Building bridges that are functional and structural

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A mechanism showing the process of designing those tasks (e.g., nature, sequence) that makes explicit the choices of context, the iterative cycles of design, if any, and the conjectures the authors had about students’ progression of thinking while working with those tasks could provide a stronger framework for studying the “bridging” process.

In their article, Geraniou and Mavrikis describe an environment to help children explore algebraic relationships through pattern building. They report on transfer of learning from the computer to paper, but also implicit is transfer from concrete to abstract contexts. I make the case that transfer from abstract to concrete contexts should complement such approaches.

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in terms of transfer to non-digital contexts, is far from guaranteed. So is it worth the trouble?

"3" Constructionists argue that microworlds provide a powerful resource for immersing learners in mathematics. Abstract objects and concepts become tangible, allowing trial and error experimentation, mental reflection and discussion (Papert 1980). Students might then discover and explore ideas that are otherwise inaccessible to them, and can be challenged in ways not always supported by typical classroom activities. Some readers of this journal will have experienced and studied this enabling power of microworlds. In my own research, students working in the SumPuzzles environment interacted with formal arithmetic equations in distinctly algebraic ways, focussing on structure not calculation, and did so with minimal explicit instruction (Jones & Pratt 2012). However, when the plug is pulled, is the knowledge constructed by the student switched off along with the computer? Work such as that by Geraniou and Mavrikis is important for exploring how students might be bridged to working with formal mathematics on paper, and helping to evaluate whether the scaffolding and fading payoff is worthwhile.

"4" Another form of transfer, or perhaps more accurately transition, is implied in the research; namely, the shift from arithmetic to algebraic ways of thinking. The authors report that many students were successful with the final bridging task, and so claim that students “can generalise and adopt [algebraic ways of thinking] when solving paper and pencil figural pattern generalisation tasks” (§26). However, there were exceptions in which students “reverted to their past experiences and worked out the answers for each consecutive term in a sequence” (§24). Researchers working in the early algebra field will be unsurprised by this. Years of learning arithmetic using conventional notation has been shown to develop “operational patterns” (McNeil & Alibali 2005), such as the expectation of a numeric answer and a propensity to perform calculations even when they are irrelevant to the task goal. Moreover, operational patterns are stubborn and can be triggered unhelpfully by traditional paper-based tasks (McNeil 2008). Carefully designed microworlds can free students from operational patterns in order to explore algebraic ways of thinking, but operations are likely to be prioritized again for some students when returning to more traditional presentations of mathematical tasks.

"5" At the heart of the MiGen philosophy is another important aspect of transfer, the shift from concrete to abstract knowledge. This has been a contentious issue of late, with a high-profile paper by Jennifer Kaminski, Vladimir Sloutsy and Andrew Heckler (2008) claiming mathematical ideas should be introduced in abstract contexts to ensure better transfer, and others challenging their finding (e.g., De Bock et al. 2011). The use of generalised patterns to support algebraic ways of thinking has been termed "functional approaches" (Kirshner 2001). Appeals are made to children’s experiences of pattern and regularity, and tasks are designed such that formal algebra offers a powerful medium for describing and generalising patterns. Alternatives, which are perhaps less visible in the literature, are "structural approaches." These start with the abstract (that is, formal symbols and their structural relationships, with no concern for real-world referents) and seek to nurture conceptual understanding that can be transferred to new contexts, be they abstract or concrete. Structural approaches perhaps have a tarnished reputation, sometimes being associated with “meaningless” arithmetic and algebraic drill. However, carefully designed tasks can enable interactions with formal notation and associated transformation rules in a rich, meaningful and educationally valuable way (Dörﬂer 2006). Microworlds that take this approach have been found to motivate engagement with algebraic ways of thinking about formal notation systems (Hewitt 2014; Jones & Pratt 2012).

"6" There are two potential reasons to consider structural approaches as complements to functional approaches. First, whereas functional approaches typically end with the production of a formal expression or equation used to describe a concrete referent (typically a pattern), structural approaches enable the exploration of how formal expressions can be transformed; the notation becomes a medium for doing mathematics rather than describing mathematics. Second, structural microworlds start with formal notation, a virtual and manipulable symbol system that closely resembles that typically seen in textbooks and classrooms. Therefore, transfer from a digital to a paper-based domain might be relatively natural and intuitive for many students.

"7" We can assume that constructionist approaches to introducing formal algebra naturally align with both functional and structural approaches. Indeed, both approaches have been shown to lend themselves to the design of microworlds that enable tangible exploration and testing of conjectures such that formal symbol systems become a natural and useful medium of mathematical learning. Ideally, we might want learners to shift flexibly between thinking about concrete referents such as generalisable patterns, and thinking with formal symbols and their transformation rules. Such a fluid and dialectic mixed-approach might be expected to strengthen algebraic experience and understanding, and so promote transfer in the broadest sense of the term.

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