I am scared to make a drawing. Students' anxiety and its relation to the use of drawings, modelling, and gender

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Emotions are important for students' learning and achievement. In the present paper, we report on a study of ninth- and tenth-graders (N=194) in which we investigated the relations between anxiety about strategy use, learning outcomes, and gender. We found that anxiety about making a drawing to solve a modelling problem was higher in female than in male students. Further, anxiety about strategy use was negatively related to different indicators of learning outcomes: strategic knowledge about drawing, number of drawings generated spontaneously while solving modelling problems, and modelling performance. Moreover, after we controlled for intra-mathematical performance, strategic knowledge about drawing, and gender, anxiety about self-generated drawing was negatively related to the use of drawings and modelling performance. This finding indicates the importance of anxiety about strategy use for learning and performance.

Keywords: Anxiety, Emotions, Strategy, Drawing, Modelling problems

Introduction

Emotions are important for the learning of mathematics, mathematical achievement, a person's future career, and human well-being (Schukajlow, Rakoczy, & Pekrun, 2017). One of the best-researched emotions is students' anxiety about mathematics. Students have been found to experience test anxiety often, and it can negatively influence students' test performance. However, much less is known about the impact of anxiety on students' strategies. In the present paper, we present a study carried out in the framework of the research project "Visualization while solving modelling problems" (ViMo). The main aim of the ViMo project is to investigate the strategy of learner-generated drawing and its relation to affective and cognitive learning factors. In the present study, we explored anxiety about making a drawing (anxiety about self-generated drawing) and its importance for students' learning outcomes. Our results contribute to clarifying the role of anxiety in strategy use, which was recently identified as an important research gap (Ramirez, Shaw, & Maloney, 2018).

Anxiety, drawing strategy, modelling, and gender

Anxiety as an achievement emotion

Definitions of emotions have emerged from different paradigms, such as the Darwinian, Freudian, or cognitive-psychological traditions (Hannula, 2015). Emotions are typically defined as phenomena that include affective, cognitive, physiological, motivational, and expressive components. The components of anxiety are uneasiness and nervous feelings (affective component), worry (cognitive), avoidance motivation (motivational), anxious facial expressions (expressive), and peripheral physiological activation (physiological) (Pekrun, 2006). In the control-value theory of achievement emotions, anxiety is considered to be a prospective emotion that is related to learning outcomes such as mathematical performance

(Pekrun, 2006). Control and value appraisals are assumed to be important for the emerging of emotions. Students feel test anxiety if they ascribe a high value to an exam and perceive themselves as not able to avoid failure on the exam. Similar to other affective constructs, anxiety has state and trait components that refer to the temporal stability of this emotion (Schukajlow et al., 2017): If students are anxious while solving a specific problem, this is an emotional state; if they are disposed to often being anxious while solving a problem, this is an emotional trait. Another important characteristic of emotions is their object, which varies from more general objects (e.g. the learning of mathematics) to specific objects (e.g. a mathematical problem) (Schukajlow et al., 2017). Mathematical activities (e.g. strategy use) can also serve as objects for emotions.

Self-generated drawing and modelling

Self-generated drawing describes the process and the product of generating an illustration that corresponds to the objects and relations described in a problem (Rellensmann, Schukajlow, & Leopold, 2017), and it has been identified as an important strategy for problem solving (Hembree, 1992). Strategic knowledge makes part of the static knowledge component of metacognition as opposed to the dynamic process component of metacognition, which includes the application of strategies (strategy use). In a prior study, we investigated the importance of strategic knowledge about drawing for solving modelling problems. Modelling problems are problems with a connection to reality, whose solutions require demanding transfer processes between reality and mathematics (Niss, Blum, & Galbraith, 2007). Modelling performance can be clearly distinguished from students' ability to solve problems without a connection to reality, called intra-mathematical performance. Students' strategic knowledge about drawing comprises students' views on the characteristics of a drawing that fits a given problem. This knowledge is positively related to students' performance in modelling problems that can be solved by using the Pythagorean theorem (Rellensmann et al., 2017). Another important predictor of student performance is their strategy use. Students who spontaneously apply a drawing strategy were found to demonstrate higher performance in mathematics than students who did not apply the strategy (Hembree, 1992). However, this finding was not always confirmed when students were asked to construct a drawing. One reason why students do not always spontaneously generate drawings might be their affective perceptions of this strategy such as anxiety about making a drawing to solve a problem.

Anxiety, gender, and performance-related outcomes

Anxiety accompanies solitary problem solving processes (DeBellis & Goldin, 2006), and because working individually is important for gaining new knowledge, different contextual factors have been accessed to explore anxiety in mathematics. One such factor is students' gender. Most studies on anxiety have revealed that female students report a higher level of anxiety in mathematics than male students do (for an overview, see Ramirez et al., 2018). To account for this finding, researchers have primarily discussed two reasons that are both related to stereotypes about gender and mathematics. One explanation refers to the hypothesis that female students report their true level of mathematical anxiety because they do not feel bad about having negative feelings toward mathematics, whereas male students try to repress their anxiety because of the stereotype that males have to be good at mathematics. Another explanation of the higher level of anxiety in women refers to the stereotype that women are worse at math than men. The crucial role of stereotypes for gender differences in anxiety is supported by the findings that gender differences disappear when students report their real-time (state) anxiety before, during, and after an exam, and they do not have time to reflect on their anxiety (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). Although these findings refer to anxiety about mathematics in general and not anxiety about the use of strategies for solving mathematical problems, we expect similar gender differences for anxiety about self-generated drawing while solving modelling problems.

Anxiety about the use of a specific strategy might be one factor that prevents students from applying this strategy while solving a problem. If a student fears failure when it comes to drawing, he or she might not try to generate a drawing, might solve the problem by using another less effective strategy, or might even give up at the very beginning. The relation between anxiety and students' strategies has rarely been investigated yet. We know that students' negative emotions (including anxiety) seem to impede their use of creative strategies (Pekrun, 2006) such as self-generated drawing. The use of inappropriate strategies is considered to be one factor that can explain why students with high levels of anxiety show poor mathematical performance in primary school (Ramirez, Chang, Maloney, Levine, & Beilock, 2016). However, the negative relation between anxiety and performance depends on students' cognitive abilities and is stronger for students with high working memory capacity. This finding indicates that anxiety about self-generated drawing might be negatively related to students' use of this strategy while solving modelling problems. A similar relation can be expected for strategic knowledge about drawing because students with high levels of anxiety about drawing tend to practice this strategy only rarely and do not have the opportunity to acquire advanced knowledge about this strategy. The relation between anxiety and modelling performance might be negative because anxious students do not make drawings to solve modelling problems. Further, students with high levels of anxiety might perform worse in modelling because their working memory might be overloaded with negative feelings, and they cannot focus on problem solving to the same degree as students who do not feel anxious.

Research questions

On the basis of prior research, we investigated the following research questions:

1. Does anxiety about self-generated drawing differ for female and male students? We hypothesized higher anxiety for female students.
2. Is anxiety about self-generated drawing related to strategic knowledge about drawing, use of drawings, and modelling performance? We expected a negative correlation between anxiety and these learning outcomes.
3. Is anxiety about self-generated drawing related to the use of drawings and modelling performance after strategic knowledge about drawing, intra-mathematical performance, and gender are controlled for? We expected that the relation would remain negative even after the strategic factor, the achievement factor, and gender were controlled for.

Method

Sample and procedure

Two hundred twenty German ninth- and tenth-graders from ten classes in middle- and high-track schools participated in the presents study (mean age 14.9 (SD = 0.64), 109 female students). On the first day of the study, among other questionnaires, students filled out a questionnaire on mathematical anxiety, age, and gender and took a test on strategic knowledge about drawing. On the second day, they worked on a modelling test and an intra-mathematical test. Students were not instructed to make a drawing. Their spontaneous use of drawings was coded by analyzing students' solutions.

Measures

Anxiety about self-generated drawing was assessed with a new Likert scale that we adapted from the anxiety scale from the Achievement Emotions Questionnaire (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011) by focusing on the items from the drawing strategy. It consisted of five items that ranged from 1 (not at all true) to 5 (completely true) and addressed emotional trait. Example: "When I make a drawing for a difficult word problem, I am very nervous." The reliability (Cronbach's α) was .860.

The strategic knowledge about drawing scale was developed and validated in a prior study (Rellensmann, Schukajlow, & Leopold, under review). It comprised eight real-world problems, each of which was followed by an item concerning situational drawings and an item concerning mathematical drawings (see Figure 1). On the 16-item test, students were asked to evaluate the utility of the drawings provided for each problem by comparing the drawings with regard to their helpfulness in solving the problem. Each item consisted of three drawings (a correct and complete drawing, a correct but incomplete drawing, and an incorrect drawing) that students rated on the scale from 1 (not helpful at all) to 5 (very helpful). The scores for each item ranged from 0 to 3, as each item offer 3 comparisons. The number of points depended on the sequence of drawings concerning their usefulness for solving the task. For example, if students identified that the correct and complete drawing was more helpful than the correct but incomplete drawing and that the correct and incomplete drawing was more helpful than the incorrect drawing, they were given 3 points (Cronbach's α .762).

The modelling performance test comprised eight problems that could be solved by applying the Pythagorean theorem (for an example, see Schukajlow, Krug, & Rakoczy, 2015). Students' solutions were scored by two raters on a scale ranging from 2 (correct problem solution) to 0 (incorrect solution resulting from an incorrect mathematical model or a missing solution). The inter-rater reliability (Cohen's κ) was >.81 for all modelling problems. Cronbach's α reliability was .772.

Students' use of the drawing strategy was assessed via the number of drawings they constructed while solving the eight problems on the modelling test. If students made a drawing for a problem, they received a score of 1; if they did not make a drawing, they received a score of 0.

The intra-mathematical test comprised ten items on applying the Pythagorean theorem or solving quadratic equations (e.g., $x^2 = 3.8^2 - 2.5^2$). They received 1 point for the correct solution and 0 points for an incorrect or missing solution. Cronbach's α Reliability was .760.

Statistical analysis

To analyze the relations between the constructs, we used Pearson product moment correlations and partial correlations. Because students worked on the tests on two different days, some data were missing (3% and 8%). Thus, we applied listwise deletion for our analysis. This means that we excluded students from the analysis if they missed the first or second test session, and we performed the analysis on 194 students.

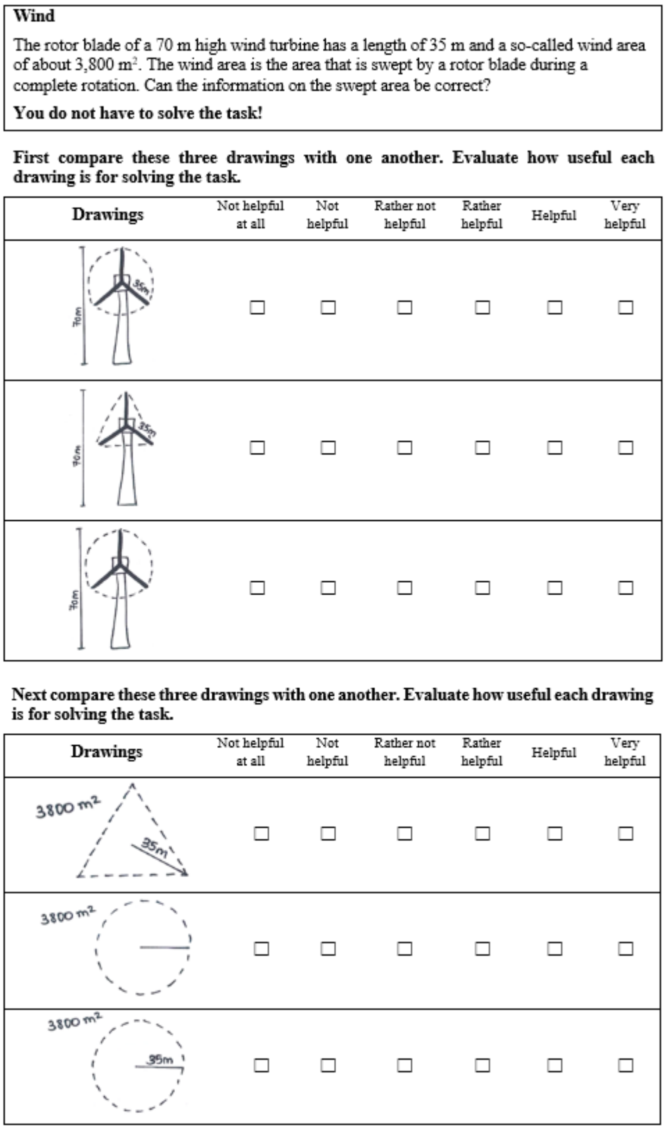

Figure 1: An item from the knowledge about drawing scale (Rellensmann et al., under review)

Results

First, we analyzed the differences in anxiety for female and male students. As expected on the basis of prior research, students' level of anxiety about self-generated drawing was significantly higher for female students (M = 2.12, SD = 0.96) than for male students (M = 1.67, SD = 0.63). About 11% of the female students and 18% of the male students denied feeling anxiety about drawing for all 5 statements. The medium effect size (*Cohen's d* = .56) indicates that women feel anxiety more often than men if they make a drawing while solving a demanding modelling problem.

The second research question was about the relation between anxiety about making a drawing and learning outcomes. The analysis of Pearson correlations revealed that students' anxiety about making a drawing was negatively related to all constructs measured in the present study (see Table 1). The effect size for the relation between anxiety about making a drawing and modelling was medium in size, and the effect sizes for the correlations between anxiety, use of drawings, and intra-mathematical performance were weak.

		SKD	UD	IM	MOD
Anxiety	r	-.118	-.154	-.140	-.327
	p^a	.041	.016	.026	<.001

Note. [a] *p:* one-tailed. SKD: strategic knowledge about drawing, UD: Use of drawings, IM: intra-mathematical performance, MOD: Modelling performance.

Table 1: Correlations between anxiety and the learning- and achievement-related measures

Students who felt anxious about making a drawing had lower levels of strategic knowledge about drawing, applied this strategy less often while solving modelling problems, and demonstrated poorer modelling performance.

The third research question focused on the analysis of the relation between anxiety about drawing, strategy use, and modelling performance after strategic knowledge about drawing, use of drawings, intra-mathematical performance, and gender were controlled for. The partial correlations confirmed a significant relation between anxiety and the use of drawings (r = -.161, p = -.026) and between anxiety and modelling performance (r = -.236, p < .001). The relations between anxiety about drawing and the use of drawings and modelling performance go beyond the contribution of the strategic factor (SKD), the cognitive factor (IM), and gender.

Discussion

In the present study, we explored the role of students' anxiety about self-generated drawing. Our analyses confirmed the gender differences for anxiety about self-generated drawings that were found for mathematical anxiety in prior studies. Although mean values for anxiety about self-generated drawing were low, our results indicate that more than nine tenths of female students and more than one sixth of male students might be worried, feel uneasiness, or feel nervous while making a drawing for a difficult modelling problem. Giving prior findings about the importance of spontaneous drawings for problem solving (Hembree, 1992) and the importance of drawings for solving modelling problems that can be solved by applying the Pythagorean theorem (Rellensmann et al., 2017), anxiety about using drawings seems to be an important construct that should be investigated in future studies. Moreover, female students might be disadvantaged while solving modelling problems because of their anxiety about using advanced strategies such as self-generated drawing. The main reason for gender differences in anxiety is considered to be social stereotypes that occur in the trait measures of anxiety. In future studies, it will be interesting to assess anxiety about self-generated drawing as a state, directly before or during problem solving, in order to clarify the stability of gender differences.

The analysis of the relations between anxiety about self-generated drawing and learning outcomes was the second main point of the present study. We hypothesized two ways in which anxiety about self-generated drawing can affect learning outcomes. First, students with high anxiety about making self-generated drawings might avoid using this strategy during problem solving because of their fear of failure, and they might look for other ways to solve the problem. The results of our analysis confirmed this hypothesis because we found a negative relation between anxiety and the number of drawings used while solving modelling problems. Moreover, a negative relation between anxiety and strategic knowledge about drawing indicates that students with high anxiety did not know the important characteristic features of good drawings. One reason for this negative relation might be that anxious students make drawings less frequently, and thus, they do not have many opportunities for improving this strategy. The relation between anxiety and the use of drawings while solving modelling problems remained negative after strategic knowledge about drawing, intra-mathematical performance, and gender were controlled for, indicating that affective constructs such as anxiety might influence the use of the strategies beyond strategic knowledge, general mathematical abilities, or gender. Second, anxiety is considered to have a negative influence on performance because it diminishes cognitive resources (e.g. working memory) while problem solving. If students are anxious during problem solving, they cannot focus on the entire problem and perform worse than students who do not feel this emotion. We found a negative correlation between anxiety about drawing and modelling performance that remained significant after strategic knowledge about drawing and intra-mathematical performance were controlled for. This finding might indicate the specific relevance of anxiety about self-generated drawing for students' modelling performance.

In sum, our findings revealed the importance of overcoming anxiety about the use of strategies. In the case of drawing, we suggest that students should learn how to apply this strategy in the classroom and to reflect on differences between more and less helpful drawings. Engagement with drawings should begin in primary school because anxiety about mathematics emerges in the early school years, and decreases performance in secondary school (Ramirez et al., 2018).

Finally, we would like to point out one limitation of the present study. Although anxiety, students' drawings, and modelling performance were ordered along the timeline, we cannot draw conclusions about causal effects of anxiety on the use of drawings or on modelling performance. Prior research has revealed some evidence of reciprocal causation between emotions and achievement (Putwain, Becker, Symes, & Pekrun, 2018). In mathematics, however, the relation between emotions and performance has yet to be clarified. For example, students' prior performance in modelling did not influence enjoyment during lessons, whereas enjoyment during lessons affected modelling performance after mathematics lessons (Schukajlow & Rakoczy, 2016). We interpret this result as evidence of possible effects of anxiety about drawing on performance in modelling. In future studies, we suggest to pay more attention to the interaction of affective, strategical and cognitive factors while solving mathematical problems.

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