Dietiker, Kysh, Sallee, & Hoey, 2010).

Marshall (2007) offers a framework that allows for the systematic design analysis of tangibles in learning environments. For example, he points to possible learning benefits: the playfulness that can be designed, the potential novelty of links, enhanced accessibility, chances of collaboration, and the learning benefits that may arise from physicality itself. Furthermore, he proposes a distinction between *expressive* and *exploratory* activities, which reminds of the more algebra-related work by Drijvers, Boon, and van Reeuwijk (2011), who distinguish between (technological) *tools for doing algebra* and *tools for learning algebra*, with the latter being subdivided into *practicing skills* and *developing concepts* (p. 185). It seems that the existing implementations of algebra tiles are more in the expressive realm of doing algebra, as they always start with a given definition of variables as unknowns, opposed to the possible exploration of their potential in describing change. It is a central goal of the MAL project to bring these two together. In the process, the following questions can be addressed: How do the physical and technical features of the designed objects interact with the didactical goals? To what extent is the integration of many algebraic concepts into one system of smart objects helpful in creating a multi-faceted image of the role of variables in algebra? What are limitations of the smart algebra tiles that could be resolved by either returning to traditional manipulatives or going virtual?

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