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Strategy-based motivation to use the drawing strategy. The relationships between self-efficacy, value, cost, and gender

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Motivation and strategies are important for students' learning. In this contribution, we investigated the motivation to use the learner-generated drawing strategy. On the basis of expectancy-value theory, we analyzed the relationships between three components of strategy-based motivation (self-efficacy, value, and cost) and gender differences in these three components of motivation. To address research questions and test hypotheses, we re-analyzed the data from a prior study (N = 402) that assessed low-secondary school students' motivation at two measurement points. Results indicate (1) a positive relationship between self-efficacy and value and a negative relationship between self-efficacy and cost and (2) lower self-efficacy and a higher value given to the drawing strategy in female students. One important implication is that gender differences should be taken into account in strategy-based motivation in research and practice.

Keywords: Motivation, gender differences, learning strategies, self-efficacy, diagram.

Introduction

Motivation is a central construct in theories of affect (Hannula, 2011). In a broader sense, motivation comprises reasons for human behavior (Middleton & Spanias, 1999). One of the most influential motivational theories in the area of educational psychology and education is the expectancy-value theory of achievement choice (Eccles & Wigfield, 2020). According to expectancy-value theory, expectations of success (including self-efficacy expectations), task value, and personal costs are crucial for achievement-related outcomes. Following the idea that affect can address different objects (Schukajlow et al., 2017), we address the concept of strategy-based motivation (SBM) in this contribution. SBM is motivation that derives from characteristics of strategies and their use. The strategy we chose for this study is the learner-generated drawing strategy, which has repeatedly been demonstrated to be very important for problem solving in mathematics (Hembree, 1992). The drawing strategy has specific importance for solving problems that require the construction of mathematical models that rely on the spatial structure of the problem, such as geometrical modelling problems (Rellensmann et al., 2017). Further, we were interested in gender differences in SBM. To the best of our knowledge, prior research has not addressed the relationships between the components of SBM, and we do not know much about how female and male students differ in SBM. The aims of this study were to analyze the relationships between self-efficacy, task value, and cost regarding the drawing strategy and to analyze gender differences in students' SBM to use the drawing strategy. To collect indications of the stability of our findings, we collected and analyzed data at two time points that served as pretest (T1) and posttest (T2) in the original study to uncover the effects of the strategy training on students' performance.

Strategy-based motivation and gender

Expectancy-value theory

Initial intentions in the development of control-value theory were to integrate findings from motivational theories and to clarify why women make different educational choices than men and rarely study STEM subjects (Eccles & Wigfield, 2020). Expectancy-value theory proposes that students' subjective beliefs are important for career choices, interest, performance, and strategy use. Expectancies are defined as beliefs about one's ability to perform an activity (here, making a drawing), and they are related to the self-efficacy expectations proposed by Bandura (2003) in social-cognitive theory. In the case of the drawing strategy, students with high expectations give a positive answer to the question "Can I make a drawing?" Task value is another component in expectancy-value theory. If students value a strategy, they will use this strategy more often. Students who value the drawing strategy give a positive answer to the question "Do I value making a drawing?" Three types of values are attainment value, intrinsic/interest value, and extrinsic/utility value. Attainment value implies that an activity (e.g., making a drawing to solve a problem) is part of an individual's personal identity. Interest value implies the feeling of enjoyment that is associated with performing an activity (e.g., enjoyment in making a drawing). Utility value refers to the students' view that an activity can help them achieve their goals (e.g., applying the drawing strategy will help them solve a problem). Personal cost is another component of motivation. Cost includes the amount of time and effort that a person will invest in an activity. Students who ascribe low cost to the drawing strategy give a positive answer to the question: "Am I free of blockages that prevent me from investing time and effort into making a drawing?" Originally, cost was suggested as part of value. There has recently been a discussion about whether cost should be a component that is distinct from task value and expectations on a theoretical and an empirical level (Eccles & Wigfield, 2020).

Expectancies, value, and cost were found to predict learning outcomes, such as educational choices and academic achievement in mathematics (Eccles & Wigfield, 2020). In our recent study, we found that self-efficacy expectations and cost with respect to the drawing strategy affected the quality of drawings and performance in solving geometry modelling problems (Schukajlow et al., 2021).

Relationships between components of motivation

Since the later eighties, researchers have intensively discussed whether the components of motivation in expectancy-value theory can be empirically separated from each other and can be assessed as distinct constructs. They found that even first-graders differentiate between expectancies and task values, and this distinction persists for school and university students (see an overview in Eccles & Wigfield, 2020). Although the magnitudes of the relationships between self-efficacy, value, and cost are related to the question of whether distinct assessments of these components are possible, these relationships have not yet been the focus of research and need further elaboration with respect to the objects of interest targeted in motivational constructs. In the case of the drawing strategy, one open question is whether students who believe they are able to make a drawing also value this strategy and assign lower costs to this strategy than students who are not sure about whether they can apply this strategy while solving a problem.

It is plausible to assume that students who value an activity are likely to engage in this activity, to gain higher proficiency in doing this activity, and to consequently report higher self-efficacy regarding the respective activity. Further, self-efficacy might be related to cost, as students who ascribe low cost to an activity may engage in the activity more often, may be more successful in this activity, and may improve their expectations. Expectancy-value theory posits what factors can affect students' task value and cost. For example, students' interpretations of their prior experiences (which are related to self-efficacy) influence their affective reactions (e.g., enjoyment and pleasure), which in turn affect task value and cost. A positive relationship between the value and cost components results from their close relationship in expectancy-value theory. Eccles and Wigfield (2020) argued that the overall value of a task depends on its costs. If students think that an activity is too time consuming and too difficult, the value of this activity decreases. For example, if a student assumes that making a drawing is not worth the time, he or she might value making drawing less than a student who ascribes low cost to the drawing strategy. Most studies have reported significant relationships between the three components of motivation. The relationship between expectations and the intrinsic value of mathematics ranged widely between .36 and .68 for students in Grades 1 to 9 in the United States (Gaspard et al., 2020). In a study of adolescent students in mathematics in Korea, cost was negatively related to expectancies (-.24) and to task value (-.23) (Jiang et al., 2018).

Gender differences in self-efficacy, value, and cost

Gender differences were one of the main starting points for the development of expectancy-value theory. According to this theory, gender differences in choices in STEM subjects can be explained by differences in expectancies and values and go back to gender stereotypes in society. Indeed, an analysis of public views in many countries confirmed inequities in expectations and achievement in mathematics between female and male students (Forgasz & Leder, 2017). Such inequities were in turn found to increase self-efficacy expectations in male students and to decrease them in female students. Consequently, there are well-documented differences between female and male students in self-efficacy in mathematics across many countries all over the world (Else-Quest et al., 2010). According to expectancy-value theory, students value activities and tasks that correspond to their social and personal identities (Eccles & Wigfield, 2020). By engaging in these tasks, students can express themselves. Given that mathematics is seen as a male domain in many societies, many female students do not see mathematics as part of their identity, and they value mathematics less than male students do. As a result, many students demonstrate a gender gap in expectancies and value. In PISA 2012, female students reported lower self-efficacy and lower interest in mathematics than male students in Germany (Cohen's d of 0.53 and 0.39 in Schiepe-Tiska & Schmidtner, 2012). However, we do not know the extent to which self-efficacy, value, and cost with respect to strategy use might differ between female and male students. As making a drawing to solve modelling problems is part of the solution process, one can have lower expectations for female students. A gender difference in anxiety with respect to strategy use supports this expectation (Schukajlow et al., 2019). For differences in value and cost, we do not have specific expectations. It might be possible that female and male students value the use of the drawing strategy to a similar extent and assign a similar level of cost to this activity while solving mathematical problems.

Research questions and hypotheses

On the basis of expectance-value theory and prior research, we investigated the following research questions in this study:

RQ1: Are the components of strategy-based motivation (self-efficacy, task value, and cost) related to each other with respect to the drawing strategy?

H1: Self-efficacy will be positively related to task value and self-efficacy and task value will be negatively related to cost.

RQ2: Do female and male students differ in self-efficacy, task value, and cost with respect to the drawing strategy?

H2: Female students will have lower self-efficacy for the drawing strategy than male students, but no clear expectations in gender differences regarding value and cost could be derived from prior research.

Method

Present study, sample, and procedure

To address the research questions and test the hypotheses, we reanalyzed a sample collected in the framework of the Visualizations While Solving Modelling Problems project. This project is aimed at clarifying the role of learner-generated visualizations in solving modelling problems, including the effects of motivation and emotions on strategy use, quality of drawings, and performance. In one of the studies, students ($N = 435$; 6 middle-track schools) in each class were assigned to one of four groups. Three groups were trained in knowledge about the drawing strategy, whereas one group practiced algebraic procedures (e.g., solving equations). A prior analysis indicated indirect positive effects of the strategy training on performance with strategic knowledge about drawing and quality of drawings as intervening variables (Rellensmann et al., 2021). Before (T1) and after (T2) the training sessions, students filled out a questionnaire on self-efficacy, task value, and cost, among other tests. At T1, they reported their gender. At T2, some students were missing, or students did not answer all the scales on the questionnaire. Thus, the overall sample included 402 students (46% female; 14.6 years of age) from all four treatment groups.

Scales on self-efficacy, value, and cost

We used 5-point scales on self-efficacy, value, and cost with respect to the drawing strategy ranging from 1 (*not at all true*) to 5 (*completely true*). We adapted the items for this study from a prior study on motivation and learning strategies in mathematics (Berger & Karabenick, 2011) by focusing the items on learner-generated drawings while solving difficult word problems (Schukajlow et al., 2021). Self-efficacy regarding the drawing strategy was assessed with three items (e.g., “I’m confident I can make a very good drawing to solve any word problem”; Cronbach’s $\alpha = .79$). Task value was assessed via interest value (2 items; e.g., “I like making drawings to solve difficult word problems”), attainment value (4 items, e.g., “making a drawing to solve difficult word problems is an important part of who I am”), and utility value (3 items, e.g., “I believe that it is important to make a drawing because drawings help me solve difficult word problems”). Cronbach’s α for the task value scale was good ($\alpha = .88$). Personal cost was

assessed with three items (e.g., “It takes a lot of effort for me to create a drawing to solve a difficult word problem”; $\alpha = .70$). A confirmatory factor analysis confirmed the structural validity of the motivation to use the drawing strategy scale (Schukajlow et al., 2021).

Results

Relationships between self-efficacy, task value, and cost

Our first research question addressed the relationships between the three components of motivation: self-efficacy expectations, value, and cost. To address the first research question, we calculated Pearson correlations. In line with our expectations, the analysis revealed a positive relationship between self-efficacy and value with respect to the drawing strategy at T1 (.394) and T2 (.482; $ps < .001$). We also found a negative relationship between self-efficacy and cost with respect to the drawing strategy at T1 (-.386) and T2 (-.154; $ps < .001$) as expected in our study. Value and cost with respect to the drawing strategy were negatively related at T1 (-.141; $p < .01$) and the two motivational variables were not related at T2 (.027; $p = .573$). These results partly confirmed our expectations.

Gender differences between self-efficacy, task value, and cost

We applied an ANOVA with the factor gender and the dependent variables self-efficacy, value, and cost to address RQ2 on gender differences in SBM (see the descriptive statistics in Table 1).

Table 1: Means and standard deviations for self-efficacy, value, and cost at T1 and T2

	Self-efficacy		Value		Cost	
	T1: <i>M(SD)</i>	T2: <i>M(SD)</i>	T1: <i>M(SD)</i>	T2: <i>M(SD)</i>	T1: <i>M(SD)</i>	T2: <i>M(SD)</i>
female	2.94(.77)	3.15(.90)	3.31(.75)	3.34(.75)	2.64(.87)	2.83(.94)
male	3.17(.85)	3.30(.82)	2.96(.79)	3.12(.76)	2.57(.90)	2.82(.91)

At T1, the ANOVA revealed overall differences between female and male students regarding SBM, $F(3, 432) = 18.319, p < .001, \eta^2 = .113$. Similarly, at T2, the ANOVA showed differences in SBM regarding drawings between female and male students, $F(3, 401) = 7.772, p < .001, \eta^2 = .055$. A post hoc analysis confirmed our expectations about low self-efficacy in the use of the drawing strategy in female students compared with male students at T1 and T2; T1: $F(df = 1) = 8.836, p < .01, \eta^2 = .020$; T2: $F(df = 1) = 2.287, p = .078, \eta^2 = .008$. Moreover, female students assigned a higher value to the drawing strategy than male students at T1, $F(df = 1) = 8.836, p < .01, \eta^2 = .020$. At T2, the value of the drawing strategy tended to be higher in female students; T2: $F(df = 1) = 2.287, p = .078, \eta^2 = .008$. The cost of the drawing strategy did not differ between female and male students; T1: $F(df = 1) = .733, p = .392, \eta^2 = .002$; T2: $F(df = 1) = 2.287, p = .851, \eta^2 < .001$.

Discussion

The aim of the present study was to analyze the relationships between three motivational components (i.e., self-efficacy, value, and cost) and to examine the gender gap in motivation.

The theoretical basis of our study came from the expectancy-value theory of achievement choices (Eccles & Wigfield, 2020). We followed the theory about the importance of the object for the investigation of effects (Schukajlow et al., 2017) and addressed SBM in our research. As a strategy, we selected learner-generated drawings, which were found to be beneficial for solving geometry modelling problems in prior studies (e.g. Rellensmann et al., 2017).

We found that self-efficacy was positively related to value and negatively related to cost at two time points. This finding indicates that students who demonstrate higher self-efficacy with respect to the use of the drawing strategy value this strategy and assign it a low cost. Our result is in line with the assumptions of expectancy-value theory about the relationship between expectancy and value beliefs and indicates the possibility of a feedback loop between expectancies on the one side and value and cost on the other side. The mechanism behind the relationship between self-efficacy and value should be investigated in future studies. One way this mechanism might work is that value increases students' engagement, and engagement positively affects performance, which in turn affects self-efficacy. Similarly, students who assign a low cost to a task are more engaged in doing this task, improve their performance, and increase their expectations of doing well when performing this task in the future. This relationship was stable across the two time points. This finding indicates stability in self-efficacy's relationship to value and cost. Cost was negatively related to value at T1, but it was not related to value at T2. This result is partly in line with our expectations. Moreover, cost's relationships with self-efficacy and value were weak at T1. Indeed, the relationship between cost and value was also weak in a prior study (Jiang et al., 2018). Along with other findings, our finding indicates that cost should be addressed as a distinct component in future studies. This is important because self-efficacy and cost have been shown to affect the quality of the drawing strategy and performance in solving modelling problems (Schukajlow et al., 2021). Another important result is that the relationships between cost and the two other components of motivation were slightly weaker at T2, and the relationship between cost and value was not even significant, which might be an indication that motivation to use the drawing strategy is not very stable. Solving problems that require the application of the drawing strategy might change students' perceptions of the cost of this strategy, which in turn might influence the relationships between cost and the two other components of the SBM. Our findings add to prior research on the relationships between the components of motivation (Gaspard et al., 2020; Jiang et al., 2018). Moreover, a new theoretical contribution of this study is that it expands the predictions of expectancy-value theory to SBM. Addressing the motivation to use the drawing strategy and investigating relationships between the three components of motivation are novel contributions of this study and, to the best of our knowledge, have not been made before.

Our analysis of gender differences in SBM revealed overall differences between female and male students at two time points. Female students reported lower self-efficacy expectations compared with male students at both T1 and T2. These differences are in line with prior findings on female students' low self-efficacy expectations regarding mathematics and confirm the existence of a gender gap (Schiepe-Tiska & Schmidtner, 2012). Interestingly, female students tend to value the use of the drawing strategy for solving modelling problems more than male students. This result was significant at T1, and the difference just missed the significance level at T2. A higher valuing of the drawing strategy in female students was unexpected because

prior research has revealed that female students often value mathematics less than male students do. Consequently, gender stereotypes are not transmitted to all problem-solving activities in mathematics, and this is an important theoretical contribution of our study. One explanation might be that doing mathematics in school and in society might be more strongly associated with calculations or numbers and less with drawing activities. An open question with possible practical implications is whether focusing on strategies in mathematics classes and offering a more complex image of mathematics in society—one that goes beyond calculations or working with numbers—can contribute to changing gender stereotypes and can decrease the gender gap. The cost of applying the drawing strategy did not reveal any gender differences in SBM. Summarizing our results regarding SBM, we see a mixed picture: Female students have lower self-efficacy expectations and place a higher value on the drawing strategy than male students, whereas female and male students ascribe similar costs to the drawing strategy. An important practical implication of our study is that it uncovered different ways in which female and male students' SBM can be supported in mathematics classrooms. To increase female students' SBM, teachers should pay more attention to self-efficacy regarding strategy use (e.g., by giving positive feedback on the quality of students' drawings), whereas male students might benefit more if teachers emphasize the value of a strategy (e.g., by emphasizing the positive effects of using drawings to solve geometrical problems.)

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