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# A pilot study on elementary pupils' conditional reasoning skills and alternatives generation skills in mathematics

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## Background and rationale

One of the main aspects of logical reasoning is conditional reasoning, i.e. reasoning with if-then statements. Conditional reasoning tasks usually present a rule of the form “*if p then q*” as a major premise, and a minor premise. Four minor premises differentiate four possible logical forms of inference: *p is true* (Modus Ponens, MP), *p is false* (Denial of the Antecedent, DA), *q is true* (Affirmation of the Consequent, AC), and *q is false* (Modus Tollens, MT). Definite conclusions can be drawn for MP (“*q is true*”) and MT (“*p is false*”), while AC resp. DA do not allow definite conclusions. Even very young children can show conditional reasoning skills in familiar everyday contexts (Markovits & Thomson, 2008). However, a link between conditional reasoning and mathematics has been found only in adolescents and adults in the context of proof (Stylianides & Stylianides, 2007).

According to Mental Model Theories, inferences are drawn by constructing mental models that encode information about specific situations in which the conditional is valid (Johnson-Laird & Byrne, 2002). The reasoners' ability to generate alternative models (beyond a model representing “*p and q*”) for the given conditional is considered a crucial prerequisite to draw valid inferences. Studies on conditional reasoning in the everyday context (De Chantal & Markovits, 2017) have shown that the alternative generation skills do predict early development of conditional reasoning. This raises the question, if the ability to generate multiple alternative models for a given mathematical premise, has an influence on students' conditional reasoning with these concepts.

## Methods

Our study aimed at examining the relation between primary students' skills in conditional reasoning with mathematical concepts, and their performance on the corresponding, alternative generation tasks. Participants were 55 elementary students (4th graders  $n=13$ :  $M=9.5$  years, 6th graders  $n=42$ :  $M=11.5$  years) from a public school in Cyprus. Their conditional reasoning skills were assessed in two conditional reasoning tasks including mathematical concepts (Datsogianni, Ufer, & Sodian, 2018). Each task contained one item for each logical form (MP, MT, DA, AC). For example, one conditional reasoning task focused on the circumference of rectangles in a context of dwarf houses. It was explained that dwarf houses always consist of several aligned rows, all with the same number of same-sized quadratic rooms. The major rule in this task was “*If a dwarf house has exactly 2 rows of 4*

rooms each, then it has 12 windows”. The alternative generation tasks asked students to generate many examples satisfying the conclusion of the major premise (i.e. “Draw as many dwarf houses as possible, that have 20 windows!”).

## Results and discussion

Students’ solved 62.7% of the mathematics conditional reasoning items correctly, illustrating early conditional reasoning skills under specific conditions. Regarding the first alternative generation task 62% of students gave 4 to 6 correct alternative solutions ( $M= 3.42$ ,  $Mdn= 4.00$ ). The second alternative generation task seemed to be more difficult since only 20% of students gave 4 to 5 correct solutions ( $M= 1.81$ ,  $Mdn= 1.00$ ). This indicates that the alternative generation tasks are feasible, but not too easy for our target sample. The number of generated alternatives correlated with students’ reasoning performance (task 1:  $\rho=0.358$ ,  $Sig.=0.001$ , task 2:  $\rho=0.343$ ,  $Sig.=0.003$ ), supporting our assumption that mathematical conditional reasoning is based on alternatives generation. Some first insights of our main study, which followed the above one, confirm that alternative generation in mathematics predicts correct logical reasoning and especially with AC form.

The results showed that the applied instrument is accessible to students while they replicate early conditional reasoning skills reported in studies from developmental psychology (e.g. Markovits & Thompson, 2008). This study replicates also previous results (De Chantal & Markovits, 2017) regarding the significant relation between alternative generation skills and students’ conditional reasoning skills, extending these results to tasks that involve mathematical concepts. The small sample size forbids taking far-reaching conclusions. However, our future research will be based on these developed tasks to describe the role of mathematical knowledge in conditional reasoning with mathematical concepts in more details investigating also whether alternative generation training could be one approach to support students’ conditional reasoning in mathematics.

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