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Learning with Concrete and Virtual
Manipulative Models: Are Models Scaffolds or Crutches?

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The development of representational competence was investigated by using 3D (concrete and virtual) models as feedback in teaching organic chemistry students to translate between 2D diagrams. In two experiments, students translated between diagrams of molecules and received verbal feedback in one of three intervention conditions: with concrete models, with virtual models, or without models. Learning was measured in three posttests (with models, without models, and after a 7-day delay). Virtual models had either low (Study 1) or high (Study 2) congruence between actions performed with the input device and resulting movements of the virtual model. In terms of learning outcomes, model-based feedback was superior to verbal-feedback alone, models functioned as a scaffold rather than as a crutch, and learning with model-based feedback was resilient over a 7-day delay. Finally, concrete and virtual models were equivalent in promoting learning, and action congruence did not affect learning.