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Modelling tasks - The relation between linguistic skills, intra-mathematical skills, and context-related prior knowledge

Many students have difficulties solving modelling tasks. However, it is not completely understood yet which skills are necessary for a successful solving process and how these are related to students' characteristics. The aim of this paper is to provide a more holistic view of the influence of students' characteristics while working on modelling tasks. It will be investigated how students' characteristics (gender and social background) are related to solving modelling tasks and whether linguistic and intra-mathematical skills, as well as prior knowledge of real-world task context, play a mediating role.

Theory

Many students have difficulties while working on modelling tasks, especially those with real-world context (e.g., Verschaffel et al., 2000). On the theoretical level, this can be explained by the fact that students have to go through several sub-processes to find a solution: They read the written task, understand it, and form a situation model based on their prior knowledge (Kintsch & Greeno, 1985). Afterwards, they solve the task using their intra-mathematical skills (Blum & Leiss, 2007). Studies show the need for language skills and intra-mathematical skills to solve word problems (e.g., Daroczy et al., 2015; Leiss et al., 2019). The influence of context-related prior knowledge has not yet been sufficiently investigated, although it is particularly important to fully comprehend the task (Kintsch, 1994). Studies have shown a positive effect of context-related prior knowledge (e.g., Cooper & Dunne, 2000). Other studies identified that students do not use their context-related prior knowledge to solve modelling tasks (e.g., Verschaffel et al., 1994).

Furthermore, studies have reported that students' characteristics such as social background and gender can influence the solving process. International comparative studies such as PISA identified that social background is related to performance in solving modelling tasks (OECD, 2013). Moreover, there is a relationship between social background, linguistic, and intra-mathematical skills (Piel & Schuchart, 2014; Plath & Leiss, 2018; Vilenius-Tuohimaa et al., 2008). Regarding gender disparities, studies pointed out an effect in favor of boys in solving modelling tasks (Lindberg et al., 2010; Plath & Leiss, 2018), as well as in intra-mathematical skills (Reinhold et al., 2020).

In linguistic skills related to modelling tasks, girls perform better than boys (Vilenius-Tuohimaa et al., 2008). The reason for these disparities has not yet been sufficiently researched. As for the relationship between personal characteristics and task context, it is known that social background and gender can have an influence on context (Boaler, 1994; Walkington et al., 2018).

Previous studies have focused on various relationships between students' characteristics, sub-skills, and modelling tasks. For a picture of the influence of personal characteristics and sub-skills of modelling, this study investigates the relationship between students' characteristics (gender and social background) and solving modelling tasks. Another objective is to examine whether sub-skills (linguistic, intra-mathematical skills, and context-related prior knowledge) play a mediating role.

Method

The DFG-funded project "Variations of Tasks Physics Mathematics and Language" (VAMPS) explores which mathematical and linguistic characteristics influence the task difficulty for students while working on modelling tasks. The present study is embedded in the VAMPS project and investigates modelling tasks from students' perspectives.

Within the project, a test instrument with 90 modelling tasks with factual text on linear functions in different real-world contexts (e.g., finance, technology, nature) was developed. The linguistic complexity of the factual text was kept constant on a medium level and was controlled by the readability index LIX (Anderson, 1981). Each student answered 15 modelling tasks with factual text from the task pool. For each task, students rated their context-related prior knowledge on a 4-level Likert scale. In addition, linguistic skills were assessed by a C-test and intra-mathematical skills by an intra-mathematical test. Finally, a short socio-demographic questionnaire was given. For modelling competencies and context-related prior knowledge, a point estimate was calculated for each of the 90 modelling tasks after estimating a one-dimensional IRT model with the statistical software package *ConQuest*.

The sample comprises $n=535$ students (f/m: 49.9%/50.1%, average age: 15.2 years, with and without migration background: 15.4%/84.6%, average parental education: 12.7 years). The study was conducted in autumn 2020 using the paper-pencil method at two comprehensive schools in grades 9 and 10.

The relation between characteristics of social background (migration background, parental education, books at home), gender, and modelling competencies was investigated by multiple regression as a path analysis in Mplus (Muthén & Muthén, 1998-2017). In addition, the extent to which students'

intra-mathematical and linguistic skills and their prior knowledge of task context mediate these correlations, was examined.

First Results

First computations of correlations show that there is a significant correlation between a privileged social background and higher linguistic skills and intra-mathematical skills. Furthermore, there is a significant correlation between a privileged social background and increased context-related prior knowledge, and higher modelling competence. With regard to gender, no significant correlation can be identified between intra-mathematical skills and context-related prior knowledge. There is a significant correlation between linguistic skills in favor of girls and modelling in favor of boys. For the three sub-skills (linguistic, intra-mathematical skills, and context-related prior knowledge) significant correlations with modelling competencies were also identified.

Based on the preliminary correlative results and previous results of various studies, it is assumed that in path analysis both gender and social background of students have a direct influence on their modelling competence. Furthermore, it is suggested that gender and social background are mediated through linguistic skills. Concerning the role of context-related prior knowledge, it is hypothesized that it also has an effect on solving modelling tasks and that it is mediated by social background.

Conclusion

The first results show the high relevance of intra-mathematical and linguistic skills as well as context-related prior knowledge for modelling competence. For schools, it indicates that children with a migration background and from educationally disadvantaged homes achieve lower solution rates in solving modelling tasks due to low linguistic and intra-mathematical skills as well as a lower prior knowledge of task context.

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