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Achievement motivation and knowledge development during exploratory learning☆

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ABSTRACT

Exploring a new concept before instruction can improve learning but can also be challenging. Individual differences in achievement motivation influence how learners respond to challenge and may therefore moderate the benefits of exploratory learning. Higher mastery orientation generally yields increased effort in response to challenge, whereas higher performance orientation yields withdrawal, suggesting that mastery orientation may help individuals better cope with and learn from exploration. Second- through fourth-grade children (N = 159) were given novel mathematical equivalence problems to solve as either an exploratory learning activity before instruction or as practice after instruction. Higher mastery orientation was associated with increased reliance on sophisticated problem-solving strategies during exploration and improved conceptual learning. In contrast, higher performance orientation corresponded with increased reliance on ineffective problem-solving strategies during exploration and impaired procedural learning. The current findings suggest that exploration prior to instruction can improve children's adoption of sophisticated problem-solving strategies and heighten their conceptual knowledge, primarily if they approach learning with a mastery orientation.

1. Introduction

1.1. Exploratory learning

Exploratory learning activities, which ask learners to engage new topics before receiving instruction, can be useful in teaching individuals new concepts. Such activities give learners an opportunity to experience the conceptual boundaries of a particular topic firsthand and realize the limits of their own understanding prior to instruction (DeCaro & Rittle-Johnson, 2012; Hiebert & Grouws, 2007). By wrestling with different solution approaches or conceptual perspectives in a trial-and-error fashion, learners encounter a broader range of both correct and incorrect strategies than might normally be encountered during more traditional "tell-then-practice" methods of instruction (Bonawitz et al., 2011; Schwartz, Chase, Oppezzo, & Chin, 2011). As a result, individuals who have an opportunity to explore a new concept before receiving instruction on the topic may develop a more sophisticated appreciation of the advantages, or disadvantages, associated with particular solution approaches. This experience may translate into deeper conceptual knowledge development and better retention (Bjork, 1994; Schwartz, Lindgren, & Lewis, 2009; Schwartz et al., 2011).

For example, DeCaro and Rittle-Johnson (2012) compared the impact of solving unfamiliar problems before or after instruction on elementary-school children's understanding of a novel mathematical concept (mathematical equivalence). Half of the children in the experiment received instruction on the concept, including definitions and examples, and then solved relevant problems with accuracy feedback (*instruct-first condition*). The other children received the same tutoring materials, but in reverse order of presentation: They first solved the problems with accuracy feedback, as an exploratory learning activity, and then received instruction (*solve-first condition*). Children learned the problem-solving procedures well (i.e., how to solve for the correct answer), regardless of what condition they were in. However, children in the solve-first condition understood the concept of mathematical equivalence better, on average, as demonstrated by their heightened performance on a comprehensive assessment of conceptual knowledge. Importantly, children in the solve-first condition benefitted conceptually from exploration even though they made more mistakes and tended to pursue more simplistic, incorrect strategies during the exploratory solve phase. Moreover, this learning difference not only emerged immediately after the tutoring intervention, but also was sustained in a retention test two weeks later. Similar results have been found with other age groups and in other domains (e.g., Day, Nakahara, & Bonn, 2010; Kapur,

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2010, 2012; Kapur & Bielaczyc, 2012; Schwartz & Bransford, 1998; Schwartz & Martin, 2004; Schwartz et al., 2011; Taylor, Smith, van Stolk, & Spiegelman, 2010).

Although exploratory learning can enhance conceptual knowledge, such exploration comes with a certain amount of challenge for the learner. Individuals typically make more mistakes during the initial steps of an exploratory learning activity (e.g., DeCaro & Rittle-Johnson, 2012), and they must focus on those mistakes in order to develop more sophisticated conceptualizations of the problem or solution (Kapur, 2010). This learning process often entails considerable effort, as individuals engage in trial-and-error learning or hypothesis testing (Kirschner, Sweller, & Clark, 2006; Klahr, 2009; Rittle-Johnson, 2006; Sweller, 2009). Learners may also encounter considerably more confusion about how to proceed (Dewey, 1910; Hiebert & Grouws, 2007). In some cases, these learning challenges may pose a "desirable difficulty" (Bjork, 1994) or "productive failure" (Kapur, 2010, 2012) that encourages learners to rethink their previous conceptions and develop better understanding, thereby preparing them to learn from further instruction (Schwartz & Bransford, 1998). In other cases, the difficulty posed by exploratory learning may be too high (Fyfe, DeCaro, & Rittle-Johnson, 2014; Kirschner et al., 2006).

1.2. Achievement motivation and response to challenge

In this study, we ask whether some learners may be better motivated than others to cope with the challenges posed by exploratory learning and thereby capitalize on the instructional experience. If so, then the beneficial results of exploratory learning may apply primarily to a particular subset of individuals, placing a boundary condition on this important educational method. We investigate this question in the current study by conducting a supplementary analysis of DeCaro and Rittle-Johnson's (2012) study to examine the underlying role of achievement motivation in children's knowledge development after exploration.

Research on achievement motivation demonstrates that individuals approach learning events with different goals and conceptions of what constitutes "ideal" learning performance. These individual differences influence how learners perform on different types of tasks, in different kinds of learning contexts (Barron & Harackiewicz, 2001; Dweck, 1986; Elliot, 2005). These motivational differences also have important implications for long-term learning and performance throughout the lifetime (Hidi & Renninger, 2006). Achievement motivation is a complex psychological phenomenon, and numerous, sometimes conflicting, theories have been proposed (e.g., Barron & Harackiewicz, 2001; Dweck & Leggett, 1998; Elliot & McGregor, 2001; Elliot, Murayama, & Pekrun, 2011; Vansteenkiste, Matos, Lens, & Soenens, 2007). The distinguishing characteristic among theories of achievement motivation is whether they conceptualize motivation as an orientation, like Dweck's (e.g., Dweck's 1986, 2006; Dweck & Leggett's, 1998) formulation of achievement motivation as a constellation of perceptions, self-evaluations, and desires or values like task preferences and interest, or as a more circumscribed goal or set of desired outcomes, like Elliot and McGregor's 2 (mastery, performance) × 2 (approach, avoid) achievement goal framework (see Elliot, 2005; Hulleman et al., 2010; Kaplan & Maehr, 2007; Senko, Hulleman, & Harackiewicz, 2011; Rawsthorne & Elliot, 1999 for review).

Each approach has been shown to be useful for understanding learning and performance in the classroom (Dweck & Leggett, 1998; Elliot, 2005; Hidi & Renninger, 2006). However, Dweck's theoretical approach (e.g., Dweck's 1986, 2006; Dweck & Leggett's, 1988) theoretical approach, which regards achievement motivation as an orientation, is especially useful for the current study, because of its emphasis on how individuals conceptualize and respond to the effort needed to overcome mistakes, confusion, difficulty, and other challenges encountered during learning (e.g., Blackwell, Trzesniewski, & Dweck, 2007; see Kaplan & Maehr, 2007; Hulleman et al., 2010 for review). Specifically, individuals can have both mastery and performance goals to different degrees (Barron & Harackiewicz, 2001). Individuals higher in *mastery orientation* desire personal growth (i.e., learning goals) and tend to view challenge, such as confusion or difficulty, as an opportunity to learn something new. Therefore, they generally seek challenge and respond to it with increased effort and interest. In fact, mastery orientation may lead individuals to interpret the effort they exert as rewarding, because effort engenders growth. Conversely, individuals higher in *performance orientation* desire to prove their ability (i.e., performance goals). As such, they tend to interpret effort as a sign of incompetence, leading them to interpret difficult learning activities as a potential threat and to withdraw from challenges (cf. Dweck, 1986, 2006).

For example, Diener and Dweck (1978, 1980) compared how mastery- and performance-oriented 4th–6th graders reacted to failure in a difficult category-learning task. Participants first completed several "solvable" categorization problems matched to their age group, with accuracy feedback. Afterward, they encountered four "unsolvable" problems that children in their age group typically cannot solve or understand without substantial assistance. While completing the solvable problems, children exhibited equal degrees of problem-solving accuracy and positive affect. They also had equally sophisticated problem-solving approaches. However, their behavior quickly diverged during the unsolvable trials. Children with higher mastery orientation responded with increased interest and effort—attributing the setback to a need for more effort. In addition, they either maintained a high degree of strategy sophistication or invented more sophisticated problem-solving strategies to successfully deal with the new challenge. In contrast, children with higher performance orientation responded with increased negative affect and disinterest—attributing failure to lack of ability. These children defensively withdrew their effort or regressed to simpler strategies that could not lead to success. Thus, children with higher mastery orientation coped better with this difficult task and, in some cases, developed more sophisticated understanding of the problem itself, as evidenced by their invention of novel problem-solving strategies (cf. Graham & Golan, 1991).

Similar observations have been made in learning conditions that are particularly confusing to the learner. Licht and Dweck (1984) asked 5th-grade children to complete a self-guided lesson on psychological principles of learning. For half of the learners, the text was extremely poorly written (confusing condition), and for the other half, the text was not confusing. Regardless of their motivational orientation, learners struggled initially in the confusing condition, earning significantly lower scores on a comprehension test than their counterparts in the non-confusing condition. Learners with higher performance orientation improved with repeated attempts; however, they never scored as well as their counterparts in the non-confusing condition. Learners with higher mastery orientation prevailed with repeated attempts, eventually equaling their counterparts in the non-confusing condition.

Other research has demonstrated that individuals with different achievement goal orientations prefer different types of learning situations. Individuals with higher mastery orientation generally prefer tasks that present an opportunity for skill development, despite posing the possibility of setbacks (e.g., mistakes, confusion). In contrast, individuals with higher performance orientation generally prefer tasks that readily demonstrate their competency without setbacks, yet do not necessarily promote development (e.g., Butler, 1999; Elliot & Dweck, 1988; cf. VandeWalle & Cummings, 1997; for review see Dweck & Leggett, 1998; Dweck & Master, 2008; Elliot, 1999; Hidi & Renninger, 2006; Grant & Dweck, 2003).

Individual differences in achievement motivation can emerge early in a child's development (Dweck & Leggett, 1998; Gunderson et al., 2013). These differences are believed to result from the way that parents and influential caregivers, such as teachers, portray abilities like intelligence as either innate and fixed, or learned and malleable, as well as how these role models react to a child's successes and failures (e.g., Ricco, McCollum, & Schuyten, 2003). For example, in a longitudinal study of the effects parental praise has on childhood development, Gunderson et al. (2013) found that mastery orientation was greatest among children whose parents tended to praise their child's effort ("process praise") instead of their innate attributes or ability ("person praise") during everyday activities in the household. Interestingly, differences in praise at ages 1–3 years predicted mastery orientation at ages 7–8 years. Experiments conducted in the classroom (e.g., Heyman, Dweck, & Cain, 1992; Kamins & Dweck, 1999) have demonstrated that children (ages 5–6 years) who were given either person criticism—or praise—had higher levels of self-blame (reporting that they were not a "good," "smart," or "nice" girl/boy), negative emotion (sadness), and decreased desire try such a task in the future or attempt to correct mistakes on their current problem—hallmarks of performance orientation. In contrast, praise regarding children's effort promoted a mastery-oriented response.

Taken together, these studies indicate that children are sensitive to the evaluations they encounter during development and are responsive to the learning and performance environments they encounter, developing and exhibiting motivational orientations that substantially impact their learning and achievement (but see Bong, 2009). It is therefore important to understand how children with different motivational orientations respond to a range of situations commonly encountered in and outside the classroom.

1.3. Current study

Individuals may respond to exploratory learning activities like they respond to challenge more generally. That is, based on their typically positive reaction to challenge, learners with higher mastery orientation may be better equipped to deal with the potential confusion and intellectual obstacles posed by exploration. We examined this possibility with a supplementary analysis of DeCaro and Rittle-Johnson's (2012) data in terms of achievement motivation.

In DeCaro and Rittle-Johnson's (2012) original study, learners who explored novel mathematics problems before receiving formal instruction (*solve-first condition*) made more mistakes during initial problem-solving than learners in a more traditional *instruct-first* condition; however, they demonstrated deeper conceptual knowledge when tested two weeks later. The current analyses evaluated whether, and how, individual differences in achievement motivation may have influenced learning from exploration. Specifically, we compared the problem-solving strategies, and subsequent learning, of individuals higher or lower in mastery and performance orientation across the solve-first and instruct-first conditions. By examining whether exploratory learning activities are more effective when children are higher in mastery orientation, the present research can provide additional insight into the ongoing debate about the relative advantages and disadvantages of exploratory learning and direct instruction (cf. Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Kirschner et al., 2006; Tobias, 2009). Specifically, if the benefits of exploratory learning primarily apply to learners higher in mastery-orientation, or if the challenges posed by exploration are detrimental to learners higher in performance orientation, then researchers and instructors will need to carefully consider when to use exploratory learning as an educational tool, or how to better prepare students to learn from exploration. This research may also reveal how learning advantages (or disadvantages) emerge during exploration.

Second- through fourth-grade children were taught the concept of *mathematical equivalence*—that values on both sides of the equal sign represent the same quantity. This concept is fundamental for future conceptual development within mathematics, such as early algebra understanding (Carpenter, Franke, & Levi, 2003; McNeil & Alibali, 2005). Elementary school children generally can successfully solve simple mathematics problems (e.g., $2 + 3 = \square$). However, they often lack a *relational understanding* of mathematical equivalence (e.g., understanding that $2 + 3$ is "the same as" 5). Children's misconceptions of the equal sign are often demonstrated by the strategies they use when they encounter more complex *mathematical equivalence problems*, with operations on both sides of the equal sign (e.g., $4 + 5 + 3 = \square + 3$; e.g., McNeil & Alibali, 2005; Perry, Church, & Goldin Meadow, 1988). Children rarely see mathematical equivalence problems in elementary school (Powell, 2012). Hence, they often view the equal sign as a procedural cue (Baroody & Ginsburg, 1983). For example, they may ignore the values to the right of the equal sign and sum the numbers on the left-hand side of the equation (resulting in the incorrect answer 12; *add-to-equals strategy*), or they may sum every number in the equation, ignoring the sides delineated by the equal sign (resulting in the incorrect answer 15; *add-all strategy*; McNeil, 2008; Perry, 1991).

These types of incorrect strategies reflect a rigid *operational understanding* of the equal sign, and they indicate a naive understanding of mathematical equivalence (Perry et al., 1998; Rittle-Johnson, Matthews, Taylor, & McEldoon, 2011). Such misconceptions cannot yield a correct answer. More importantly, they undermine the acquisition of conceptual understanding, because they limit children's ability to notice how mathematical equivalence problems differ from more standard addition problems (McNeil & Alibali, 2000, 2005). Children can continue to use an operational view of the equal sign even after they learn its relational meaning (McNeil, Rittle-Johnson, Hattikudur, & Peterson, 2010). This resembles learning errors identified in the achievement motivation literature, in which performance orientation leads otherwise able children to perseverate on disconfirmed strategies or revert to more naive representations of a problem that are characteristic of younger, less experienced children after failure trials (e.g., Diener & Dweck, 1980; cf. Dweck & Leggett, 1998). Thus, it is important to understand the factors that contribute to the development and retention of conceptual knowledge in this domain.

1.4. Hypotheses

Considering the literatures on exploratory learning and achievement motivation, we predicted different learning outcomes depending on the type of knowledge assessed. We assessed learners' knowledge of mathematical equivalence both immediately after they completed an individual tutoring session and approximately two weeks later. We also examined problem-solving strategies during the tutoring session itself. In the predictions that follow, we expected achievement motivation to impact learning most in the solve-first condition, because of the pronounced need to persist in the face of difficulty in this condition.

1.4.1. Conceptual knowledge

In the present research, we were primarily interested in the effect of achievement motivation on the development of learners' *conceptual knowledge*—their ability to grasp the underlying principles of mathematical equivalence—after exploration. Prior work suggests that exploration before instruction primarily benefits conceptual knowledge, but is mistake-prone and initially more confusing than solving problems after instruction (Kapur, 2012; Kapur & Bielaczyc, 2012, Schwartz et al., 2009; cf. Alfieri et al., 2011; Kirschner et al., 2006). Previous research also indicates that individual differences in achievement motivation influence learning and performance primarily when children encounter challenging tasks (Dweck, 1986, 2006; Dweck & Master, 2008). Mastery orientation typically leads children to respond to initial setbacks with increased resolve, and by maintaining or inventing more sophisticated learning strategies (e.g., Diener & Dweck, 1978, 1980). Thus, we expected higher mastery orientation to be associated with improved conceptual knowledge, specifically in the more demanding solve-first condition.

Due to discrepancies in the literature (Grant & Dweck, 2003; Hulleman et al., 2010; Senko et al., 2011), the prediction for performance orientation in the solve-first condition is less straightforward. Higher performance orientation often leads individuals to respond to setbacks with defensive withdrawal of effort and regressive thinking (e.g., Diener & Dweck, 1978, 1980; cf. Dweck, 2006; Dweck & Leggett, 1998). Therefore, performance orientation may be detrimental to conceptual knowledge in the solve-first condition. Alternatively, performance orientation may not actually hurt conceptual knowledge, compared to that obtained in the instruct-first condition. Instead, performance orientation may simply hinder one's ability to profit from the exploratory learning opportunity. This prediction is supported by two hypotheses presented in Barron and Harackiewicz's (2001) *multiple-motives framework*, which suggests that mastery and performance goals can represent separate motivational signals (additive goals hypothesis) with potentially different degrees of relevance for conceptual versus procedural understanding (specialized goals hypothesis). According to the specialized goal hypothesis, the mastery motive is more relevant to conceptual knowledge than the performance motive, because understanding and deeper processing of information are more clearly central to personal development and less diagnostic of ability (Barron & Harackiewicz, 2001; Senko et al., 2011; cf. Grant & Dweck, 2003). To the extent that the specialized goal hypothesis holds true, performance orientation may alternatively have no discernible impact on conceptual knowledge in our study (see Table 1).

1.4.2. Procedural knowledge

We also evaluated *procedural knowledge*, or the ability to execute the correct action sequences to solve problems (e.g., Rittle-Johnson & Alibali, 1999). Procedural knowledge and conceptual knowledge are believed to be related to one another to some extent (Rittle-Johnson & Alibali, 1999, Rittle-Johnson, Siegler, & Alibali, 2001). However, problem-solving assessments in particular provide especially diagnostic information about ability, towards which individuals higher in performance orientation are thought to be especially responsive (Dweck, 1986, 2006; Elliot, 1999). Indeed, according to Barron and Harackiewicz's (2001) specialized goals hypothesis, performance orientation may be more relevant than mastery orientation to the development of procedural knowledge (cf. Grant & Dweck, 2003; Senko et al., 2011). As such, we predicted that there would be a negative relationship between performance orientation and procedural knowledge development in the solve-first condition, with a positive—but weaker—relationship for mastery orientation (see Table 1).

1.4.3. Problem-solving strategies

In addition to assessing knowledge outcomes after tutoring, we examined children's problem-solving strategies during the tutoring session. Such information may reveal how achievement motivation impacts learning during exploration.

DeCaro and Rittle-Johnson (2012) previously reported that children in the solve-first condition tended to use poorer problem-solving strategies during the exploratory activity (specifically, greater use of incorrect add-to-equal and add-all strategies and less frequent use of correct relational strategies). But, ultimately, this challenge helped them understand the concept of math equivalence better.

In the present research, we hypothesized that these benefits emerge primarily for children higher in mastery orientation, because they would eventually abandon the ineffective operational strategies and begin using more sophisticated relational strategies, as seen in prior studies that examined children's hypothesis-testing strategies (e.g., Diener & Dweck, 1978, 1980; Elliot & Dweck, 1988; cf. Dweck & Leggett, 1998). Thus, in the solve-first condition, mastery orientation should be associated with decreased reliance on operational strategies and increased usage of relational strategies. In contrast, performance orientation should be associated with increased reliance on operational strategies and decreased usage of relational strategies (see Table 1).

Table 1
Hypotheses for solve-first condition.

Conceptual knowledge (CK)
▪ **Higher mastery orientation associated with higher CK** ▪ Higher performance orientation associated with either lower CK (Dweck & Leggett, 1998) or no effect (*specialized goals hypothesis;* Barron & Harackiewicz, 2001)
Procedural knowledge (PK)
▪ Higher mastery orientation possibly associated with higher PK (Dweck & Leggett, 1998), but likely less so than with CK (*specialized goals hypothesis*; Barron & Harackiewicz, 2001) ▪ **Higher performance orientation associated with lower PK**
Problem-solving strategies during tutoring intervention
▪ Higher master orientation associated with decreased use of ineffectual operational strategies and increased use of effectual relational strategies after initial learning setbacks ▪ Higher performance orientation associated with increased use of ineffectual operational strategies and decreased use of effectual relational strategies after initial learning setbacks

Notes: Primary hypotheses are in bold. Performance in the instruct-first condition was not expected to be associated with mastery or performance orientation (see text).

2. Methods

2.1. Participants

Participants were second- through fourth-grade children enrolled in a suburban public school serving a middle-class population. Children who scored below 80% on a pretest assessing procedural and conceptual knowledge of mathematical equivalence were selected for the study. The final sample ($N = 159$, 56% female) consisted of 77 second-graders, 56 third-graders, and 26 fourth-graders (age $M = 8.5$ years, range 7.3–10.8 years) from fifteen classrooms. Approximately 18% were ethnic minorities (10% African-American, 6% Asian, and 2% Hispanic).

2.2. Research design and procedure

Consenting children with parental consent to participate in the study first completed a pretest in their classrooms, followed by a self-report measure of their achievement motivation orientation. This session lasted approximately 30 min. Within one week following the pretest, children selected for the study participated in individual tutoring sessions on mathematical equivalence. Children were randomly assigned to the *instruct-first condition* ($n = 79$: 40 second-graders; 27 third-graders; 12 fourth-graders) or the *solve-first condition* ($n = 80$: 37 second-graders; 29 third-graders; 14 fourth-graders). The session ended with a posttest assessing children's procedural and conceptual knowledge. The entire session lasted approximately 45 min. Approximately two weeks later, children completed an equivalent retention test. The retention test also included a measure of far-transfer, which consisted of more advanced problems that combined elements of both procedural and conceptual knowledge.

2.3. Tutoring session

2.3.1. Conditions

The instruct-first and solve-first conditions were identical, except that the presentation order for the instruction ("instruct") and problem-solving ("solve") portions of the lesson were reversed. Thus, in the instruct-first condition, the problems served as practice after a lesson on mathematical equivalence. In the solve-first condition, these same problems served as an exploratory learning activity followed by formal instruction.

2.3.2. Instruction

During instruction (adapted from Matthews & Rittle-Johnson, 2009), children were taught the relational meaning of the equal sign. Five number sentences (e.g., $3 + 4 = 3 + 4$) were individually shown on the computer screen. The experimenter explained the structure of each number sentence (i.e., that there are two sides) and the explicit meaning of the equal sign (i.e., that the equal sign means that both sides are "equal or the same").

2.3.3. Problem-solving

During the problem-solving phase, children completed six mathematical equivalence problems presented individually on the computer. The problems progressed in difficulty. Problem 1 was a three-operand problem, involving an operation on the right side of the equation (i.e., 10 = 3 + ☐). This type of problem is less of a departure from what children in this age group typically encounter and is typically easier to solve, unlike Problems 2–6, which involved operations on both sides of the equal sign (Powell, 2012; Rittle-Johnson et al., 2011). Specifically, problems 2–3 were four-operand problems (e.g., 3 + 7 = ☐ + 6), and Problems 4–6 were five-operand problems (e.g., 5 + 3 + 9 = 5 + ☐). Children could use pencil and paper to solve each problem. After entering their answer on the computer, children were asked to report their problem-solving strategy. Then they were shown the correct answer. Children were additionally assigned to either self-explain on each problem (i.e., explain why particular answers were correct/incorrect) or solve a second set of six problems instead; however, this manipulation had no discernible effects and will not be discussed further.

2.4. Knowledge assessments

Children's knowledge was assessed several times (i.e., pretest, tutoring, posttest, and retention test) and across different evaluative contents, including procedural knowledge (problem-solving ability), conceptual knowledge, far-transfer, and problem-solving strategies. A short assessment was also taken mid-way through tutoring; this data is reported in DeCaro and Rittle-Johnson (2012) but is not central to the present discussion.

2.4.1. Problem-solving strategies

Children's problem-solving strategies during the tutoring session were categorized based on their verbal reports as either relational, operational, other correct, or other incorrect for each of the six problems that they attempted. This coding allowed us to keep track of the types of strategies learners used with each successive problem. One trained researcher coded the strategies of all students, and a second researcher independently coded the strategies of 20% of students. Both researchers were blind to experimental condition and hypotheses. There was high agreement between the ratings (kappa = .80).

As shown in Table 2, *relational strategies* evidenced a deliberate attempt to equalize the values on each side of the equation or conceptualize the values as equivalent. *Operational* and *other incorrect strategies* both evidenced an erroneous conceptualization of the equal sign. However, operational strategies represented naïve and simplistic misconceptions of the equal sign (i.e., *add-all* and *add-to-equals* strategies; McNeil, 2008; McNeil & Alibali, 2005; Perry et al., 1988; cf. Rittle-Johnson et al., 2011). These categories allowed us to examine how children's conceptualizations developed in sophistication during training, especially in response to initial setbacks.

Table 2
Relational, operational, and other incorrect strategies.
Adapted from DeCaro and Rittle-Johnson (2012).

Correct strategies	Sample explanation 3 + 4 + 8 = ☐ + 8
Relational strategies	
Equalizer	3 + 4 is 7, 7 + 8 is 15, and 7 + 8 is also 15
Grouping	I took out the 8 s and I added 3 + 4
Add–subtract	I did 8 + 4 + 3 equals 15, and subtract 8
Other correct strategies	
Incomplete procedure	I added 7 plus 8 (gave correct answer)
Insufficient work	I used my fingers
Incorrect strategies	
Operational strategies	
Add-all	I added 8 and 3 and 4 and 8 together
Add-to-equals	I just added 3 + 4 + 8
Other incorrect strategies	
Don't know	I don't know
Other incorrect	I just added 8 to 3

2.4.2. Pretest, posttest, and retention test

We measured children's conceptual and procedural knowledge of mathematical equivalence by adapting assessments from past research (e.g., McNeil & Alibali, 2005; cf. Rittle-Johnson et al., 2011; Matthews, Rittle-Johnson, McEldoon, & Taylor, 2012). *Conceptual knowledge* items (10 items) assessed two key concepts: the symbolic meaning of the equal sign and the structure of equations (see Table 3). Each item was scored using the criteria in Table 3; inter-rater agreement was high (on 20% of randomly-selected responses; *kappas* = .89–.96). *Procedural knowledge* items consisted of eight mathematical equivalence problems, with operations on both sides of the equal sign (e.g., 4 + 5 + 8 = ☐ + 8), and two easier nonstandard problems (e.g., 7 = ☐ + 5). Answers to procedural knowledge items were scored as correct if they came within one point of the correct answer, to reduce false negatives due to a child's minor calculation errors (Matthews et al., 2012). Performance on both assessments was reported as percentage correct. The posttest was identical to the pretest, except that different problems were used (Rittle-Johnson et al., 2011).

The retention test was identical to the posttest, but also included seven *far-transfer items* (see Table 3). Far-transfer (*kappas* = .77–.93) assessed learners' ability to apply the concept of mathematical equivalence to solve especially difficult problems that were not directly targeted during tutoring and which required a deeper level of inference involving the concept of math equivalence (cf. Matthews et al., 2012). Moreover, these problems spanned both conceptual and procedural knowledge: significant correlations were found between performance on the far transfer items and learners' retention test scores on both conceptual knowledge, $r(159) = .37$, $p < .001$, and procedural knowledge scores $r(159) = .57$, $p < .001$. Hence, learners not only had to understand the concept of mathematical equivalence to do well on far-transfer but also properly execute problem-solving procedures.

We were most interested in longer-term learning, and the results of the posttest closely mirrored those of the retention test. Therefore, we report only the results of the retention test.

2.5. Achievement motivation

We assessed children's achievement motivation at the end of the pretest session. In keeping with Dweck's (1986, 2006) conceptualization of achievement motivation as an overall orientation, we used items adapted from Nicholls, Cobb, Wood, Yackel, and Patashnick (1990), Roedel, Schraw, and Plake (1994), and Elliot and Church (1997), to better represent learners' motivation as a constellation of goals, preferences, and subjective feelings about effort (cf. Ricco et al., 2003). Specifically, items were adapted to more clearly tap the concepts of effort (i.e., "working hard") and ego involvement (i.e., "I am smart") (cf. Dweck & Leggett, 1998; Grant & Dweck, 2003).

The practical need to measure elementary-school students' pretest procedural and conceptual knowledge and achievement motivation within a single 30-minute class period, without individualized assistance (e.g., child's parent) for help and guidance (e.g., Ricco et al., 2003), constrained the number of items that could be devoted to any single topic. Thus, our instrument was shorter than some achievement motivation instruments, using two items per motivational subscale (but see Barron & Harackiewicz, 2001; Blackwell et al., 2007; Elliot & McGregor, 2001; and Gunderson et al., 2013; for instruments that use only three items for each subscale).

Two items assessed mastery orientation, particularly the "response to challenge" aspect of mastery orientation (Nicholls et al., 1990; Roedel et al., 1994) hypothesized to play a significant role in learners' reactions to exploratory learning: a) "I want to learn as much as possible

Table 3
Representative conceptual knowledge and far transfer assessment items.

Concept	Item	Scoring criteria
Conceptual Knowledge		
Structure of equations	1) Correct encoding: Reproduce 3 equivalence problems, one at a time, from memory after a 5 sec delay	1 point if put numerals, operators, equal sign and blank in correct respective positions for all 3 problems
	2) Recognize correct use of equal sign in multiple contexts	
	(a) Indicate whether 7 equations in non-standard formats, such as $8 = 5 + 3$ and $5 + 3 = 3 + 5$, are true or false	1 point if 75% of equations correctly identified as "true" or "false"
	(b) Explain why 2 equations are true	1 point per explanation if shows through words or math that both sides of the equation are the same
Meaning of equal sign	1) Define the equal sign	1 point if defined relationally (e.g., "both sides are the same")
	2) Identify the pair of numbers from a list that is equal to another pair of numbers (e.g. 6 + 4)	1 point if identified correct pair of numbers
	3) Identify the symbol from a list that, when placed in the empty box (e.g. "10 cents ☐ one dime"), will show that the two sides are the same amount	1 point if chose the equal sign
	4) Rate definitions of the equal sign: Rate 3 definitions (2 fillers) as "good," "not good," or "don't know"	1 point if rated the statement "The equal sign means two amounts are the same" or "The equal sign means the same as" as a good definition.
	5) Which (of the above) is the best definition of the equal sign	1 point if chose the relational definition (see above)
	6) Define the equal sign in the context of a money-related question (e.g., 1 dollar = 100 pennies)	1 point if defined relationally
Far transfer		
Maintains equivalence	1) $17 + 12 = 29$ is true. Is $17 + 12 + 8 = 29 + 8$ true or false? How do you know? (3 items)	1 point if mention the same thing done to both sides (e.g., "They added 8 to both sides")
Compensatory strategy	2) *Without adding* 67 + 86, can you tell if the statement below is true or false? $67 + 86 = 68 + 85$. How do you know?	1 point if mention relations between values on the two sides (e.g., "67 is one less then 68, same with 85 and 86")
	3) Solve $898 + 13 = 896 + \square$. *You can try to find a shortcut so you don't have to do all the adding.* (2 items)	1 point if within one of the correct answer
Multiple instances	4) Find the value of *m*. $m + m + m = m + 12$	1 point if within one of the correct answer

Note: Conceptual knowledge items reprinted from DeCaro and Rittle-Johnson (2012).

about math, even if I have to work hard," and b) "In math class, I prefer course material that really challenges me so I can learn new things" ($\alpha = .72$).

Two items assessed performance orientation, particularly the "social comparison" and "self-worth" aspects of performance orientation (Elliot & Church, 1997; Roedel et al., 1994) hypothesized to play as significant role in determining how learners respond to exploratory learning: a) "In math class, it is important for me to do well compared to others in my class," and b) "It is important for me to show that I am smart." The Cronbach's alpha of reliability (i.e., internal consistency) for the performance orientation measure was low ($\alpha = .50$). This is primarily because these two items represent two different, but related, aspects of performance orientation. Low scale reliability decreases the statistical power in significance tests that use the scale to predict behavior, making it harder to detect effects that exist; however, this does not invalidate the findings (Bacon, 2004; Nunnally, 1978).

Children circled their responses on a 4-point Likert-type scale ranging from 1 (*Disagree*) to 4 (*Agree*) with no indifference point. Items were administered as part of a written packet, and were read aloud to the younger children (i.e., second graders). We created mastery-orientation and performance-orientation scores for each individual by averaging the two responses on each subscale (Elliot & Church, 1997).

Neither learners' mastery orientation ($M = 3.42$, $SD = .76$) nor their performance orientation ($M = 3.35$, $SD = .82$) differed by experimental condition, grade, or classroom ($Fs < 1$), indicating that these factors did not influence the motivation results in the analyses that follow. In addition, learners' pretest scores for conceptual and procedural knowledge did not significantly correlate with their mastery or performance orientation scores ($ps > .105$), indicating that performance earlier in the pretest session did not adversely bias children's responding on the mastery and performance orientation items measured later in that session. Moreover, any potential bias would be statistically controlled for in our regression analyses (described below), which partial out any overlap, however small, between prior knowledge and achievement motivation when using achievement motivation to predict students' learning and performance.

3. Results

3.1. Overview

We examined the impact of mastery and performance orientation on learning in the two tutoring conditions. Learning measures included conceptual knowledge, procedural knowledge, and far transfer. We also examined children's problem-solving strategies during tutoring. We used multiple regression for all analyses to examine mastery and performance orientation as separate signals, as proposed in Barron and Harackiewicz's (2001) multiple-motives framework. Preliminary analyses revealed that there were no significant two-way (i.e., Mastery Orientation × Performance Orientation) interactions between mastery and performance orientation, or three-way (Condition × Mastery Orientation × Performance Orientation) interactions with condition. Thus, these interaction terms were not included in the final model.

The predictors in the regression model were mastery orientation score, performance orientation score, condition (0 = *instruct-first*, 1 = *solve-first*), and two interaction terms (Condition × Mastery Orientation, Condition × Performance Orientation). Thus, the final model represents the independent and joint effects of achievement motivation and instructional condition on the dependent variables. We also included children's age and conceptual ($M = 36.3\%$, $SD = 19.4$) and procedural knowledge ($M = 46.6\%$, $SD = 27.4$) pretest scores as statistical controls for prior knowledge. Prior knowledge was associated with improved knowledge acquisition and problem-solving performance across all the dependent measures; age had no significant effects. Each predictor was mean centered to preserve its original unit of measurement (Cohen, Cohen, West, & Aiken, 2003). Significant interactions and a-priori predictions were explored through simple slopes analyses (Aiken & West, 1991). Estimated means were plotted in figures as one standard deviation above and below the mean to represent the effect of low versus high achievement motivation on the dependent variable as a function of condition. Effect sizes are reported as squared semi-partial correlations (sr^2), which indicate the percentage variance accounted for by a particular effect (Cohen et al., 2003).

Children in the instruct-first and solve-first conditions did not differ at pretest by their procedural knowledge, conceptual knowledge, or achievement motivation (Fs < 1). As with prior research using similar measures (e.g., Ames & Archer, 1988; Button et al., 1996), mastery and performance orientation were not correlated, $r(156) = .08$, $p = .151$, further supporting the conclusion that these were separate motivational signals additively contributing to learners' behavior (Barron & Harackiewicz, 2001; Senko et al., 2011).

3.2. Conceptual knowledge

We expected higher mastery orientation to be associated with better conceptual knowledge in the solve-first condition (see Table 1). Research indicates that performance orientation could have one of two possible effects on conceptual development, depending on which of two prominent motivational theories best captures the current situation (Table 1). Performance orientation could decrease conceptual knowledge acquisition, as indicated by a drop in conceptual knowledge in the solve-first condition compared to the instruct-first condition (cf. Grant & Dweck, 2003). Or, performance orientation could hinder learners from using exploration to their benefit, as indicated by a lack of improvement in the solve-first condition (cf. Barron & Harackiewicz, 2001).

The overall model was significant, $F(8, 147) = 7.45$, $p < .001$, $R_a^2 = .250$. At retention test, learners in the solve-first condition demonstrated marginally higher conceptual knowledge ($M = 67.1\%$, $SD = 21.5$) than learners in the instruct-first condition ($M = 62.2\%$, $SD = 22.9$) ($B = .06$, $SE = .03$, $p = .078$, $sr^2 = .015$). There was also a significant main effect of mastery orientation; higher mastery orientation was, on average, associated with an increase in conceptual knowledge across conditions ($B = .04$, $SE = .02$, $p = .040$, $sr^2 = .021$). These effects were qualified by a marginal Mastery Orientation × Condition interaction ($B = .08$, $SE = .04$, $p = .059$, $sr^2 = .017$). Because we made a-priori predictions about the relationship between mastery orientation and conceptual knowledge in each condition, we conducted follow-up analyses to examine the simple effects. As depicted in Fig. 1, higher mastery orientation was associated with significantly higher conceptual knowledge in the solve-first condition ($B = .08$, $SE = .03$, $p = .009$, $sr^2 = .033$). For every one SD increase in mastery orientation, children scored 8% higher on the conceptual knowledge test, indicating that higher mastery orientation helped children learn from exploration. As predicted, mastery orientation was unrelated to conceptual knowledge in the instruct-first condition ($B = .00$, $SE = .03$, $p = .879$, $sr^2 = .000$).

There was no main effect of performance orientation ($B = -.01$, $SE = .02$, $p = .493$, $sr^2 = .002$) or Performance Orientation × Condition interaction ($B = .00$, $SE = .04$, $p = .938$, $sr^2 = .000$), indicating that performance orientation neither helped nor hurt conceptual knowledge attainment in the solve-first condition or instruct-first condition.

Thus, as expected, individuals higher in mastery orientation benefitted most from exploration, with regard to their conceptual knowledge development. Moreover, in keeping with Barron and Harackiewicz's (2001) additive and specialized goals hypotheses, performance

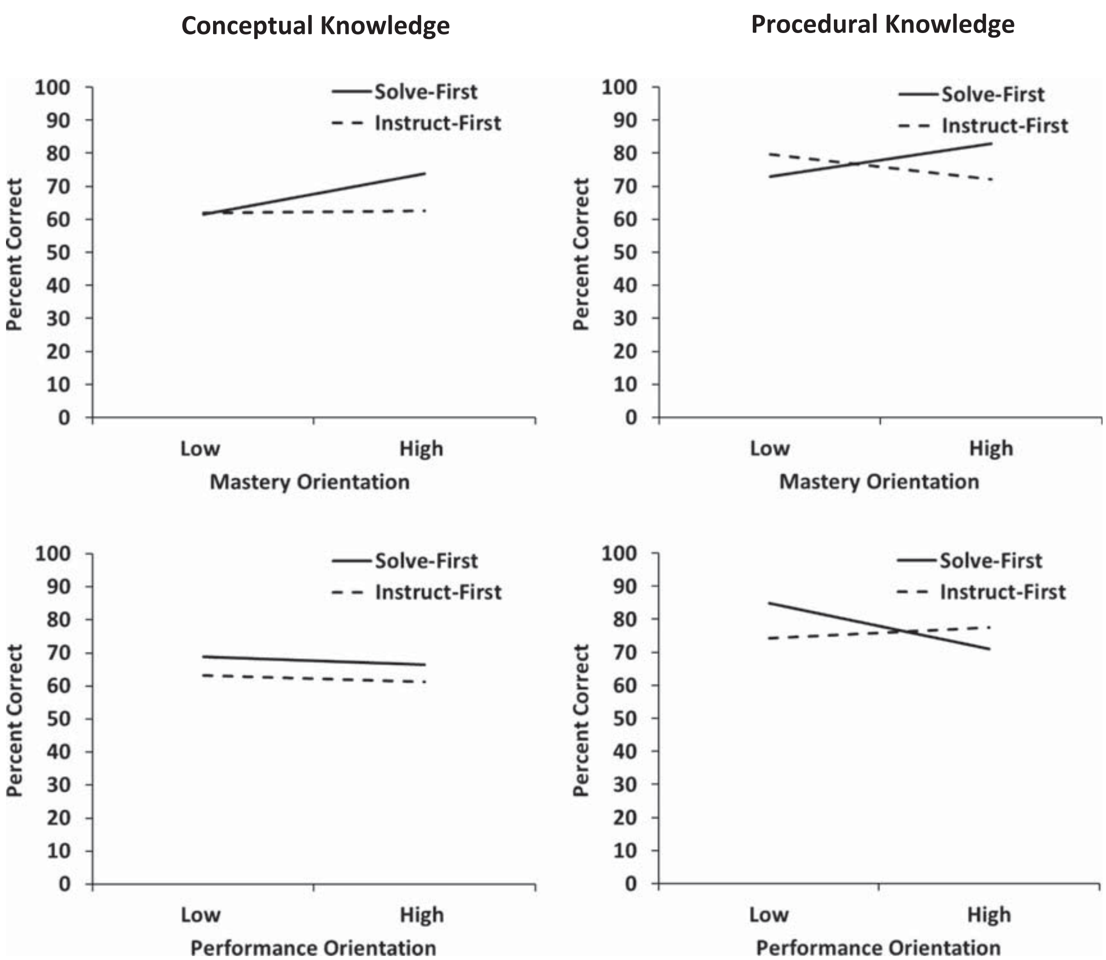

Fig. 1. Percent correct on conceptual knowledge and procedural knowledge scales at retention test. *Note:* Low and high mastery and performance orientation points are plotted at ±1 SD from the mean (centered).

orientation had no discernible influence on conceptual knowledge development following exploration.

3.3. Procedural knowledge

We expected higher mastery orientation to be associated with improved procedural knowledge in the solve-first condition (cf. Grant & Dweck, 2003). However, this effect may be weaker than that for conceptual knowledge, if demonstrated ability on a test is, indeed, less relevant to mastery-oriented individuals, as proposed in Barron and Harackiewicz's (2001) specialized goals hypothesis (Table 1). In contrast, we expected higher performance orientation to be associated with poorer procedural knowledge in the solve-first condition (Table 1; cf. Grant & Dweck, 2003).

The overall model was significant, $F(8, 147) = 5.90$, $p < .001$, $R_a^2 = .202$. As expected, there was no overall effect of condition on procedural knowledge at retention test ($B = .02$, $SE = .04$, $p = .634$, $sr^2 = .001$). On average, learners in the two conditions solved problems about equally well (solve-first: $M = 76.5\%$, $SD = 27.6$; instruct-first: $M = 76.1\%$, $SD = 29.2$). There was no main effect of mastery orientation ($B = .01$, $SE = .03$, $p = .813$, $sr^2 = .000$). However, a Mastery Orientation × Condition interaction emerged ($B = .12$, $SE = .06$, $p = .036$, $sr^2 = .023$). As depicted in Fig. 1, the interaction was driven by a cross-over effect; the simple effects within this cross-over interaction did not emerge as significant. Higher mastery orientation was associated with a trend towards higher procedural knowledge in the solve-first condition ($B = .07$, $SE = .04$, $p = .118$, $sr^2 = .013$), whereas it was associated with a trend towards poorer procedural knowledge in the instruct-first condition ($B = -.05$, $SE = .04$, $p = .159$, $sr^2 = .010$). These findings are consistent with Barron and Harackiewicz's (2001) proposal (i.e., specialized goals hypothesis) that procedural knowledge is less relevant to mastery orientation than conceptual knowledge (Table 1; cf. Senko et al., 2011).

There was no main effect of performance orientation ($B = -.03$, $SE = .03$, $p = .210$, $sr^2 = .008$). However, a significant Performance Orientation × Condition interaction emerged ($B = -.11$, $SE = .05$, $p = .041$, $sr^2 = .022$). As shown in Fig. 1, for every one *SD* increase in performance orientation, there was a 9% predicted decrease in procedural knowledge in the solve-first condition ($B = -.09$, $SE = .04$, $p = .035$, $sr^2 = .023$). Performance orientation was unrelated to procedural knowledge in the instruct-first condition ($B = .02$, $SE = .03$, $p = .536$, $sr^2 = .002$).

The overall pattern of results for procedural knowledge indicates that higher mastery orientation may be associated with improved procedural knowledge after exploration, though this effect is likely to be weak if present. More importantly, higher performance orientation was associated with worse procedural knowledge acquisition from exploration, compared to the more traditional instruct-first condition. This finding is consistent with Dweck's formulation of performance orientation, as well as Barron and Harackiewicz's (2001) additive and specialized goals hypotheses.

3.4. Far transfer

Far transfer items assessed whether learners developed a more sophisticated, relational conceptualization of mathematical equivalence, and could additionally execute appropriate problem-solving procedures to solve these rather difficult, novel problems. Because of the complex nature of these items, mastery and performance orientation could have differential effects. Mastery orientation is likely to positively predict performance in the solve-first condition, because of its hypothesized association with conceptual knowledge (i.e., specialized goals hypothesis; Barron & Harackiewicz, 2001) and task difficulty (Dweck, 1986, 2006; Grant & Dweck, 2003). In contrast, higher performance orientation is likely to negatively predict performance, because of its hypothesized negative relationship with task difficulty (Dweck, 1986; Dweck & Leggett, 1998; Grant & Dweck, 2003) and presumed relevance for procedural problem-solving tasks (i.e., specialized goals hypothesis; Barron & Harackiewicz, 2001).

The overall model was significant, $F(8, 147) = 6.30$, $p < .001$, $R_a^2 = .215$. There was no main effect of condition (solve-first: $M = 24.3\%$, $SD = 24.5$; instruct-first: $M = 26.0\%$, $SD = 23.7$) ($B = .00$, $SE = .04$, $p = .949$, $sr^2 = .000$). There was no significant main effect of mastery orientation ($B = .04$, $SE = .02$, $p = .121$, $sr^2 = .012$). There also was no significant Mastery Orientation × Condition interaction ($B = -.07$, $SE = .05$, $p = .128$, $sr^2 = .012$). However, because we had a-priori hypotheses about the nature of the relationship between mastery orientation and far transfer within each condition, we explored these simple effects. As illustrated in Fig. 2, higher mastery orientation was associated with significantly higher far-transfer scores in the solve-first condition ($B = .07$, $SE = .04$, $p = .042$, $sr^2 = .012$), but was unrelated to far-transfer in the instruct-first condition ($B = .00$, $SE = .03$, $p = .969$, $sr^2 = .000$), indicating a potential benefit to far transfer due to exploration. Indeed, for every one *SD* increase in mastery orientation, learners scored about 7% higher on far transfer in the solve-first condition.

In addition, there was a significant main effect of performance orientation, such that higher performance orientation was, on average, associated with a 5% decrease in far transfer scores across conditions ($B = -.05$, $SE = .02$, $p = .033$, $sr^2 = .023$). However, this effect was qualified by a significant Performance Orientation × Condition interaction ($B = -.09$, $SE = .04$, $p = .041$, $sr^2 = .021$). As shown in Fig. 2, one *SD* increase in performance orientation was associated with approximately 9% lower far-transfer scores in the solve-first condition ($B = -.09$, $SE = .04$, $p = .008$, $sr^2 = .036$), but was unrelated to scores in the

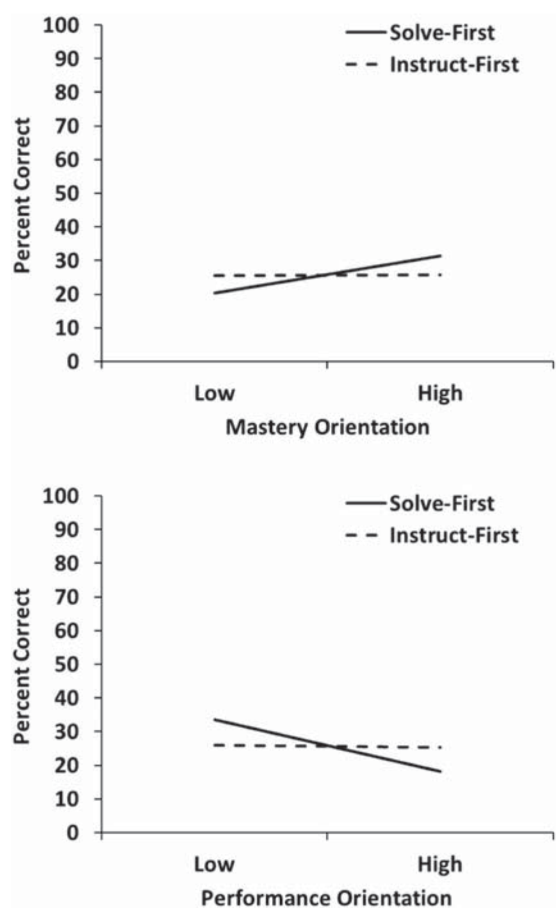

Fig. 2. Percent correct on far transfer scale. *Note:* Low and high mastery and performance orientation points are plotted at ±1 SD from the mean (centered).

instruct-first condition ($B = .00$, $SE = .03$, $p = .915$, $sr^2 = .000$). Performance orientation was associated with reduced ability to solve complex far-transfer problems overall and after an exploratory learning condition. Thus, individual differences in achievement motivation were related to learners' readiness to address these more complex far-transfer items, with mastery orientation potentially benefitting learning after exploration and performance orientation clearly associated with poorer learning.

3.5. Problem-solving strategies

To provide further insight into how the knowledge benefits and decrements observed at retention test may have emerged, we examined the strategies that children used during the problem-solving portion of the tutoring session. For individuals in the solve-first condition, this section served as exploratory problem-solving; for individuals in the instruct-first condition, this served as additional practice problems. As previously described, this problem-solving block consisted of six problems that increased in difficulty, beginning with a *three-operand* problem, which had an operation on the right side of the equation and is more typically encountered by children in this age group, and progressing to *four*- and then *five-operand* problems that children in this age group typically struggle to solve without considerable assistance, in part because they have operations on both sides of the equal sign (McNeil, 2008; Rittle-Johnson et al., 2011). We first examined children's overall strategy selection; then we examined their problem-solving strategies on three-, four-, and five-operand problems separately. These analyses enabled us to explore how many mistakes children made initially in the two conditions and how they reacted to those learning setbacks. Data from six children (1 solve-first condition, 5 instruct-first condition) were excluded from these analyses due to incomplete data.

Table 4
Regression slopes for tutoring session: percent usage of relational and operational strategies by condition, achievement motivation, and problem type (overall and three, four, or five operands).

	Overall	Operands		
		Three	Four	Five
Relational strategies				
Condition	−.12(.05)*	.04(.07)	−.24(.06)***	−.11(.06)
MO	.04(.03)	.09(.04)*	.01(.04)	.04(.04)
PO	−.03(.03)	−.01(.04)	−.02(.04)	−.06(.04)
MO × Condition	.15(.07)**	.29(.09)***	.12(.08)	.15(.08)*
Instruct-first	−.03(.04)	−.05(.06)	−.05(.05)	−.04(.05)
Solve-first	.11(.05)*	.24(.07)***	.07(.06)	.12(.06)*
PO × Condition	−.16(.06)**	−.08(.08)	−.09(.08)	−.23(.07)**
Instruct-first	.04(.04)	.03(.05)	.03(.05)	.05(.04)
Solve-first	−.11(.05)*	−.06(.06)	−.06(.06)	−.18(.06)**
Operational strategies				
Condition	.09(.03)*	−.09(.06)	.14(.05)**	.11(.04)**
MO	.01(.02)	−.03(.04)	.03(.03)	.01(.03)
PO	.03(.02)	.03(.04)	.04(.03)	.03(.03)
MO × Condition	−.04(.05)	−.04(.08)	.01(.07)	−.08(.05)
Instruct-first	.03(.03)	−.01(.05)	.03(.05)	.05(.04)
Solve-first	−.01(.03)	−.05(.06)	.04(.05)	−.03(.04)
PO × Condition	.10(.04)*	.08(.07)	.03(.06)	.16(.05)***
Instruct-first	−.02(.03)	−.01(.04)	.03(.04)	−.05(.03)
Solve-first	.09(.03)**	.08(.06)	.06(.05)	.11(.04)**

Note: MO = Mastery Orientation; PO = Performance Orientation. Slope coefficients represent unstandardized regression coefficients (*SE*s given in parentheses).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

3.5.1. Overall strategy use

Table 4 summarizes the statistical results for children's usage of relational and operational strategies across all six problems, and separately for each type of problem. There were no main effects of either mastery or performance orientation ($ps > .200$). Looking at all six problems (*overall* column), we see that there was a main effect of condition on relational strategy use ($B = -.12$, $SE = .05$, $p = .014$, $sr^2 = .025$). The overall model for relational strategy use was significant, $F(8, 142) = 12.96$, $p < .001$, $R^2_a = .389$. On average, children in the solve-first condition used relational strategies less often than children in the instruct-first condition. This finding reflects the overall difficulty of exploratory learning in the solve-first condition, compared to the instruct-first condition. This effect of condition across all six problems was qualified by interactions with both mastery orientation ($B = .15$, $SE = .07$, $p = .024$, $sr^2 = .021$) and performance orientation ($B = -.16$, $SE = .06$, $p = .010$, $sr^2 = .028$). As illustrated in Fig. 3 and summarized in Table 4, each one *SD* increase in mastery orientation was associated with a predicted 11% increase in use of relational strategies in the solve-first condition ($B = .11$, $SE = .05$, $p = .021$, $sr^2 = .022$). In contrast, higher performance orientation was associated with an 11% decrease in the use of relational strategies, compared to lower performance orientation, in the solve-first condition ($B = -.11$, $SE = .05$, $p = .019$, $sr^2 = .023$). As predicted, neither mastery nor performance orientation was associated with relational strategy use in the instruct-first condition ($ps > .200$; Table 4). In fact, children in the solve-first condition with higher mastery orientation appear to have matched their instruct-first counterparts in use of relational strategies (Fig. 3).

Operational strategy use was consistent with these findings. The overall model for operational strategy use was significant, $F(8, 142) = 6.64$, $p < .001$, $R^2_a = .231$. As summarized in Table 4 and illustrated in Fig. 3, there was a main effect of condition on operational strategy use ($B = .09$, $SE = .03$, $p = .014$, $sr^2 = .032$). On average, children in the solve-first condition were more likely to use operational strategies than children in the instruct-first condition. There was no Mastery Orientation × Condition interaction ($B = -.04$, $SE = .05$, $p = .336$, $sr^2 = .005$). In addition, there was no main effect of performance orientation ($B = .03$, $SE = .02$, $p = .118$, $sr^2 = .013$). However, there was a significant Performance Orientation × Condition interaction ($B = .10$, $SE = .04$, $p = .016$, $sr^2 = .030$). Higher performance orientation was associated with a 9% increase in use of operational strategies in the solve-first condition for each one-*SD* increase ($B = .09$, $SE = .03$, $p = .011$, $sr^2 = .033$), suggesting that the difficulty associated with exploratory learning lead these children to persist with naïve, ineffective strategies. As predicted, there was no effect of performance orientation in the instruct-first condition ($B = -.02$, $SE = .03$, $p = .507$, $sr^2 = .002$).

Thus, though the solve-first condition posed a significant challenge to learners overall (i.e., averaged across all six problems), mastery orientation was associated with increased reliance on relational strategies, whereas performance orientation was associated with decreased reliance on relational strategies and a concurrent increase in operational strategies.

3.5.2. Strategy use by problem type

Table 4 also summarizes the effects of condition and achievement motivation separately for each type of problem (three-, four-, and five-operand). Main effects of condition for both relational and operational strategy use revealed that learners struggled with the four-operand problems in the solve-first condition. They responded to these more difficult problems with less relational strategy use ($B = -.24$, $SE = .06$, $p < .001$, $sr^2 = .071$) and greater operational strategy use ($B = .14$, $SE = .05$, $p = .007$, $sr^2 = .042$) relative to the instruct-first condition. However, once learners subsequently encountered the even more difficult five-operand problems, the moderating impact of motivational orientation began to emerge.

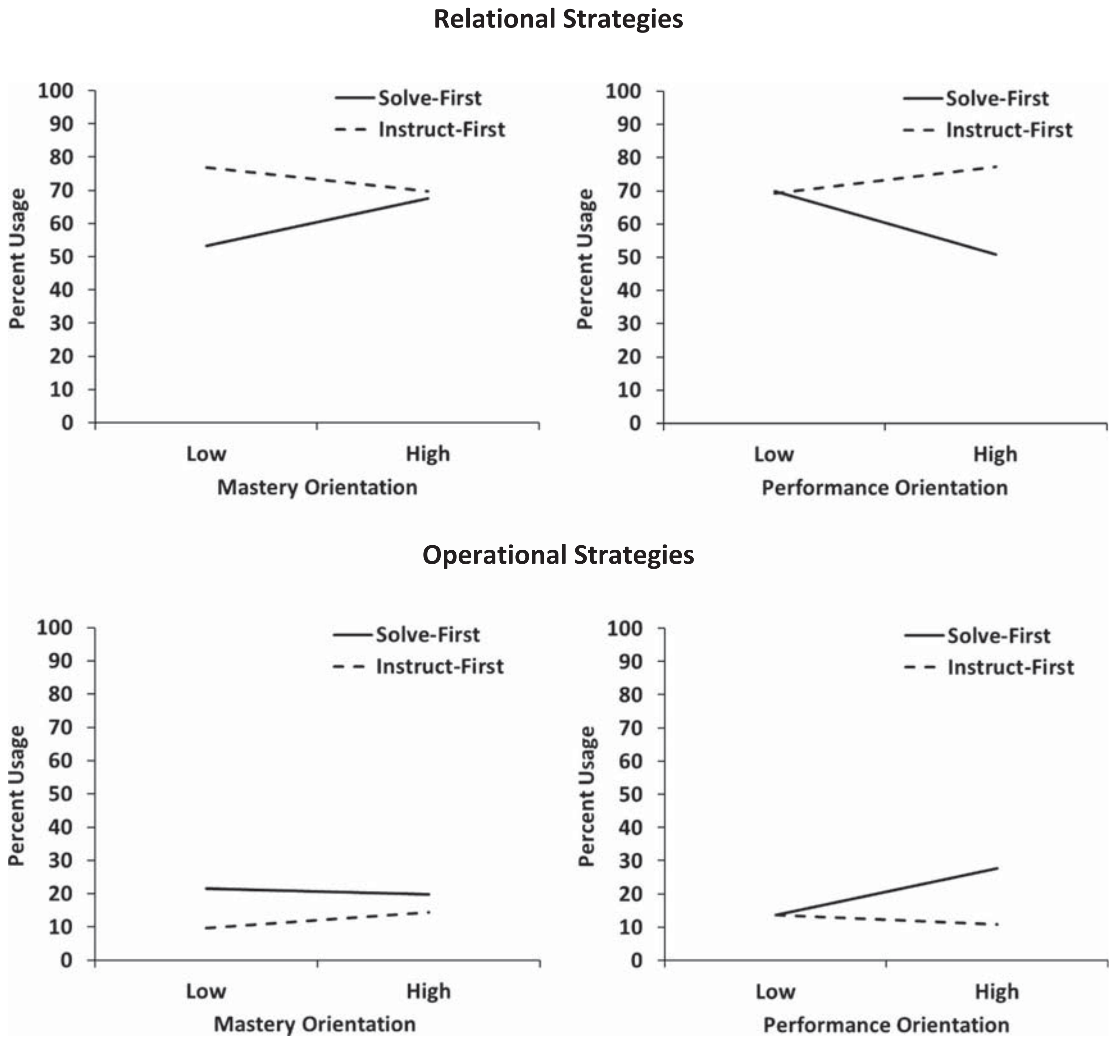

Fig. 3. Tutoring session: percent usage of relational strategies and operational strategies out of all six problems. *Note:* Low and high mastery and performance orientation points are plotted at ±1 SD from the mean (centered).

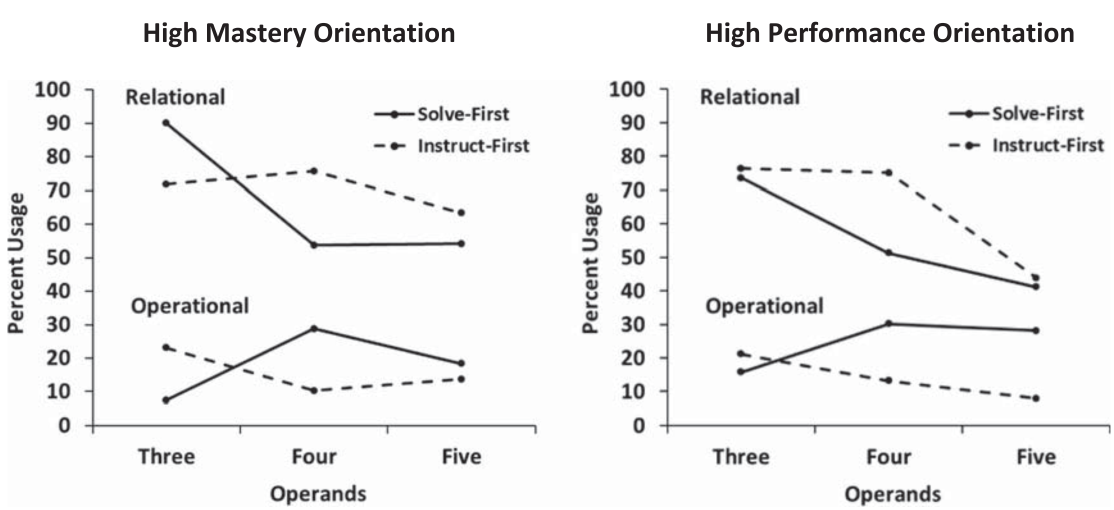

Fig. 4. Percent usage of relational and operational strategies during tutoring by problem type (three, four, and five operands) and high mastery versus performance orientation. *Note*: Learners encountered the problems in the order shown; three-, four-, then five-operand problems. The three-operand problem had an operation on the right side of the equal sign, while four- and five-operand problems had operations on both sides of the equal sign.

Overall, higher mastery orientation was associated with maintenance of sophisticated strategy use on the five-operand problems, whereas performance orientation was associated with further decline. There was a marginal Mastery Orientation × Condition interaction ($B = .15$, $SE = .07$, $p = .054$, $sr^2 = .017$). In the solve-first condition, each one *SD* increase in mastery orientation was associated with a 12% increase in relational strategy use ($B = .12$, $SE = .06$, $p = .049$, $sr^2 = .017$). There was also a Performance Orientation × Condition interaction for both relational ($B = -.23$, $SE = .07$, $p = .002$, $sr^2 = .045$) and operational ($B = .16$, $SE = .05$, $p = .001$, $sr^2 = .058$) strategy use. In the solve-first condition, each one *SD* increase in performance orientation was associated with an 18% decrease in relational strategy use on five-operand problems ($B = -.18$, $SE = .06$, $p = .002$, $sr^2 = .043$) and an 11% increase in use of operational strategies ($B = .11$, $SE = .04$, $p = .006$, $sr^2 = .043$).

These effects are more clearly revealed in Fig. 4, where we used a median split to depict strategy usage for each type of problem separately for high mastery orientation ($n = 79$) and high performance orientation ($n = 76$). Problems were encountered in the order presented in Fig. 4. As previously described, the first problem was a three-operand problem, which is easier (e.g., less complex) than the other problems and less of a departure from what children in this age group typically encounter, though still novel (McNeil, 2008, Rittle-Johnson et al., 2011). Children high in mastery orientation were more likely to use a relational strategy on this problem in the solve-first condition than in the instruct-first condition, suggesting that they were more likely to find a successful strategy without instruction (see also Table 4). As children encountered four-operand problems in the solve-first condition, relational strategy use decreased and operational strategy use increased, indicating that children used sophisticated strategies less and simpler incorrect strategies more, regardless of motivational orientation. However, by the time they encountered five-operand problems, children with higher mastery orientation leveled off in their usage of sophisticated relational strategies and simultaneously decreased their usage of incorrect, operational strategies. This finding is consistent with Dweck et al.'s research, in which higher mastery oriented children either invented new strategies when they encountered setbacks or quickly stabilized, halting a decline into further incorrect strategy usage (e.g., Diener & Dweck, 1978, 1980; cf. Dweck & Leggett, 1998, Dweck & Master, 2008). In contrast, children with higher performance orientation continued their decline in use of sophisticated relational strategies while continuing to use simpler, incorrect operational strategies at a relatively high level, again consistent with Dweck et al.'s core findings.

4. Discussion

Exploratory learning prior to instruction is challenging (Klahr, 2009), but can also benefit learning of important concepts beyond the level gained with traditional tell-then-practice instruction (Schwartz et al., 2009). We tested the hypothesis that individual differences in achievement motivation influence the level and type of knowledge attained from exploration. Individuals higher in mastery orientation, who value learning goals, view challenging learning situations as an opportunity for knowledge growth and respond with increased effort and persistence. In contrast, individuals with higher performance orientation, who primarily seek to demonstrate ability, may view challenging learning situations as a threat to this goal and withdraw their effort or perseverate on disconfirmed strategies (e.g., Ames & Archer, 1988; Diener & Dweck, 1978; see Dweck & Leggett, 1998; Dweck & Master, 2008 for review). Thus, although previous research has demonstrated that exploratory activities benefit learning, there may be important individual differences in the ability to capitalize on this instructional format.

In the current study, second- through fourth-grade children were randomly assigned to one of two tutoring conditions. In the instruct-first condition, children received instruction on the concept of mathematical equivalence; then they practiced solving increasingly difficult mathematical equivalence problems. In the solve-first condition, children did these same instructional activities in reverse order, solving the problems as an exploratory learning activity before receiving formal instruction on the concept of mathematical equivalence. A retention test administered two weeks later assessed conceptual knowledge (i.e., knowledge of the mathematical equivalence concept), procedural knowledge (i.e., problem-solving ability), and far-transfer, which required a more sophisticated understanding of mathematical equivalence as well as application of appropriate procedures to solve especially difficult, novel problems. Taken together, these assessments enabled us to examine the effects of learning format and achievement motivation on different aspects of learning and performance.

Because exploratory learning invokes more confusion and difficulty than providing instruction on a concept first (Kirschner et al., 2006), we expected individual differences in achievement motivation to primarily impact learning in the solve-first condition. Indeed, at retention test, learners performed similarly in the less demanding instruct-first condition, but differed in the more demanding solve-first condition. Higher mastery orientation was associated with improved conceptual knowledge and far-transfer in the solve-first condition but not in the instruct-first condition, indicating that mastery orientation facilitated conceptual learning from exploration. Performance orientation, in contrast, did not impact conceptual learning from exploration. However, higher performance orientation was associated with lower procedural knowledge and far-transfer in the exploratory, solve-first condition. Taken together, these findings suggest that when children are higher in mastery orientation, they are motivationally better suited to cope with, and thrive within, an exploratory learning environment.

These observed differences in knowledge development were associated with differences in learners' problem-solving strategies during the tutoring intervention. Relational problem-solving strategies (e.g., equating values on each side of the equal sign) reflect a deeper understanding of mathematical equivalence. Operational strategies (e.g., adding every number in the equation, while ignoring the placement of the equal sign) reflect a more superficial understanding of mathematical equivalence (Carpenter et al., 2003; Rittle-Johnson et al., 2011). In keeping with the higher demands placed on learners, children in the solve-first condition were less likely to use relational strategies, and more likely to use operational strategies, than their counterparts in the instruct-first condition. However, this overall effect of condition on strategy use was moderated by achievement motivation. During exploration, higher mastery orientation was associated with greater use of relational strategies, whereas higher performance orientation was associated with increased use of operational strategies and a concurrent decrease in usage of relational strategies. These differences emerged over time, when learners encountered increasingly complex problems.

These findings are consistent with findings in the achievement motivation literature and may help explain why exploration was only useful to some children. Individual differences in achievement motivation have been shown to influence how learners cope with confusing task instructions and lessons (e.g., Licht & Dweck, 1984), respond and adapt to seemingly impossible problems (e.g., Diener & Dweck, 1978, 1980), process and engage with new material (Belenky & Nokes-Malach, 2012), and achieve long-term academic goals (e.g., Blackwell et al., 2007; Grant & Dweck, 2003; cf. Dweck & Leggett, 1988; Dweck & Master, 2008; Hidi & Renninger, 2006). The challenge and confusion associated with exploration may lead some children to abandon old strategies and explore new ones, but lead others to perseverate on disconfirmed strategies that ultimately impede learning.

This particular observation may inform the ongoing debate about the relative benefits of exploratory learning and direct instruction. Exploration may pose a “desirable difficulty,” which prompts learners to develop an enriched understanding of underlying concepts and solutions (Bjork, 1994; Bonawitz et al., 2011). However, exploration may alternatively pose too significant a challenge (Kirschner et al., 2006). The current findings demonstrate that using exploratory problem-solving activities in combination with instruction can be beneficial—but namely for children who have higher mastery orientation. It is important to emphasize that children in our two learning conditions began with equal demonstrated ability, as indicated by similar pretest scores. It was only after learners encountered significant challenge, especially during the four- and five-operand problems of the exploratory (solve) phase, that they showed learning and performance differences. The current findings therefore highlight the importance of considering motivational influences on learning and strategy selection (cf. Dweck, 1986; Hidi & Renninger, 2006).

In addition to supporting Dweck's formulation of achievement motivation (e.g., Dweck, 1986, 2006; Dweck & Leggett, 1998), our findings are consistent with two of four hypotheses proposed by Barron and Harackiewicz (2001) about the nature of the relationship between mastery and performance orientation. Specifically, our findings support the idea that achievement motivations act as separate signals that simultaneously and independently influence behavior (additive goals hypothesis). In addition, our results support the idea that achievement motivations can impact particular types of outcomes (e.g., conceptual and procedural knowledge) in different ways (specialized goals hypotheses).

Our findings did not support two additional hypotheses proposed by Barron and Harackiewicz (2001). The *interactive goals hypothesis* proposes that achievement motivations interact, producing optimal performance among those high in both mastery and performance orientation. The *selective goals hypothesis* proposes that individuals select the most appropriate and advantageous motivational mindset for the task. In our experiment, mastery and performance orientation were uncorrelated and did not interact; moreover, high levels of both mastery and performance orientation did not lead to the highest performance levels. For example, mastery and performance orientation had opposite effects on far transfer in the solve-first condition. This finding indicates that the effects of these motivational mindsets would counteract each other in children who are high on both mastery and performance orientation, yielding poorer performance than those who are only high in mastery orientation. In addition, high performance orientation did not facilitate learning on any of the tasks examined, but did hurt performance on procedural learning. Taken together, these results argue against the interactive and selective goals hypotheses. Numerous studies have investigated the relationship between mastery and performance orientation (e.g., whether and how they are correlated) and different functional forms of mastery and performance orientation (e.g., Barron & Harackiewicz, 2001; Darnon, Benoít, Gilliéron, & Butera, 2010; Grant & Dweck, 2003; Schwinger & Wild, 2012). However, no overall pattern has emerged, in part because of differences in the performance environment, task domain, motivational measures, age groups, and other factors used across studies (Hulleman et al., 2010; Kaplan & Maehr, 2007; Senko et al., 2011).

Future research is needed to test the boundaries and pervasiveness of our findings. Our experiment included second through fourth-grade children (ages 7–10 years). Research has demonstrated the impact of mastery and performance orientation in this age group (e.g., Gunderson et al., 2013; Dweck & Heyman, 1998; Kamins & Dweck, 1999), as well as younger children (e.g., Heyman et al., 1992; Moorman & Pomerantz, 2008) and older individuals (e.g., Diener & Dweck, 1980; Grant & Dweck, 2003). However, children's achievement motivation is known to change over time (e.g., across school years), as they mature and encounter new performance demands (Bong, 2009; Schwinger & Wild, 2012). Children may even place different meaning on achievement with increased maturity. For example, research with young children from four to six years old finds that they interpret performance orientation with respect to abstract self-worth (e.g., being a "bad" boy/girl), whereas older children appear to treat self-worth more fully in terms of their ability (e.g., "smartness"), though the behavioral and affective outcomes appear to be the same (Grant & Dweck, 2003; Heyman et al., 1992; Kamins & Dweck, 1999). With maturity, achievement motivation may also become more complex and nuanced within a particular individual, taking on multiple dimensions (e.g., mastery approach/avoidance; Bong, 2009; Schwinger & Wild, 2012).

Because we assessed achievement motivation as a naturally-occurring individual difference, we cannot be certain that some other, unmeasured, factor such as task interest did not contribute to the observed effects. Interest is related to achievement motivation (Rawsthorne & Elliot, 1999). For example, inducing a mastery mindset through experimental manipulation can increase task interest, compared to inducing performance orientation (e.g., Butler, 1987; Vansteenkiste et al., 2007). Dweck's (1985, 1986, 2006) formulation of achievement motivation as a constellation of perceptions, self-evaluations, and values explicitly acknowledges task interest as a component of achievement motivation. Therefore, from our standpoint, mastery and performance orientation are expected to be associated with task interest. Achievement motivation and task interest relate to one another reciprocally, reinforcing and fueling one another; thus, while they may not be entirely separable, they also are not entirely reducible to each other (Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008; Hidi & Renninger, 2006).

The effects of mastery- and performance-orientation in the current study are based on a brief, 4-item measure adapted from Elliot and Church (1997), Nicholls et al. (1990), and Roedel et al. (1994), and the reliability of the performance orientation measure was limited. We chose to use this measure due to practical constraints working with child participants in a school-based setting where time was limited. Despite this shortened assessment, general patterns consistent with our hypotheses emerged across a number of dependent measures in our study (i.e., conceptual knowledge, procedural knowledge, far-transfer, and intervention strategy use). Thus, any limitations due to our shortened measure are tempered by the fact that consistent and significant findings emerged with these measures. However, one possibility is that marginal or non-significant effects in our dataset would emerge as significant with a more extensive, reliable measure.

We focused on a specific conceptualization of mastery and performance orientation, in keeping with our interest in learners' reaction to confusion and effortful exploration of a novel concept. The desire for mastery is a complex motivational phenomenon. Researchers have identified several components to mastery orientation, including goals for learning, understanding, and improving; enjoyment and preference for challenge; and interest and curiosity (Grant & Dweck, 2003; Hulleman et al., 2010). Some even distinguish between approach-motivated and avoidance-motivated ways of pursuing mastery (e.g., Elliot & McGregor, 2001). Our study focused on response to challenge in particular, as we expected this facet of mastery orientation to be most associated with performance in challenging, exploratory learning settings. Performance orientation can additionally be separated into concerns about self-worth, social comparison or appearance to others, and desirable performance outcomes (e.g., good grades), as well as dislike for challenge and approach versus avoidance motivated ways of pursuing one's goal(s) (Elliot et al., 2011; Grant & Dweck, 2003; Hulleman et al., 2010). We included the constructs "self-worth" and "social comparison" as important components of performance orientation in the current work, because these have reliably predicted children's reactions to effort needed to overcome confusion, novelty, and mistakes encountered during learning (Dweck & Leggett, 1998; Blackwell et al., 2007; cf. Miele & Molden, 2010). Thus, our findings are limited to these specific characterizations of mastery and performance orientation, which are consistent with other studies (e.g., Ames & Archer, 1988; Blackwell et al., 2007), but not necessarily all characterizations of achievement motivation (e.g., Elliot et al., 2011; cf. Hulleman et al., 2010). Future research is needed to determine how other aspects of achievement motivation contribute to learning by exploration.

The current findings also resulted from a single, scripted tutoring intervention, which focused on a particular mathematical domain and a relatively brief exploratory phase. In order to fully capture the relationship between achievement motivation and exploratory learning, it will be important to test these ideas in other learning environments. In this way, research can continue to provide important insights into knowledge development from exploration. For example, in the present research, children received accuracy feedback in the presence of the experimenter. Children high in performance orientation may feel threatened by such public feedback, given their concern with looking smart or impressive compared to other learners. Hence, experiencing difficulty during exploration in the presence of another person may counterproductively exacerbate performance orientation, leading to maladaptive learning behavior (e.g., Dweck & Leggett, 1998). Performance-oriented children may therefore respond better to private or confidential feedback, allowing the child alone to see, and potentially learn from, the mistakes made. However, to our knowledge, this particular hypothesis has not been tested in child learners (see Butler, 1993, 1999; VandeWalle & Cummings, 1997, for adult learners).

In addition, exploratory learning environments do not always include accuracy feedback. It is unclear how children with varying achievement motivations would respond to exploration without feedback, because few achievement motivation studies have examined no-feedback conditions, and those that have differed vastly in their design (e.g., Butler, 1987; Mueller & Dweck, 1998; Souchal et al., 2013). However, it seems likely that our results would remain largely unchanged, or possibly become even stronger, because of the increasing challenge and confusion of exploratory learning environments without feedback (e.g., Kirschner et al., 2006).

More generally, it may be important to consider the difficulty of the exploratory learning activity with respect to the ability of the learner. Even the most mastery-oriented learner is unlikely to profit from an exploratory activity that places too many demands on cognitive load (Senko & Harackiewicz, 2005). In addition, simple exploratory activities that reinforce learner competence may not have deleterious effects for learners higher in performance orientation.

Finally, given the benefits of mastery orientation for exploration, future research might also examine the impact of scaffolding learner motivation during exploration—by promoting a mastery orientation for all learners. For example, students may adopt the achievement orientations emphasized by their parents (e.g., Gunderson et al., 2013; Moorman & Pomerantz, 2008) and educators (e.g., Ames & Archer, 1988; Turner et al., 2002), or respond to situational goal inductions and process praise that highlight the value of effort (e.g., Mueller & Dweck, 1998; Senko & Harackiewicz, 2005). Hence, it may be possible to lessen the detrimental effects of performance orientation through appropriate modeling or scaffolding, allowing the benefits of mastery orientation to be extended to more learners during exploration.

In conclusion, the current study demonstrates that, although exploratory learning activities can support knowledge development in general, achievement motivation can lead some individuals to especially profit from exploration. By understanding the demands such activities place on different individuals, we may better understand the factors that boost learning from exploration, allowing us to design more effective learning environments.

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