READING COMPREHENSION, ENJOYMENT, AND PERFORMANCE IN SOLVING MODELLING PROBLEMS: HOW IMPORTANT IS A DEEPER SITUATION MODEL?

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In an experimental study with ninth graders (N=165), we investigated whether presenting reading comprehension prompts would have a positive impact on students' enjoyment and performance in modelling. Contrary to our expectations, the enjoyment and modelling performance of students who received reading comprehension prompts were similar to those of the students in the control group. Further, we found that students' success in answering the reading comprehension questions was positively related to their enjoyment and modelling performance. However, after we controlled for intra-mathematical performance, the relation between reading comprehension and modelling disappeared, whereas the relation between reading comprehension and enjoyment remained significant. Implications for future research are discussed.

INTRODUCTION

Reading comprehension is an essential precondition for successful modelling, and deficits in reading comprehension can be responsible for the occurrence of errors in solving modelling problems. Hence, it is important to ask whether presenting reading comprehension prompts, which have been found to improve students' reading comprehension in different domains (Levin & Pressley, 1981; Rickards, 1976), can also lead to better modelling performance. In the present paper, we examined whether reading comprehension prompts would have a positive influence on students' performance and enjoyment in solving modelling problems. Further, we investigated whether answering the reading comprehension questions correctly would play a role. We therefore analyzed the relation between success in answering the reading comprehension questions and modelling performance and the relation between reading comprehension and task enjoyment.

THEORETICAL BACKROUND AND RESEARCH QUESTIONS

The Role of Reading Comprehension in Mathematical Modelling

The core of mathematical modelling is the translation of a real-world situation into a mathematical model. The translation process requires an adequate understanding, structuring, and simplification of the initial real-world situation. This means that students need to be able to build an adequate mental model of the situation before it can be mathematized. Even the first step of "understanding the situation" in the

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modelling process can be demanding for students and is often a source of errors (Blum, 2015; Leiss, Schukajlow, Blum, Messner, & Pekrun, 2010). This is not only because the reading comprehension that is necessary to solve modelling problems is cognitively demanding but also because students are used to word problems that can be solved without the effort of building an adequate mental model of the real-world situation ("Situation model") through the direct application of the given numbers in a straightforward calculation (Verschaffel, Greer, & de Corte, 2000). However, for modelling problems, which often include superfluous or missing information, such strategies are not sufficient and can lead to incorrect solutions (Krawitz, Schukajlow, & Van Dooren, 2016). Because of the fact that the real-world situation is mostly presented in written form (Verschaffel et al., 2000), it is obvious that reading comprehension is a necessary condition for deriving a situation model from the text, and it plays an important role in understanding and further structuring and simplifying the written information that is presented about the real-world situation.

A first indication of a positive relation between reading comprehension and performance in solving modelling problems comes from research on word problems. The positive relation between the two factors was found to remain significant even after technical reading skills were controlled for (Vilenius-Tuohimaa, Aunola, & Nurmi, 2008). Leiss et al. (2010) demonstrated that mathematical reading comprehension – assessed via the request to select the numerical information that was important for solving a given modeling problem – is even more important for modelling problems than for word problems. This study showed a significant relation between mathematical reading comprehension and performance in solving modelling problems (.486) and a smaller but also significant relation with performance on word problems (.183). Also, in Leiss et al.'s (2010) study, general reading comprehension was measured with a standardized reading test. In contrast to mathematical reading comprehension, general reading comprehension was not correlated with performance on the word problems or the modelling problems. This suggests that the specificity with which reading comprehension is assessed plays an important role.

Although mathematical reading comprehension was found to be important for modelling, we do not know much about how improvements in reading comprehension influence modelling processes. Because posing questions that were focused on the contents of the text was found to benefit students' understanding in research on reading comprehension (Levin & Pressley, 1981; Rickards, 1976), we applied this approach to investigate how the use of reading comprehension prompts would affect modelling performance.

Reading comprehension and enjoyment while solving modelling problems

Students' enjoyment as they solve math problems depends on whether they assign value to the activity of solving math problems and whether they perceive this activity to be sufficiently controllable (Pekrun, 2006). Because the perception of control, which is often assessed via self-efficacy, is closely related to performance, higher performance should result in greater enjoyment. Empirical evidence for this impact has been provided by the findings that students' mathematical performance in grades

3 and 6 has a positive impact on enjoyment in grades 6 and 9, respectively (Hannula, Bofah, Tuohilampi, & Metsämuuronen, 2014) and that students' grades at the beginning of the school year are positively related to their enjoyment during the school year (Ahmed, van der Werf, Kuyper, & Minnaert, 2013). As reading comprehension is an important part of modelling activities, and modelling is positively related to enjoyment (Schukajlow & Krug, 2014), higher reading comprehension should also result in greater enjoyment.

Further indications for the positive relation between reading comprehension and enjoyment in modelling has come from research in other domains. Deep reading comprehension was found to be accompanied by enjoyment (Guthrie et al., 2007). As students' enjoyment in solving modelling problems might refer to all modelling activities, deeper reading comprehension should result in greater enjoyment in modelling. Moreover, improvements in reading comprehension should also positively affect students' enjoyment in modelling.

However, to the best of our knowledge, we could not find research that had investigated the relation between students' reading comprehension and their enjoyment while solving modelling problems.

Research Questions

These considerations led us to pose the following research questions:

1. Does the presentation of reading comprehension prompts have a positive effect on modelling performance? Is higher reading comprehension positively related to modelling performance?
2. Does the presentation of reading comprehension prompts lead to greater enjoyment in solving modelling problems? Is higher reading comprehension positively related to enjoyment?

We expected that presenting reading comprehension prompts would lead to better modelling performance because answering the reading questions might lead to a deeper comprehension of the real-world situation presented in the text (Levin & Pressley, 1981) and thus to better solutions on the modelling tasks. Further, taking into account previous research (Leiss et al., 2010), we expected a positive relation between reading comprehension and modelling performance. Regarding the extent to which students enjoyed solving the modelling tasks, we expected benefits of presenting reading comprehension prompts because previous research showed that deep text comprehension was accompanied by enjoyment (Guthrie et al., 2007). Moreover, because of the positive impact of prior performance on enjoyment (Ahmed et al., 2013; Hannula et al., 2014; Pekrun, 2006), we expected that students who answered the reading comprehension prompts correctly would show greater enjoyment when solving the modelling tasks.

METHOD

Sample and design

Data were collected within the Taiwanese-German research program (TaiGer) on the influence of cultural-societal factors on mathematics education. The sample involved 65 ninth graders (46 % female, mean age = 15.12 years) in seven middle-track classes (German Realschule) at three different schools. Students in each classroom were randomly assigned to an experimental (EG) or a control condition (CG). All students had to take a 60-minute test that included three descriptions of real-world contexts (here, called situation statements) and corresponding modelling problems. The test version for the experimental condition also included reading comprehension prompts corresponding to the situation statements.

Measures

Two of three situation statements and the related modelling tasks were adapted from previous studies, and we developed other tasks on our own. In the following, one of the three situation statements from the test is presented as an example (see Figure 1).

Fire Brigade

In 2004, the Munich fire brigade got a new fire engine with a turn-ladder. Using the cage at the end of the ladder, the fire brigade can rescue people from great heights. According to the official rules, while rescuing people, the truck has to keep a distance of at least 12 meters from the burning house. Technical data of fire engine are shown in the table below.

Table 2

Technical data of fire engine	
Engine model:	Daimler Chrysler AG Econic 18/28 LL - Diesel
Construction year:	2004
Power:	205 kw (179 HP)
Cubic capacity:	6374 cm^3
Dimensions of fire engine:	Length 10 m width 2.5 m height 3.19 m
Dimensions of ladder:	Length up to 30 m
Weight of unloaded truck:	15540 kg
Total weight:	18000 kg

Figure 1: Situation statement of the real-world context "Fire brigade"

The test version for the experimental condition included six reading-comprehension prompts (two prompts for each situation statement). For the "fire brigade" context, one of the two reading comprehension prompts was:

"What is the longest possible length of the ladder?"

The answers to the reading comprehension prompts were scored dichotomously as right or wrong. The mean of the six answers to the reading comprehension prompts was used to assess reading comprehension performance. Thereby, the internal consistency was low, as expected, since the reading comprehension prompts were developed to address different aspects of the problem (Cronbach's α = .518).

Students in both groups were given six modelling problems (two for each situation statement). All of the modelling problems referred to the Pythagorean Theorem. For the "fire brigade" context, one of the modelling problems is presented here as an example:

> "What is the maximal height from which the Munich fire brigade can rescue people with this fire engine? Find one possible solution and briefly explain your solution."

The solutions to the modelling problems were coded by applying a three-step coding scheme (from wrong = 0 to right = 2). The reliability for the six modelling problems was acceptable (Cronbach's α = .719).

In line with Schukajlow and Krug's (2014) study, students' enjoyment was operationalized in a prospective and task-specific manner. Therefore, the students were first asked only to read the modelling problems and to use a 5-point Likert scale ranging from 1 (not at all true) to 5 (completely true) to rate whether they would enjoy working on the tasks ("I would enjoy solving these problems"). After answering this question, the students solved the respective modelling problems. The reliability of the scale was satisfactory (Cronbach's α = .738).

Moreover, an intra-mathematical performance test on the Pythagorean Theorem was administered (10 minutes, Cronbach's α = .635). The intra-mathematical performance test was used to control for students' intra-mathematical abilities in assessing the relation between reading comprehension and modelling performance or enjoyment, respectively, and also to verify the comparability of the groups. A sample task is presented in Figure 2.

1. Calculate the length of the diagonal *d* of a rectangle with the length of 3 cm and the width of 4 cm.
   How long is the diagonal *d*?

   ☐ 5 cm ☐ 6 cm ☐ 6.5 cm ☐ 7 cm ☐ 8 cm

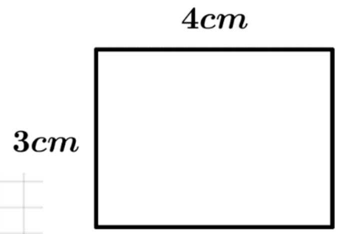

Figure 2: Sample task from the intra-mathematical performance test

We removed three of the 165 students from our analysis because they did not answer the enjoyment questions. We included the remaining 162 students (N_{EG} = 81; N_{CG} = 81) in our analysis. Missing values on the reading comprehension prompts and the modelling problems were coded zero, whereas for enjoyment the mean of the remaining items was calculated.

RESULTS

As a preliminary result, we found that the two groups had comparable intra-mathematical performances (EG: M = .29 (.20); CG: M = .29 (.21); t(160) = -0.048, p = .962). This result confirmed the comparability of the groups.

To investigate whether the presentation of reading comprehension prompts had an effect on modelling performance (research question 1), we used an independent t-test to compare the modelling performance of the EG ($M = .27$, $SD = .35$) with that of the CG ($M = .24$, $SD = .33$). The results showed that the groups did not differ significantly in their modelling performance ($t(160) = .609$, $p = .543$). Thus, the reading comprehension prompts did not have a significant effect on modelling performance. A correlational analysis (Pearson correlation) was used to examine the relation between students' modelling performance and the correctness of their answers to the reading comprehension prompts (research question 1). A low correlation between reading comprehension and modelling performance was found ($r(79) = .198$, $p < .05$, one-tailed). However, a much greater proportion of the variance in modelling performance was explained by intra-mathematical performance ($r(160) = .519$, $p < .01$, one-tailed), and the relation between reading comprehension and modelling performance disappeared after intra-mathematical performance was controlled for (partial correlation: $r(79) = .077$, $p = .248$, one-tailed).

Regarding students' enjoyment (research question 2), the EG ($M = 2.58$, $SD = .97$) reported nearly the same enjoyment as the CG ($M = 2.59$, $SD = .94$, $t(160) = -.123$ $p = .902$). Thus, the reading comprehension prompts did not have a significant effect on students' enjoyment. However, similar to the relation found in research question 1, reading comprehension was positively related to students' enjoyment ($r(79) = .220$, $p < .05$, one-tailed). Moreover, this relation remained significant even after intra-mathematical performance was controlled for ($r(79) = .202$, $p < .05$, one-tailed).

SUMMARY AND DISCUSSION

In the present study, we investigated the effects of reading comprehension prompts on students' modelling performance and enjoyment. Further, we examined the relations between students' success in answering the reading comprehension prompts and their modelling performance and enjoyment. Contrary to our expectations, the results showed that presenting reading comprehension prompts did not lead to an improvement in students' modelling performance or enjoyment. This indicates that the positive impact that was previously found from asking questions about text comprehension (Levin & Pressley, 1981; Rickards, 1976) could not be directly transferred to modelling performance in the current study. Thus, simply providing reading comprehension prompts does not seem to be sufficient for improving modelling. It is possible that students answered the prompts superficially so that the intended engagement with the text and the expected deeper understanding was not fulfilled. This explanation was supported by the results of our correlational analysis, which showed that success in answering the reading comprehension questions was positively related to students' modelling performance and enjoyment, respectively. Students who answered the reading comprehension questions successfully showed better modelling performance and greater enjoyment of the modelling tasks. Hence, it is not the presentation of the reading comprehension prompts on its own but rather students' actual engagement with the questions that seems to be the determining factor. The positive relation between reading comprehension and modelling performance confirms findings from previous studies, although the correlation we found was lower (.198 compared with .486, which was reported by Leiss et al. (2010)). This may have occurred because the reading comprehension test in our study focused on the construction of a situation model, whereas in Leiss et al.'s (2010) study, the students were asked to select the information that was important for solving the problem. Thus, in addition to general reading comprehension activities, the students in the previous study had to idealize and structure their situation model, and therefore were strongly engaged in modelling activities.

The positive relation between answering the reading comprehension questions correctly and students' modelling performance disappeared after we controlled for intra-mathematical performance. Hence, students' intra-mathematical performance seems to be crucial for students' modelling performance. However, the positive relation between students' reading comprehension and their enjoyment of the tasks remained even when we controlled for intra-mathematical performance. Students with deeper reading comprehension enjoyed solving the modelling problems more than students with surface reading comprehension, even when the two groups of students had comparable intra-mathematical abilities. This confirms the previous finding that a deeper understanding is accompanied by greater enjoyment (Guthrie et al., 2007) and moreover indicates that a deeper comprehension of the real-world situation results in a greater enjoyment of modelling.

Finally, we want to acknowledge the following limitations of our study. The benefits of prompting students to answer reading comprehension questions were hypothesized because of the findings of prior studies. In the present study, we thus used the reading comprehension prompts to enhance students' understanding of the text as well as to measure their reading comprehension. With this design, however, it is not possible to examine whether the prompts led to better reading comprehension in the experimental group compared with the control group. In addition, the modelling problems we used were found to be very demanding for the students in terms of constructing a mathematical model, so it is possible that this interfered with the examination of the interplay between reading comprehension and modelling because even students with a good understanding of the situation potentially had trouble solving the modelling problems.

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