Applying the cognitive load perspective to examine use of manipulative materials in early place value instruction

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Visual and physical aids, such as manipulative materials and worked examples are often used as forms of instructional material in mathematics education. Worked examples have been shown to be an effective method of instruction with novice learners, as shown by higher test performance, shorter acquisition times and lower cognitive load during acquisition (Atkinson, Derry, Renkl, & Wortham, 2000; Chen, Kalyuga, & Sweller, 2015; Paas & van Gog, 2006; Sweller, 2006). In primary schools, worked examples are often used in conjunction with illustrations of manipulative materials, and the physical use of such materials. One such example is the use of Multi-base Arithmetic Blocks (MAB) to teach the early concepts of place value. Physically manipulating the materials to encourage learning is inherently a biologically primary skill, and children intuitively use the materials during play to learn secondary skills. However, it is suggested that the topic of place value is too disassociated from biologically primary skills to be easily and intuitively acquired through play. Indeed, whilst the use of worked examples alongside illustrations of MAB blocks in instructional material is common, their efficacy has not been investigated in young students. Using the concepts of cognitive load theory, which investigates how the learner's limited working memory and vast long-term memory can be used to design efficient educational material, this study examined the effects of using worked examples alongside MAB blocks to teach place value to young students. Thirty-eight Year 4 students from private schools in Sydney were invited to participate and were randomly assigned to two different groups. The first group was presented with place value problems and was given access to both the physical and visual representations of MAB blocks. The second group was given the same set of place value problems, but was not provided with any MAB block access. A pre-test was used to establish the baseline understanding relevant to the topic of place value, followed by the acquisition phase where children worked through the worked examples. A post-test and a delayed test, conducted one week after the post-test, were used to gauge whether any learning has taken place. Statistically significant differences were found in the post-test scores between the MAB blocks ($n = 20$, $M = 74.0$, $SD = 0.883$), and Control ($n = 18$, $M = 91.1$, $SD = 0.758$) groups, $F(1, 37) = 52.883$, $p < 0.01$. Statistically significant differences were also found in the delayed test performance marks between the MAB block group ($n = 20$, $M = 79.0$, $SD = 1.252$) and the Control group ($n = 18$, $M = 95.6$, $SD = 0.784$), $F(1, 37) = 25.872$, $p < 0.01$. The group that did not have access to visual aids or physical MAB blocks performed better than the group given access to the blocks. This indicated that despite the widespread use of MAB blocks in primary school to teach place value, the use of such blocks may produce a redundancy effect, leading to an increased extraneous load, and negatively affecting learning.