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Short Intervention, Sustained Effects: Promoting Students' Math Competence Beliefs, Effort, and Achievement

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The present study investigated the effectiveness of two short relevance interventions (writing a text or evaluating quotations about the utility of mathematics) using a sample of 1,916 students in 82 math classrooms in a cluster randomized controlled experiment. Short-term and sustained effects (6 weeks and 5 months after the intervention) of the two intervention conditions on students' competence beliefs (self-concept, homework self-efficacy), teacher-rated individual effort, and standardized test scores in mathematics were assessed. Hierarchical linear regression analyses showed that students' homework self-efficacy was higher in both intervention groups 6 weeks and 5 months after the intervention compared to the control condition. Students' self-concept, teacher-rated effort, and achievement in mathematics were promoted through the quotations condition, partly in the long term.

KEYWORDS: competence beliefs, effort, expectancy-value theory, math achievement, relevance intervention

How can secondary school students be supported to become more self-confident, hardworking, and successful in mathematics? To foster student motivation and performance, especially in science, technology, engineering, and mathematics (STEM) subjects, researchers and educational stakeholders promote relevance-enhanced teaching (e.g., Davis & McPartland, 2012; Osborne & Dillon, 2008). Indeed, yearlong teaching programs systematically emphasizing connections between mathematical learning material and career opportunities have been found to raise students' math grades (Woolley, Rose, Orthner, Akos, & Jones-Sanpei, 2013), and shorter interventions using writing assignments about the personal relevance of STEM subjects have been shown to improve students' perceived utility of and interest in STEM (e.g., Hulleman & Harackiewicz, 2009).

These findings are promising, but only little is known about the potential of short relevance interventions implemented in school classrooms (for an exception, see Hulleman & Harackiewicz, 2009). First, there is a need for comparative studies to investigate the relative strength of different intervention approaches. To this end, successful intervention strategies could be combined or added with new features to create various treatment conditions. Second, the majority of studies on the effects of classroom-based relevance interventions focused mainly on the focal construct (value beliefs) and achievement as outcomes. The impact of relevance interventions on students' competence beliefs and effort, however, has not yet been investigated

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in school classroom settings. Concerning treatment effects on performance, students' grades or exam scores but no standardized test scores have been used as achievement measures, producing inconsistent findings (e.g., Hulleman, Godes, Hendricks, & Harackiewicz, 2010, Study 2; Woolley, Rose, Orthner, Akos, & Jones-Sanpei, 2013). Besides, no outcomes other than grades have so far represented the teachers' perspective in the evaluation of relevance interventions.

To shed light on these research gaps, we used data from the Motivation in Mathematics (MoMa) study in which two different relevance interventions (one adapted from previously used approaches and one novel one) were implemented in 82 math classrooms in Grade 9 using a cluster randomized controlled study design. Prior analyses have found these interventions to improve students' value beliefs of mathematics (Gaspard, Dicke, Flunger, Brisson, et al., 2015) and students' self-reported effort (Gaspard et al., 2016). The present study analyzed and compared the short-term and sustained effects of the same treatments on further outcomes neglected in previous classroom-based relevance experiments, namely, students' self-concept, homework self-efficacy, teacher-rated effort, and standardized test scores in mathematics.

The Importance of Perceived Utility Value in Mathematics

The Eccles et al. (1983) expectancy-value theory (EVT) is a powerful framework highlighting the importance of students' perceived utility value in determining students' achievement-related behaviors and performance (Eccles & Wigfield, 2002). According to EVT, students perceive high levels of utility value when they believe that engaging in an academic task will help them reach their personal goals. With regards to intrinsic and extrinsic motivation—two motivational concepts referring to either doing an activity for inherent satisfaction or to reach some separable outcome (self-determination theory, e.g., Ryan & Deci, 2000)—the utility value component defined in expectancy-value theory simultaneously comprises both intrinsic and extrinsic reasons for putting effort in a task (Eccles, 2005). More precisely, task completion is valued because the outcome of the task is expected to serve another end; this goal, however, may be personally meaningful to the student. Supporting students to relate the learning contents to their personal goals and to thus link intrinsic and extrinsic reasons for task engagement seems a promising approach for classroom motivational interventions (e.g., Trautwein et al., 2013).

Numerous empirical studies underline that it is beneficial for students' motivation, behavior, and performance when students perceive the learning contents to be useful (for overviews, see Roeser, Eccles, & Sameroff, 2000; Wigfield & Cambria, 2010; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006). In mathematics, students reporting high levels of utility value also show high levels of competence beliefs (for instance, self-efficacy and ability perceptions), effort, and achievement (e.g., Cole, Bergin, & Whittaker, 2008; Eccles & Wigfield, 1995; Gaspard, Häfner, Parrisius, Trautwein, & Nagengast, 2017; Husman & Hilpert, 2007). However, studies on the development of students' value beliefs demonstrate that students' utility value in mathematics is decreasing continuously throughout secondary school (e.g., Chouinard, Karsenti, & Roy, 2007; Chouinard & Roy, 2008; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). In line with these findings, interviews have shown that secondary school students have a hard time coming up with concrete examples for the utility of mathematical knowledge in real-life situations (Harackiewicz, Hulleman, Rozek, Katz-Wise, & Hyde, 2010).

Researchers have therefore examined how students' perceived utility value can be promoted and found relevance-enhanced teaching approaches to bear a huge potential in fostering STEM-related student outcomes in both laboratory and natural learning settings (for overviews, see Durik, Hulleman, & Harackiewicz, 2015; Lazowski & Hulleman, 2016; Rosenzweig & Wigfield, 2016; Yeager & Walton, 2011). Two types of strategies have been employed to convey the relevance of STEM subjects to students: (a) providing information about the utility of the learning material, for instance, for daily life (e.g., Durik & Harackiewicz, 2007, Study 2) and (b) having students generate arguments for the utility of the learning material themselves (e.g., Hulleman & Harackiewicz, 2009). Results concerning the effectiveness of these intervention strategies, however, vary across different types of settings (laboratory vs. classroom), outcomes, and students' prerequisites (see Durik, Hulleman, et al., 2015). In a series of lab studies (Canning & Harackiewicz, 2015, Studies 1 and 2; Durik & Harackiewicz, 2007, Study 2; Durik, Shechter, Noh, Rozek, & Harackiewicz, 2015, Study 1; Hulleman et al., 2010, Study 1; Shechter, Durik, Miyamoto, & Harackiewicz, 2011, Study 1), both strategies have been shown to raise undergraduates' perceived utility of and interest in a math multiplication technique. Furthermore, the provision of utility information promoted students' involvement, effort, competence valuation, perceived competence, and test scores when applying the same technique—in particular for high achievers. For low achievers, a combination of both strategies has been found to increase students' perceived utility of and interest in the math multiplication technique as well as test scores when applying the technique (Canning & Harackiewicz, 2015, Study 2).

Fewer studies intervened on students' utility value of STEM subjects in real-life classroom settings, but their success is compelling: Providing information about the utility of mathematical learning contents for career opportunities has been found to foster secondary school students' math grades (Woolley et al., 2013). Having students generate arguments for the relevance of specific topics in science or psychology courses promoted students' utility value, interest, success expectancies, and—partially—grades or exam scores, especially for students with low actual or perceived competence (Hulleman et al., 2010, Study 2; Hulleman & Harackiewicz, 2009; Hulleman, Kosovich, Barron, & Daniel, 2017, Study 2). An overview of the central characteristics of these classroom-based studies (setting, sample size, intervention, evaluation design, and results) is provided in Table 1. Drawing from these studies, we created two relevance interventions including new features with regards to the focus, strategies, and level of the interventions and compared their short-term and sustained effects on previously neglected outcomes, including different perspectives (students and teachers).

Characteristics of the MoMa Interventions

In previous school interventions in STEM subjects, students typically looked into the relevance of specific learning topics for their lives using numerous writing assignments or teacher-led lessons (see Table 1). However, instead of concentrating on topic-specific relevance, students in the MoMa interventions had to reflect on the personal relevance of mathematics as a broader domain, in particular for future education and career pathways. This approach aims to support students' continuous math investment over and above the topic currently dealt with in class (cf. correlational and experimental research on the importance of students' school and professional goals for their math investment, e.g., Peetsma & van der Veen, 2011; Schuitema, Peetsma, & van der Veen, 2014).

In addition, the MoMa interventions integrated previous successful intervention approaches, namely, presenting and self-generating utility arguments (e.g., Durik & Harackiewicz, 2007, Study 2; Hulleman & Harackiewicz, 2009), into one approach. Combining different interventions may have additive effects if the interventions depend on different mechanisms (Yeager & Walton, 2011). Self-generating utility arguments in individual writing assignments enables students to make personalized connections with the learning material (Hulleman et al., 2017). The personalization of the intervention message in turn has been found to be crucial for the meaningfulness and effectiveness of educational interventions (Walton, 2014; Yeager & Walton, 2011). However, as students might lack concrete examples of the utility of mathematics in real-life situations (Harackiewicz et al., 2010), generating utility arguments in individual essays without any preparation (e.g., Hulleman & Harackiewicz, 2009) might be a difficult task for them. Presenting some examples for the utility of mathematics for specific education and career pathways might help students in reflecting about their own personal relevance of mathematics in a more productive way. In addition, discussing occupations in which general math knowledge and analytic skills are needed might create a moment of sudden insight for students—in particular, when the need for mathematics is not very obvious (e.g., for studying social sciences). This might help to change the way students think about the

Table 1
Overview of Relevance Interventions in STEM Subjects in the Classroom

			Intervention				
Study	Setting	Sample Size	Level	Instructor	Design	Evaluation Design	Reported Results
Hulleman and Harackiewicz (2009)	High school, Grade 9 Subject: science (biology, integrated science, physical science)	n = 262 E: n = 136 C: n = 126	Student	Research assistant, teacher	8 essays in 1 semester: E: describe utility of course material to one's life C: summarize course topic	SQ before first and after last essay End-of-semester grade (1 week after last essay) No follow-up	No main effects Effects on interest in science and grades moderated through success expectations No effects on interest in science-related courses and careers No moderation through gender and race
Hulleman, Godes, Hendricks, and Harackiewicz (2010), Study 2	College Introductory psychology course	n = 318 E1: n = 78 E2: n = 82 C1: n = 78 C2: n = 80	Student	Research assistant	2 essays in 3 weeks: E1: describe relevance of course topic in a letter to a significant person in one's life E2: discuss relevance of media report for course topic C1: summarize course topic C2: discuss how abstract of scientific article expands on course topic	SQ before first and after second essay End-of-year grade (3 weeks after last essay) No follow-up	Main effects of E1 and E2 on situational interest Effects of E1 and E2 on utility value and maintained interest moderated through initial performance No effects on grades

(continued)

Table 1 **(continued)**

			Intervention				
Study	Setting	Sample Size	Level	Instructor	Design	Evaluation Design	Reported Results
Hulleman et al. (2017), Study 2	University Introductory psychology course	n = 357 E1: n = 116 E2: n = 122 C: n = 119	Student	Teacher (online)	2 essays (after first and second exam): E1, E2: relate course material to one's life E2 (enhanced intervention): (after first exam) create implementation intentions for relating course material to one's life, (after second exam) reflect on self-regulation strategies C: summarize course topic	SQ before first and about 6 weeks after second essay Exam scores throughout the semester Final course grade	Main effects of E1 and E2 on success expectancy and grade Effects of E1 and E2 on interest and success expectancy moderated through initial performance Effects of E1 and E2 on final exam scores moderated through success expectancy and initial performance; three-way-interactions with initial performance, gender No effects on utility value or cost
Woolley, Rose, Orthner, Akos, and Jones-Sanpei (2013)	Middle school, Grades 6–8 Subject: mathematics (and others)	n = ~6,500 E: n = 3,295 C: n = ~3,200	School	Teacher	E: follow 10 teacher-led math lessons per year in Grades 6–8 including career relevant examples and problems linked to the standard curriculum (class-level intervention) C: regular instruction	End-of-year grades in Grades 3–5 End-of-year grades in Grades 6–8 No follow-up	Main effects on math grades in Grades 7 and 8 No effects on math grades in Grade 6

Note. E = experimental group; C = control group; SQ = student questionnaire.

relevance of mathematics (cf. Walton, 2014). We expected that the effectiveness of the first MoMa intervention condition, namely, writing a text about the personal relevance of math (Hulleman & Harackiewicz, 2009), would benefit from a preceding input on the utility of mathematics.

Another way to possibly enhance the effectiveness of social-psychological interventions is the use of contextually appropriate anecdotes or quotations from older students about situations in which they needed mathematical knowledge (Yeager & Walton, 2011). This assumption is supported by a social cognition perspective as found in social learning theory (Bandura, 1977), possible-selves theory (Markus & Nurius, 1986), and identity-based motivation (Oyserman & Destin, 2010), which postulate that students can learn from persons they identify with. Accordingly, young adults describing the utility of mathematics in their lives could help students imagine a potential future identity and the importance of mathematical skills in developing this identity. As interview quotations provide personal and authentic utility information, they might be an effective tool to encourage students' personal reflection about the relevance of mathematics (see Harackiewicz, Rozek, Hulleman, & Hyde, 2012, who used a similar approach as part of a more comprehensive motivation intervention in STEM subjects). Having students evaluate quotations about the relevance of mathematics in the second MoMa intervention condition was thus aimed at supporting students' own valuing of math.

Compatibility with students' natural learning environment is an important precondition for the effectiveness of classroom-based interventions. Previous relevance interventions in STEM subjects were mainly conducted at the student level (see Table 1). As students are typically taught together in classes, however, intervening at the classroom level would come closer to the natural learning setting. At the same time, class-level interventions allow for students' active participation, for instance, in discussions about the relevance of mathematics. This might help in triggering personal reflection and thus increase treatment effects. As an additional advantage, between-class experimental designs allow for a more precise estimation of the intervention effects: They bear a reduced risk of diffusion effects that occur in within-class experimental designs when classmates randomized into different intervention conditions interact with each other (Craven, Marsh, Debus, & Jayasinghe, 2001).

Lastly, we also evaluated the effectiveness of the interventions more broadly than the studies presented in Table 1. More precisely, research is missing investigating direct treatment effects of classroom-based relevance interventions on motivational, behavioral, and achievement outcomes simultaneously. Findings so far considered students' grades (all studies shown in Table 1), interest (all studies by Hulleman et al.), utility value (Hulleman et al., 2010, Study 2, 2017, Study 2), and cost and success expectancy (Hulleman et al., 2017, Study 2). However, further motivational outcomes such as students' self-concept and self-efficacy, behavioral outcomes such as effort, and standardized performance measures have been neglected in previous research. Moreover, as all previous outcome measures with the exception of grades were measured using students' self-reports, the teacher's perspective has not yet been considered in the evaluation of the effectiveness of relevance interventions. Besides, the sustainability of the intervention effects through the use of a follow-up measurement has so far only been investigated for performance (Hulleman et al., 2017, Study 2; Woolley et al., 2013).

Competence Beliefs, Effort, and Test Scores: Understudied Outcomes of Classroom-Based Relevance Interventions

A closer examination of the Eccles et al. (1983) expectancy-value theory suggests a range of educational outcomes that could be affected by relevance interventions. First of all, EVT assumes students' value beliefs to be positively interrelated (Eccles & Wigfield, 2002), which implies that promoting students' utility value may also foster other value beliefs (see Gaspard, Dicke, Flunger, Brisson, et al., 2015, for the effects of the MoMa interventions on students' value beliefs). Furthermore, according to EVT, students' utility value is closely associated with students' competence beliefs and predicts achievement-related behaviors (e.g., effort) and test performance (Eccles & Wigfield, 2002; Wigfield et al., 2006)—outcomes that are understudied when analyzing the effectiveness of relevance interventions in secondary schools.

If students are aware of the utility of a subject for attaining their personal goals, they may be ready to tackle related tasks intensely and thereby discover their academic potential in a domain (see Hulleman et al., 2017). They may also be willing to put in more effort, thus positively engaging in learning (e.g., Reschly & Christenson, 2012). Hence, pondering over the relevance of the learning material could promote students' academic self-concept, self-efficacy, and effort. Students' academic self-concept is a domain-specific competence belief referring to how students evaluate their abilities in an academic domain (Eccles & Wigfield, 2002). Students' math self-concept has been found to be a strong predictor of students' interest, effort, persistence, choice of task difficulty, course choice, and performance in mathematics (e.g., Denissen, Zarrett, & Eccles, 2007; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Trautwein, Lüdtke, Roberts, Schnyder, & Niggli, 2009). Students' self-efficacy is a task-specific competence belief assessing students' confidence in their ability to successfully accomplish a specific task like their math homework (Bandura, 1994). Students' math homework self-efficacy has been shown to influence students' homework-related value beliefs as well as homework effort and compliance in mathematics (Trautwein, Lüdtke, Schnyder, & Niggli, 2006)—behaviors that in turn impact math performance (e.g., Zimmerman & Kitsantas, 2005).

Supporting the assumptions made in EVT, numerous nonexperimental studies have shown positive associations of secondary school students' utility value beliefs with their self-concept or self-efficacy concerning mathematics or math homework (e.g., Chouinard et al., 2007; Eccles & Wigfield, 1995; Husman & Hilpert, 2007; Jacobs et al., 2002; Trautwein & Lüdtke, 2009) as well as effort in mathematics (e.g., Chouinard et al., 2007; Cole et al., 2008; Trautwein, Lüdtke, Kastens, & Köller, 2006; Trautwein, Lüdtke, Schnyder, et al., 2006). In addition, in lab experiments, subgroups of students (e.g., low achievers) were more confident in applying a new math technique correctly and put more effort in using the technique after reading about its utility (Durik & Harackiewicz, 2007, Study 2; Shechter et al., 2011, Study 1). Similarly, a classroom intervention during which undergraduate students collected arguments about the personal relevance of various topics in introductory psychology fostered low achievers' expectancies to succeed in the course (Hulleman et al., 2017, Study 2). However, the effects of relevance interventions conducted in secondary school classrooms on students' domain-specific self-concept, task-specific self-efficacy, and effort as well as the sustainability of such effects have not yet been investigated.

Furthermore, relevance interventions could promote students' test performance. Yet, whereas lab-based relevance experiments have been found to foster students' test scores (e.g., Canning & Harackiewicz, 2015, Studies 1 and 2; Durik & Harackiewicz, 2007, Study 2), classroom-based intervention studies have only investigated students' grades or exam results as achievement outcomes so far; these analyses yielded inconsistent results, namely, either main effects (Woolley et al., 2013), moderated effects (e.g., Hulleman & Harackiewicz, 2009; Hulleman et al., 2017, Study 2), or no effects (Hulleman et al., 2010, Study 2) on grades or exam scores. These mixed results might in part be due to teachers' subjective grading practices (e.g., McMillan, 2001). Consequently, there is a need to analyze whether classroom-based relevance interventions promote achievement measured by standardized test scores.

The Current Study

In the present study, we investigated the short-term and sustained effects of two short relevance intervention conditions (quotations, text) implemented at the classroom level on ninth-grade students' competence beliefs, teacher-rated effort, and test scores in mathematics compared to a control group. Based on previously established approaches, students were first presented arguments for the utility of mathematics and then reflected on the personal utility of mathematics in an individual writing assignment. Drawing on a social cognition perspective (Bandura, 1977; Markus & Nurius, 1986; Oyserman & Destin, 2010) and prior intervention approaches (Harackiewicz et al., 2012), students in the quotations condition commented on interview quotations by young adults about the relevance of mathematics. Adapted from a successful strategy first tested by Hulleman and Harackiewicz (2009), students in the text condition generated texts about the personal relevance of mathematics. We included a broad range of important outcomes, namely, students' self-concept, homework self-efficacy, effort, and standardized test scores in mathematics. As students' effort is observable (e.g., Fredricks, Blumenfeld, & Paris, 2004), teachers rated individual students' effort in the current study, thereby including teachers' perspective on the effectiveness of the interventions and going beyond previous investigations concerning student-reported effort (Gaspard et al., 2016). To learn about the sustainability of the intervention effects, we used a follow-up design evaluating treatment effects 6 weeks and 5 months after the interventions.

Prior analyses with the same data set showed that students' utility value was fostered through both intervention conditions for at least 5 months and that students' other value beliefs of mathematics (attainment and intrinsic value) except for cost were promoted to different degrees (Gaspard, Dicke, Flunger, Brisson, et al., 2015). Furthermore, the quotations condition had stronger effects on students' self-reported effort than the text condition (Gaspard et al., 2016). Grounded on EVT (Eccles & Wigfield, 2002) and findings from correlational (e.g., Chouinard et al., 2007; Cole et al., 2008; Trautwein, Lüdtke, Kastens, et al., 2006) and experimental research (e.g., Durik & Harackiewicz, 2007, Study 2; Hulleman et al., 2017, Study 2), we hypothesized students' self-concept, homework self-efficacy, teacher-rated effort, and test scores in mathematics to be promoted through both intervention conditions. Due to lack of empirical evidence, no hypotheses were formulated concerning the stability of the treatment effects and the comparative strength of the two intervention conditions.

Method

Sample and Data Collection

Data were gathered in the project Motivation in Mathematics in 82 ninth-grade math classrooms from 25 academic track schools (*Gymnasium*) in the German state of Baden-Württemberg. The sample size was based on a power analysis for a multisite cluster randomized trial indicating a power of $\beta = .73$ to detect an effect of $\delta = .20$ per intervention condition compared to the control condition (see Gaspard, Dicke, Flunger, Brisson, et al., 2015, for more information). In the present sample, mathematics was taught as one comprehensive subject including different domains such as algebra, geometry, or calculus during four compulsory lessons per week. There was no further tracking of students in math courses within school. Math homework assignments were common in all but one class (98.8%). A total of 1,978 students with active parental consent participated in the study, corresponding to a participation rate of 96.0%. Sixty-two students absent during the day of the intervention were excluded from the analyses, yielding a sample of 1,916 students (53.3% female; mean age at the start of the study: M = 14.41 years, SD = 0.57; mean SES/ISEI[1]: M = 65.24, SD = 16.21). The large majority of students were Caucasian, and students with an immigrant background (21.2% with at least one parent born outside Germany) came from predominantly Western countries and were Caucasian.

Data collections took place from September 2012 to March 2013 and were administered by trained researchers. Students in the intervention conditions completed questionnaires before the intervention (pretest = T1) as well as 6 weeks (posttest = T2) and 5 months (follow-up = T3) after the intervention. Students in the waiting control group completed the same questionnaires at the same time points but did not receive any intervention before T3. Students' competence beliefs and effort were measured at all three time points. Students' math achievement was measured in the beginning of the school year and at the follow-up. Students' perceived utility of mathematics was also measured at all three time points and will be reported to give an account of how it was associated with the outcome variables and affected by the interventions (see also Gaspard, Dicke, Flunger, Brisson, et al., 2015). All 82 classes fully completed all waves of data collections.

Relevance Interventions

In the beginning of the study, all 73 participating teachers and their classes[2] were randomly assigned within their schools to one of the three study conditions (quotations: 25 classes, 561 students; text: 30 classes, 720 students; waiting control group: 27 classes, 635 students[3]). Before the first data collection, teachers participated in an information session about the design and theoretical background of the study. To gain teachers' trust in the project and avoid spillover effects (Craven et al., 2001), teachers in the waiting control group were informed that their classes would also receive the intervention after the last data collection and that they were not supposed to ask their colleagues in the experimental groups about the contents of the intervention. Teachers in the experimental groups were not informed whether their classes had been assigned to the quotations or text condition.

After students in all treatment conditions had completed the pretest, students in the intervention conditions received a 90-minute standardized relevance intervention led by five trained researchers in class and followed by two short intervention reinforcements to be completed at home. To control for implementation fidelity, researchers recorded the actual procedure of each intervention in the minutes. Every researcher conducted 8 to 13 interventions with roughly equal distribution between the two intervention conditions.

The interventions were designed combining previously tested strategies, namely, the presentation and self-generation of relevance arguments (e.g., Canning & Harackiewicz, 2015, Study 2), with newly developed features.

As a result, the interventions consisted of a psychoeducational presentation and an individual writing assignment differing by condition. High initial competence beliefs have been shown to be a prerequisite for appreciating relevance information (Canning & Harackiewicz, 2015; Durik, Hulleman, et al., 2015; Durik, Shechter, Noh, Rozek, & Harackiewicz, 2015, Study 2). As a confidence reinforcement, students were informed about research results concerning the importance of effort, different interpretations of achievement-related experiences, and frame of reference effects in school classrooms (see Marsh, 2005; Wigfield et al., 2006) in the first part of the presentation. The second and main part of the presentation dealt with the utility of mathematics as a broader domain for future education, career opportunities, and leisure time activities.

After the presentation, students completed individual writing assignments differing by condition. Based on theories of social cognition that assume that students can learn from persons they identify with (e.g., Bandura, 1977; Markus & Nurius, 1986; Oyserman & Destin, 2010), students in the quotations condition were encouraged to reflect on the personal relevance of mathematics by reading six interview quotations from young adults who describe the utility of mathematics to their lives. Covering a broad range of real-life situations, the quotations stemmed from a preceding interview study in which 30 persons (ranging from college students to working adults) were asked to describe personal situations where they needed math skills. During the intervention, the students were asked to evaluate the relevance of these quotations to their own lives by responding to a set of questions (for sample quotations and questions, see Appendix in the online version of the journal). Students in the text condition were asked to collect arguments for the personal relevance of mathematics to their current and future lives and then write a coherent text detailing their notes. This task was adapted from prior relevance interventions (e.g., Hulleman & Harackiewicz, 2009) by switching the focus of the assignment from specific course topics to mathematics as a domain (for the instruction and a sample text written by a student, see Appendix in the online version of the journal).

At the end of the intervention, students received a portfolio including two short intervention reinforcements to be filled out at home 1 week and 2 weeks after the intervention session, respectively. In the first reinforcement, students were asked to summarize what they remembered from their individual writing assignments in class. The second reinforcement differed by condition and corresponded to the type of individual assignment dealt with in class (quotations: reflection on given relevance information; text: self-generation of relevance arguments). Students in the quotations condition were asked to choose one out of several arguments about the relevance of mathematics provided on a webpage (www.dukannstmathe.de) and describe why it was convincing to them. Students in the text condition were asked to explain why mathematics was useful to a person they knew.

Students in classes in the waiting control condition did not follow any presentation or do any individual writing assignments. However, they received the more successful intervention approach after the last measurement point.

Measures

Math Competence Beliefs

Students' competence beliefs in mathematics were assessed with a student questionnaire using 4-point Likert type scales ranging from 1 (*completely disagree*) to 4 (*completely agree*) that were adapted from previous studies (e.g., Baumert, Gruehn, Heyn, Köller, & Schnabel, 1997; Prenzel et al., 2006). Math self-concept was measured with five items (e.g., "I am good at math," $\alpha = .93$). The math homework self-efficacy scale consisted of four items (e.g., "When I try hard, I can solve my math homework correctly," $\alpha = .76$).

Math Effort

Teachers rated individual students' math effort by responding to the item "This student works thoroughly on all of his/her math tasks and homework assignments" on a 4-point Likert type scale ranging from 1 (*completely disagree*) to 4 (*completely agree*).

Math Achievement

Students' results from a curriculum-based standardized test assessing math knowledge in the state of Baden-Württemberg in the beginning of Grade 9 served as an initial measure of math performance. The test assessed students' competencies in the mathematical domains of algebra, geometry, and probability calculus with 38 math problems. The math problems focused on three aspects of math proficiency: numbers and algorithms, space and shapes, linking and modeling (38 questions; assessed by percent correct). At the follow-up, students completed a 3-minute normed speed test, which measured students' fluency of solving typical math operations (50 questions; maximum number of points = 50) (Schmidt, Ennemoser, & Krajewski, 2013). Validity studies showed that this short speed test is a very good proxy for students' achievement in longer assessments using standardized, curriculum-based math tests (Ennemoser, Krajewski, & Schmidt, 2011; Schmidt et al., 2013). The internal consistency of the test was good (Cronbach's $\alpha = .89$).

Math Utility Value

Students' utility value of mathematics was measured through student ratings using a 4-point Likert type scale ranging from 1 (*completely disagree*) to

4 (*completely agree*). A comprehensive utility value scale consisting of 12 items (e.g., "I will often need math in my life") out of a newly developed value instrument was used (Gaspard, Dicke, Flunger, Schreier, et al., 2015). The scale showed good internal consistency (Cronbach's α = .84) (for more details, see Gaspard, Dicke, Flunger, Schreier, et al., 2015).

Statistical Analyses

Multilevel Regression Analyses

In order to test the treatment effects on students' competence beliefs, teacher-rated effort, and achievement, two-level linear regression analyses[4] were computed with Mplus (Version 7; Muthén & Muthén, 1998–2012) for each of the outcome variables. Separate multilevel regression analyses were carried out using students' competence beliefs and teacher-rated effort at T2 and T3 as well as students' math test scores at T3 as outcomes and two dummy variables indicating the treatment (quotations, text) as class-level predictors. Each outcome variable was regressed on the intervention conditions at the class level, the control condition being the reference group. In line with the recommended procedure to test intervention effects in cluster randomized trials (Raudenbush, 1997), initial values of the respective outcome variables were used as covariates both at the student level and class level. To account for contextual effects, all effects on the respective outcomes were freely estimated at both levels (Korendijk, Hox, Moerbeek, & Maas, 2011; Marsh et al., 2009). Covariates were added to the models using group-mean centering at the student level (Enders & Tofighi, 2007) and manifest aggregation at the class level (Marsh et al., 2009).

Effect Sizes

Before running the analyses, all continuous (but not dichotomous) variables were standardized. Consequently, the regression coefficients of the dummy variables can be directly interpreted as measures of the class-level effect sizes of the intervention conditions on the outcomes as compared to the control condition (Marsh et al., 2009; Tymms, 2004).

One-Tailed Versus Two-Tailed Tests

To evaluate the statistical significance of the treatment effects, the use of two-tailed tests is recommended, particularly if the literature does not support any directional hypotheses (e.g., Howell, 2012). Yet given our directional a priori hypotheses, the significance of the treatment effects was tested on the basis of one-tailed tests with an α level of 5%. This testing procedure additionally improves the power to detect small treatment effects at the class level (Stevens, 2012).

Missing Data

Missing data ranged from 2.3% to 19.6% for the outcome variables (see Table 2). Based on suggestions for the treatment of missing values by Graham (2009), the full information maximum likelihood method integrated in Mplus was used to deal with missing data. To make the assumption of missing at random more plausible, correlations of three auxiliary variables (students' gender; pretest cognitive ability score assessed with a figural cognitive ability test by Heller & Perleth, 2000; and end-of-year math grade in Grade 8) with the predictor variables were included in the models at both levels (Enders, 2010). The auxiliaries' and predictors' residuals were also included in the models at both levels.

Implementation Fidelity

To account for implementation fidelity, analyses were run with two types of samples: (a) including all classes participating in the interventions and (b) excluding two classes in which deviations from the intervention manual had been recorded in the minutes. Deviations occurred in two classes in the text condition: In one class, the initial presentation had to be held without any projector due to technical problems; in the other class, the researcher conducting the intervention noted that students were reluctant to participate in the intervention and in particular did not work quietly on their individual writing assignments. A comparison of the results showed no noteworthy differences, which is why all classes were included in the final analyses.

Results

Descriptive Statistics, Randomization Check, and Effects on Perceived Utility Value

Before analyzing treatment effects, the descriptive statistics (see Table 2) and the intercorrelations of all outcome variables including utility value beliefs (see Table 3) were calculated at all measurement points. As a randomization check, the differences in the pretest means for students' perceived utility value, competence beliefs, teacher-rated effort, and math achievement between the three study conditions were tested for statistical significance. No statistically significant differences between the conditions emerged, based on two-tailed Wald χ^2 tests (Bakk & Vermunt, 2016) with an α level of 5% (utility value: $\chi^2(2) = 0.79$, $p = .675$; self-concept: $\chi^2(2) = 0.88$, $p = .643$; homework self-efficacy: $\chi^2(2) = 3.73$, $p = .155$; teacher-rated effort: $\chi^2(2) = 5.01$, $p = .082$; math test score: $\chi^2(2) = 1.51$, $p = .470$). Concerning intervention effects on the focal construct, students' perceived utility of mathematics, analyses revealed a significant promotion through both the quotations

Table 2

Descriptive Statistics of the Sample Characteristics and the Study Variables per Intervention Condition

	Quotations (561 Students, 52.8% female)				Text (720 Students, 52.4% female)				Control group (635 Students, 55.6% female)			
	n	*M*	*SD*	ICC	*n*	*M*	*SD*	ICC	*n*	*M*	*SD*	ICC
Sample characteristics												
Age	561	14.61	0.45	.00	718	14.63	0.47	.00	635	14.64	0.47	.01
Cognitive ability score	519	19.96	4.01	.04	681	19.99	4.22	.05	610	19.62	4.27	.01
Math grade in Grade 8[a]	557	2.81	0.97	.04	714	2.73	0.97	.06	624	2.89	0.90	.02
Study variables[b]												
T1 Utility value	517	2.56	0.49	.05	680	2.52	0.47	.07	607	2.52	0.49	.09
Self-concept	515	2.76	0.79	.03	678	2.74	0.81	.04	606	2.67	0.81	.05
Homework self-efficacy	427	2.80	0.62	.03	599	2.72	0.62	.06	514	2.71	0.65	.04
Effort (TR)	497	3.03	0.81	.11	695	2.92	0.85	.03	601	2.84	0.94	.05
Test score	517	48.67	16.50	.08	676	49.85	18.19	.20	600	46.26	16.75	.15
T2 Utility value	530	2.64	0.50	.04	680	2.53	0.51	.08	601	2.45	0.50	.08
Self-concept	530	2.78	0.80	.03	679	2.73	0.80	.04	602	2.63	0.81	.06
Homework self-efficacy	492	2.82	0.64	.05	659	2.71	0.67	.05	586	2.67	0.65	.03
Effort (TR)	541	3.07	0.79	.10	719	2.89	0.90	.05	581	2.84	0.97	.05
T3 Utility value	516	2.60	0.49	.02	627	2.53	0.49	.11	557	2.44	0.51	.07
Self-concept	514	2.84	0.76	.03	628	2.80	0.76	.05	559	2.70	0.77	.05
Homework self-efficacy	460	2.89	0.64	.02	581	2.82	0.65	.05	523	2.71	0.69	.04
Effort (TR)	540	3.05	0.85	.09	710	2.90	0.92	.07	622	2.87	0.94	.03
Test score	516	32.59	7.51	.03	634	31.85	8.55	.04	559	30.74	8.24	.02

Note. ICC = intraclass correlation coefficient; T = time point; TR = teacher rating.
[a]In Germany, the grading system ranges from 1 (best grade) to 6 (worst grade).
[b]All study variables refer to the subject of mathematics.

Table 3

Intercorrelations of the Study Variables Within Class (Below Diagonal) and Between Class (Above Diagonal)

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
T1	(1)	Utility value	—	.52***	.58***	.02	.23*	.72***	.55***	.27*	–.02	.73***	.48***	.41***	–.03	.03
	(2)	Self-concept	.38***	—	.60***	.10	.38***	.29*	.81***	.38***	.06	.35**	.78***	.46***	.05	.14
	(3)	HW self-efficacy	.31***	.48***	—	.06	.34**	.36**	.60***	.66***	.14	.38***	.63***	.54***	.07	.09
	(4)	Effort (TR)	.16***	.28***	.13***	—	.28**	.09	.14	.03	.55***	.02	.11	.17	.50***	.43***
	(5)	Test score	.23***	.54***	.27***	.42***	—	.15	.44***	.25**	.24*	.12	.34**	.43***	.21*	.48***
T2	(6)	Utility value	.68***	.29***	.25***	.14***	.19***	—	.44***	.29*	.12	.84***	.36**	.45***	.05	.16
	(7)	Self-concept	.36***	.84***	.47***	.29***	.54***	.35***	—	.44**	.12	.41***	.88***	.55***	.09	.29**
	(8)	HW self-efficacy	.30***	.38***	.58***	.15***	.28***	.29***	.46***	—	.21*	.25†	.46***	.48**	.19*	.14†
	(9)	Effort (TR)	.23***	.30***	.16***	.67***	.41***	.21***	.33***	.18***	—	.06	.07	.20*	.72***	.37***
T3	(10)	Utility value	.60***	.27***	.19***	.11***	.20***	.66***	.30***	.26***	.18***	—	.36***	.47***	.12	.02
	(11)	Self-concept	.32***	.79***	.43***	.25***	.50***	.31***	.85***	.41***	.29***	.35***	—	.58***	.04	.26*
	(12)	HW self-efficacy	.29***	.41***	.52***	.10**	.27***	.30***	.48***	.59***	.16***	.33***	.51***	—	.19*	.20*
	(13)	Effort (TR)	.20***	.30***	.15***	.62***	.37***	.18***	.32***	.21***	.71***	.16***	.33***	.17***	—	.30**
	(14)	Test score	.16***	.43***	.19***	.22***	.51***	.11***	.40***	.20***	.24***	.12***	.40***	.18***	.24***	—

Note. T = time point; HW = homework; TR = teacher rating.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .01$.

condition (posttest: $\beta = .30$, $p < .000$; follow-up: $\beta = .26$, $p < .001$) and the text condition (posttest: $\beta = .14$, $p = .011$; follow-up: $\beta = .16$, $p = .004$) (see Gaspard, Dicke, Flunger, Brisson, et al., 2015).

Treatment Effects at Posttest and Follow-Up

Treatment effects at posttest and follow-up are reported in Table 4. Concerning math self-concept, students in classes in the quotations condition reported statistically significant higher values at the posttest ($\beta = .10$, $p = .019$) than students in classes in the control condition, controlling for their initial values. At the follow-up, this effect was slightly smaller and missed statistical significance ($\beta = .09$, $p = .062$). The text condition did not show a statistically significant effect on students' math self-concept neither at the posttest ($\beta = .03$, $p = .240$) nor follow-up ($\beta = .03$, $p = .264$).

With regards to math homework self-efficacy, students in classes in the quotations condition reported statistically significant higher values than students in classes in the control condition at both the posttest ($\beta = .16$, $p = .002$) and follow-up ($\beta = .20$, $p = .001$). For students in classes in the text condition, no treatment effect on math homework self-efficacy was observed at the posttest ($\beta = .08$, $p = .069$). However, at the follow-up, a statistically significant positive treatment effect emerged ($\beta = .16$, $p = .008$), which was not significantly different from the effect of the quotations condition according to a Wald χ^2 test, $\chi_2(1) = 0.37$, $p = .544$.

Concerning students' individual effort in mathematics as rated by their teachers, positive effects of the quotations condition emerged at both the posttest ($\beta = .14$, $p = .029$) and the follow-up ($\beta = .12$, $p = .046$). The text condition had no statistically significant effect on students' effort as observed by their teachers neither at the posttest ($\beta = .01$, $p = .463$) nor follow-up ($\beta = -.01$, $p = .474$).

As for math achievement, students in classes in the quotations condition had statistically significant better scores in the speed test ($\beta = .18$, $p = .004$) than students in classes in the control condition. Students in classes in the text condition, however, did not perform significantly better at the test ($\beta = .06$, $p = .168$) than students in classes in the control group.

Discussion

What can be done to help secondary school students become more self-confident, work harder, and show higher performance in mathematics? Based on the findings of the present study, a short relevance intervention (90 minutes in class, two reinforcement tasks at home) seems to be a promising support measure. In a cluster randomized controlled experiment, the effectiveness of two relevance interventions including the presentation of examples about the utility of mathematics for various life domains and individual writing assignments differing by condition was compared in math

Table 4

Effects of the Relevance Interventions on Students' Competence Beliefs, Teacher-Rated Effort, and Test-Based Achievement in Mathematics

	Self-Concept						Homework Self-Efficacy						Teacher-Rated Effort						Test Score		
	T2			T3			T2			T3			T2			T3			T3		
	β	(*SE*)	*p*	β	(*SE*)	*p*	β	(*SE*)	*p*	β	(*SE*)	*p*	β	(*SE*)	*p*	β	(*SE*)	*p*	β	(*SE*)	*p*
Student level																					
DV at T1	.84	(.02)	.000	.79	(.02)	.000	.59	(.03)	.000	.53	(.02)	.000	.67	(.03)	.000	.63	(.02)	.000	.55	(.03)	.000
Class level																					
DV at T1	.83	(.06)	.000	.80	(.06)	.000	.69	(.08)	.000	.62	(.09)	.000	.52	(.10)	.000	.46	(.09)	.000	.30	(.06)	.000
Quotations	.10	(.05)	.019	.09	(.06)	.062	.16	(.05)	.002	.20	(.06)	.001	.14	(.08)	.029	.12	(.07)	.046	.18	(.07)	.004
Text	.03	(.05)	.240	.03	(.05)	.264	.08	(.06)	.069	.16	(.06)	.008	.01	(.07)	.463	–.01	(.07)	.474	.06	(.06)	.168
Residuals																					
Student level	.27	(.01)	.000	.35	(.02)	.000	.63	(.03)	.000	.68	(.03)	.000	.51	(.03)	.000	.58	(.03)	.000	.72	(.03)	.000
Class level	.02	(.01)	.000	.02	(.01)	.001	.01	(.01)	.104	.02	(.01)	.057	.05	(.01)	.000	.05	(.01)	.000	.02	(.01)	.002

Note. Students' gender, pretest cognitive ability score, and end-of-year math grade in Grade 8 were included in the models as auxiliary variables. β = standardized regression coefficient; *SE* = standard error; *p* = one-tailed *p* value; DV = dependent variable; T = time point.

classrooms in Grade 9. Commenting on quotations about the relevance of mathematics fostered students' self-concept, homework self-efficacy, teacher-rated effort, and test scores in mathematics until up to 5 months after the intervention. Writing a text about the relevance of mathematics promoted students' long-term homework self-efficacy in mathematics to the same extent as the quotations condition, but no statistically significant effects were found on other outcomes under study.

New Insights Into the Effectiveness of Classroom-Based Relevance Interventions

Researchers in STEM fields acknowledge a need for relevance-enhanced teaching approaches that are highly effective and implementable by educational practitioners in real-life classroom contexts (e.g., Davis & McPartland, 2012; Osborne & Dillon, 2008). However, experimental studies testing the effectiveness of different relevance interventions under realistic and natural educational conditions are still rare. Using an adequate sample size of 82 ninth-grade classes, the effects of two class-level relevance interventions implemented in a real-life classroom setting on students' competence beliefs, teacher-rated effort, and achievement were assessed in the current study. Such a broad range of important outcomes has rarely been considered in prior motivation intervention studies (see meta-analytic and narrative reviews on motivation interventions in education by Lazowski & Hulleman, 2016; Rosenzweig & Wigfield, 2016). The direct comparison of two treatment conditions, inclusion of the teacher's perspective, and use of a follow-up measurement in the treatment evaluation constitute further innovations in classroom-based relevance intervention research.

The Quotations Condition: A Promising New Approach

The overall pattern of results found in the present study suggests that a newly developed intervention approach including the evaluation of quotations about the relevance of mathematics in young adults' lives was more effective than a strategy adapted from prior research, namely, the self-generation of arguments for the relevance of mathematics in a text (e.g., Hulleman & Harackiewicz, 2009). This finding corresponds with the results concerning the effects of the MoMa interventions on students' value beliefs (Gaspard, Dicke, Flunger, Brisson, et al., 2015) and student-rated effort (Gaspard et al., 2016) and may be explained in various ways.

First, although several examples of the utility of mathematics were discussed in the presentation preceding the writing assignment, finding and describing reasons for the relevance of mathematics as a domain in a text might have been a difficult task for the students (see Harackiewicz et al., 2010). Students in the text condition might therefore not have come up with the same number and range of relevance arguments that students read in the quotations.

Second, the writing of a text using reasoned argument—a typical task performed in diverse school subjects—might have been less engaging to students than the comparatively novel task of commenting on quotations. Compared to the text assignment, the novelty of the quotations assignment might thus have resulted in more in-depth and sustained learning about the relevance of mathematics (see Finn & Zimmer, 2012).

Third, differences in the quality of the connections made between mathematical knowledge and students' personal lives might also have contributed to the different pattern of results for the intervention conditions (e.g., Canning & Harackiewicz, 2015; Hulleman & Cordray, 2009; Hulleman et al., 2017). By getting authentic information about the utility of mathematics from young adults that ninth graders can easily connect to, students might have identified with the interviewees and realized that mathematical knowledge will be meaningful to their possible future (e.g., Markus & Nurius, 1986; Oyserman & Destin, 2010). In addition, students in the quotations condition were asked to relate the interviewees' utterances about the utility of mathematics to their personal lives by answering several questions one after the other (see Appendix in the online version of the journal). This guided step-by-step procedure might have helped students in the quotations condition to reflect on the personal relevance of mathematics more in depth than students in the text condition (see Acee & Weinstein, 2010, for another example of a successful motivation intervention using a step-by-step guidance to process persuasive messages).

Promoting Students' Competence Beliefs, Effort, and Achievement: Are the Effects Stable?

A closer look at the results of the present study suggests that students' math self-concept was promoted through the quotations condition for 6 weeks, whereas students' homework self-efficacy was fostered through both intervention conditions for 5 months. These differential treatment effects on students' competence beliefs might pertain to conceptual differences in the nature of these two outcomes (Bong & Skaalvik, 2003): Students' domain-specific self-concept seems to be more stable and less easily malleable than students' homework self-efficacy beliefs, which was also reflected in the high predictive power of students' initial math self-concept for students' subsequent math self-concept in the present study (see Table 4). The disappearance of the positive effect of the quotations condition on students' self-concept at the follow-up might have resulted from two processes taking place over time: On the one hand, students may not (yet) have perceived any actual improvement in their math achievement (compared to their previous math achievement or their performance in other domains).

An actual improvement in performance in turn has been found to be a precondition of a sustained promotion of students' domain-specific self-concept (see meta-analysis on self-concept interventions by O'Mara, Marsh, Craven, & Debus, 2006). On the other hand, students may have compared their own math achievement with their classmates' math performance. Such internal and external frame of reference processes (Marsh, 1986) could have led to a re-adaption to students' initial levels of math self-concepts over the course of 5 months.

Another particularly interesting finding is that teachers of classes in the quotations condition rated their students as putting more effort in their math tasks. As effects only occurred in one intervention condition and largely corresponded with findings on students' self-reported effort (Gaspard et al., 2016), it is unlikely that teachers gave a positively biased account of their students' effort due to their awareness of the class's study condition. To the contrary, it could be that the effects found on students' effort were actually underestimated due to the limited objectivity of the teacher ratings. In our sample, 57% of the teachers had already taught their students in mathematics in previous school years. Additional analyses showed that these teachers' judgments of students' effort were significantly more stable (r_{T1-T2} = .70) than those of the teachers who had not taught their classes in earlier school years (r_{T1-T2} = .63, p = .008). Preexisting evaluations of students' attitudes as well as social comparisons between the students in a class, as has been emphasized, for instance, in research on teachers' evaluations of students' achievement (e.g., McMillan, 2001; Südkamp, Kaiser, & Möller, 2012), might then have contributed to an underestimation of the intervention effects on students' effort.

Last but not least, the positive effect of the quotations condition on students' achievement 5 months after the intervention highlights the potential of this intervention approach in the longer run. The increase in both motivation and effort—factors that are particularly important for students' achievement in standardized math tests (e.g., Cole et al., 2008; Marsh et al., 2005)—might have resulted in the better test performance of students in the quotations condition.

Limitations and Suggestions for Future Research

Apart from constraints to the generalizability of the current research findings and the need for replication with other student samples—which applies to all intervention studies—there are four central limitations to the present investigation as well as resulting research suggestions. First, because in Germany students are typically not administered more than one state-based standardized achievement test (as used in the pretest) within one school year and subject, a different achievement measure had to be used in the posttest. To minimize the risk that students coping better with one of the two types of math tests would be unevenly distributed across control and experimental groups, a huge sample was used, and randomization was blocked within school. However, using achievements tests based on the same metrics would have strengthened the study even further.

Second, as this study's focus consisted of analyzing and comparing the main effects of two relevance interventions, no statements can be made about the mechanisms leading to the differences in the effects on the studied outcomes within and between the intervention conditions. More research is needed to clarify, for instance, why students' math self-concept was promoted only shortly after the intervention whereas students' homework self-efficacy was mainly affected 5 months after the intervention. Similarly, further studies are needed to explore why the quotations condition fostered all of the studied outcomes whereas the text condition only promoted homework self-efficacy. Qualitative content analyses of students' writing assignments (e.g., the range and type of relevance arguments found in the text condition, see Canning & Harackiewicz, 2015, Studies 2 and 3) and elaborate investigations on students' responsiveness (i.e., the degree to which students worked on the intervention material as intended, e.g., Hulleman & Cordray, 2009), which both are beyond the scope of the current study, might provide additional insights into these open questions. Besides, students' literacy skills might affect the quality of students' writings and thus the intervention effects. Investigating the mediating role of students' reading and writing skills in essay-based relevance interventions would be an interesting direction for future research.

Third, the unique contributions of the different elements of the relevance interventions to their effectiveness cannot be disentangled in the present study. Based on theoretical considerations made in EVT (Eccles & Wigfield, 2002) and empirical evidence from prior relevance intervention studies (e.g., Durik, Shechter, et al., 2015; Hulleman & Harackiewicz, 2009; Woolley et al., 2013), three elements were combined: First, a confidence reinforcement was implemented to avoid negative treatment effects on students who believe they cannot improve their math achievement; second, examples about the utility of mathematics were provided to facilitate working on the third element, the individual writing assignments. As students have heterogeneous motivational preconditions and needs, a combination of these different elements was chosen to address a maximum of students. Such a high fit with educational reality is an important prerequisite to enable the scaling up of educational interventions (Cohen & Loewenberg Ball, 2007). It would thus be up to future studies to investigate the importance of the three treatment elements used in the present interventions by creating different conditions with and without these respective elements (e.g., Canning & Harackiewicz, 2015; Durik, Shechter, et al., 2015).

Last but not least, the present interventions have been implemented by trained researchers who were unfamiliar with and to the classes. Future research also needs to examine the effectiveness of the present interventions when math teachers themselves carry them out in their classrooms. When teachers are responsible for implementing an intervention in their classes, there are several sources of infidelity, such as the dosage of the intervention or students' responsiveness to the treatment (e.g., Hulleman & Cordray, 2009), which could affect the treatment's effectiveness. Teachers might focus on specific elements of the interventions more strongly than others or even completely adapt the contents of the treatment based on personal and professional beliefs as well as their students' motivational features (Cohen & Loewenberg Ball, 2007). Comparing the effectiveness of teacher- and researcher-led relevance interventions with each other would thus be a crucial next step to find the most effective way of implementing the current interventions (cf. implementation science, e.g., Forman et al., 2013).

Conclusions

Despite its shortness (90 minutes in class, two short reinforcement tasks at home), the present relevance intervention program showed a sustained impact on students' competence beliefs, teacher-rated effort, and test scores in mathematics in a real-life learning setting. Integrating the presentation of utility information and a self-generation task into one approach was particularly impactful when students commented on interview quotations about the utility of mathematics in daily life situations in a writing assignment. The success of this type of relevance intervention in fostering a broad range of important educational outcomes could inspire future researchers to develop further practically relevant and even more sustained motivation interventions in STEM (e.g., by integrating different motivation theories, see Acee & Weinstein, 2010). In addition, the interventions tested in the present study could be extended by including teachers in the implementation process. By taking such further steps, the current investigation could have the potential to contribute to improving educational practice and attracting more students to STEM-related courses and occupations on a larger scale.

Notes

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[1]The ISEI is an international standard measure indicating the status of the occupation, ranging from 16 to 90.

[2]Nine of the teachers taught two classes each.

[3]Unequal class sample sizes in different conditions resulted from the fact that classes whose teachers participated with two classes were deliberately assigned to the same condition. The sample characteristics of each condition can be found in Table 2.

[4]As maximally 1.2% of the variance in the outcome variables was due to differences between schools, the school level was neglected in the analyses.

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