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Achievement Motivation and Strategy Selection during Exploratory Learning

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Abstract

Exploratory learning before instruction can benefit understanding, but can also be challenging. Individual differences in response to challenge, such as achievement motivation, may therefore moderate the benefits of exploratory learning. Higher mastery orientation generally leads to increased effort in response to challenge, whereas higher performance orientation leads to withdrawal. Children (2nd-4th grade; $N=159$) were given mathematical equivalence problems to solve as either an exploratory learning activity (before instruction) or as practice (after instruction). Higher mastery orientation was associated with improved learning from exploration. In contrast, performance orientation did not lead to learning improvements—and sometimes even hurt learning. Higher mastery orientation was also associated with more sophisticated problem-solving strategies during exploration. Although exploratory activities have the potential to advance strategy selection and subsequent learning, achievement motivation may boost or hinder these benefits.

Keywords: exploratory learning, achievement motivation, mathematics, strategy selection

Introduction

Exploratory instructional activities can increase individuals' understanding of new concepts. 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). As a result, learners who explore a new concept before receiving direct instruction on the topic may develop a more sophisticated appreciation for why or how a particular solution approach is better, or worse, than another. This training potentially translates into deeper understanding and better retention of the material (Schwartz, Lindgren, & Lewis, 2009).

For example, Schwartz et al. (2011) examined the learning of eighth-grade students who explored density problems before receiving instruction. These students exhibited better understanding of the problem structure and better transfer to novel problems at a later test compared to those who received instruction before solving the density

problems. Similar findings have been observed for ninth-grade students learning descriptive statistics (Kapur, 2012; Schwartz & Martin, 2004) and college students learning cognitive psychology (Schwartz & Bransford, 1998).

Although exploratory learning can enhance conceptual understanding, such exploration can be challenging for the learner. Compared to more traditional tell-then-practice instruction, learners typically make more mistakes during exploratory learning activities, and they must focus on those mistakes in order to develop more sophisticated conceptualizations of the problem (Kapur, 2010). This learning process often entails considerable effort, as individuals engage in trial-and-error learning or hypothesis-testing (Kirschner, Sweller, & Clark, 2006; Rittle-Johnson, 2006). Learners also may encounter considerably more confusion about how to proceed (Dewey, 1910). In some cases, these learning challenges may pose a "desirable difficulty" (Bjork, 1994) or "productive failure" (Kapur, 2010) 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 (Kirschner et al., 2006).

Achievement Motivation and 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. Research on achievement motivation demonstrates that individuals approach learning events with different goals and conceptions of what constitutes "ideal" learning performance. These differences influence how individuals interpret and respond to challenge during learning (Dweck & Leggett, 1988; Elliot & McGregor, 2001). Individuals can have both mastery and performance goals to different degrees (Barron and Harackiewicz, 2006). Individuals higher in *mastery-orientation* desire personal growth (i.e., learning goals) and tend to view challenge as an opportunity to learn something new. Therefore, they generally seek challenge and respond

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to it with increased effort and interest. 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 (Dweck, 1986).

For example, Diener and Dweck (1978) compared how mastery- versus 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, known to be too advanced for their age group. While completing the solvable problems, children with higher performance- versus mastery-orientation 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 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 developmentally simpler strategies that could not lead to success. Thus, children with higher mastery-orientation learned more from this difficult task and solved more developmentally challenging problems. Similar observations have been made in confusing learning conditions (Licht & Dweck, 1984).

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 by comparing the problem-solving strategies, and subsequent learning, of individuals higher or lower in mastery versus performance orientation. Children were instructed on a novel mathematical concept. Half were given instruction, and then solved practice problems with accuracy feedback (*instruct-first condition*). The other half received the same materials, but in reverse order: They first completed exploratory problem-solving with accuracy feedback, and then received instruction (*solve-first condition*).

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 in mathematics, such as early algebra understanding (McNeil & Alibali, 2005). Children in these grades often lack a *relational understanding* of mathematical

equivalence (e.g., understanding that $2+3$ is “the same as” 5). Children often demonstrate their misconceptions of the equal sign with the strategies they use for mathematical equivalence problems such as $4+5+3=_+3$ (e.g., McNeil & Alibali, 2005). In these problems, children often view the equal sign as a procedural cue. For example, they may ignore the values to the right of the equal sign and sum the numbers on the left side (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).

These types of incorrect strategies reflect an *operational understanding* of the equal sign, and indicate a developmentally immature understanding of mathematical equivalence (Rittle-Johnson et al., 2011). Such responses also resemble learning errors identified in the achievement motivation literature, in which performance-orientation leads learners (e.g., 4th-6th graders) to perseverate on disconfirmed strategies or revert to less mature (e.g., preschool level) representations of a problem following failure trials (e.g., Diener & Dweck, 1978).

Hypotheses

Considering the literatures on exploratory learning and achievement motivation, we predicted different learning outcomes depending on the type of knowledge assessed. We assessed learner’s 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. These questions were examined by reanalyzing previously-reported-data (DeCaro and Rittle-Johnson, 2012) to examine the role of achievement motivation.

Conceptual Knowledge Our main interest in the present research was how achievement motivation affects learners’ *conceptual knowledge*, their ability to grasp the underlying principles of mathematical equivalence, following exploration. Prior work suggests that exploration primarily benefits conceptual knowledge (Schwartz et al., 2009), but is mistake-prone and initially more confusing than a tell-then-practice instructional approach (e.g., Alfieri et al., 2011). Previous research also indicates that individual differences in achievement motivation influence learning and performance primarily when learners encounter challenging tasks (Dweck, 1986). Mastery orientation typically leads learners to respond to initial setbacks with increased resolve, and by maintaining or inventing more sophisticated learning strategies (e.g., Diener & Dweck, 1978). Thus, we expected higher mastery orientation to be associated with improved conceptual knowledge, specifically in the more demanding solve-first condition.

The prediction for performance orientation in the solve-first condition is less straightforward. Higher performance orientation often leads learners to respond to setbacks with defensive withdrawal of effort and regressive thinking (e.g.,

Diener & Dweck, 1978). 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, it may simply hinder one's ability to profit from the exploratory learning opportunity. This prediction is supported by Barron and Harackiewicz's (2005) *multiple-motive hypothesis*, which suggests that mastery and performance motives represent separate signals with different degrees of relevance for conceptual versus procedural knowledge. According to this 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.

Procedural Knowledge We also evaluated *procedural knowledge*, or the ability to execute the correct action sequences to solve problems. Procedural knowledge is strongly correlated with conceptual knowledge (Rittle-Johnson & Alibali, 1999). However, problem-solving assessments provide especially diagnostic information about ability. Therefore, according to Barron and Harackiewicz's (2005) multiple-motive hypothesis, performance orientation may be more relevant to procedural knowledge than mastery orientation (cf. Grant & Dweck, 2003). We therefore predicted a positive, but weaker, relationship between mastery orientation and procedural knowledge in the solve-first condition. Moreover, we predicted a negative relationship between performance orientation and procedural knowledge acquisition (cf. Dweck & Leggett, 1988; Grant & Dweck, 2003).

Problem-Solving Strategies In addition to assessing knowledge outcomes (after tutoring), we examined children's problem-solving strategies during tutoring. Such information may reveal how achievement motivation impacts learning from exploration. Because children in the solve-first condition completed the problems as an exploratory activity, we expected them to use poorer problem-solving strategies. Specifically, they might use fewer *relational strategies* that evidence understanding of the equal sign as a relational symbol. Instead, they might rely more on *operational strategies*, in keeping with developmentally simpler views of the equal sign as an operational symbol (i.e., "add-all" or "add-to-equals").

Although we thought the solve-first condition would be more challenging, we expected mastery orientation to promote a more adaptive response to these setbacks (cf. Diener & Dweck, 1978). Specifically, mastery orientation should be associated with increased use of relational strategies and decreased use of operational strategies. In contrast, performance orientation should be associated with increased reliance on these developmentally simpler, operational strategies (and decreased use of relational strategies).

Method

Participants

Participants were 2nd-4th grade children at a suburban public school. Children who scored below 80% on a pretest assessing procedural and conceptual knowledge of mathematical equivalence were selected ($N=159$, 56% female, age $M = 8.5$ years, range 7.3-10.8 years). Approximately 18% were ethnic minorities (10% African-American, 6% Asian, and 2% Hispanic).

Research Design and Procedure

Consenting children first completed a pretest in their classrooms, followed by a self-report measure of their achievement motivation. 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* ($n = 79$) or the *solve-first condition* ($n = 80$). Children were additionally assigned to either self-explain (i.e., explain why particular answers were correct/incorrect) or solve extra problems instead; however, this manipulation had no discernible effects and will not be discussed further. The session ended with a posttest assessing children's procedural and conceptual knowledge. Approximately two weeks later, children completed an equivalent retention test.

Tutoring Session

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 problems served as an exploratory learning activity followed by formal instruction.

Instruction During instruction (adapted from Matthews & Rittle-Johnson, 2009), children were taught about the relational meaning of the equal sign. Five number sentences (e.g., $3+4=3+4$) were individually shown on the computer. 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").

Problem-Solving During the problem-solving phase, children completed six mathematical equivalence problems presented individually on the computer. Problems increased in difficulty from three operands (i.e., $10=3+_$) to five operands (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.

Learning Assessments

Problem-Solving Strategies. Children’s problem-solving strategies in the tutoring session were categorized as relational, operational, or other incorrect ($\kappa=.80$). *Relational strategies* evidenced a deliberate attempt to equalize the values on each side of the equation or conceptualize the values as equivalent (Rittle-Johnson et al., 2011). *Operational* and *other incorrect strategies* both evidenced an erroneous conceptualization of the equal sign. However, operational strategies represented misconceptions previously identified as developmentally less sophisticated and fundamentally inadequate (i.e., *add-all* and *add-to-equals* strategies; McNeil & Alibali, 2005).

Posttest and Retention Test We measured children’s conceptual and procedural knowledge of mathematical equivalence by adapting assessments from past research (Rittle-Johnson et al., 2011). *Conceptual knowledge* items assessed two key concepts: the symbolic meaning of the equal sign and the structure of equations (8 items; $\kappa=.89-.96$). *Procedural knowledge* items consisted of ten mathematical equivalence problems. Answers to procedural knowledge items were scored as correct if they came within one point of the correct answer, to reduce false negatives. The retention test was identical to the posttest, but also included eight *far-transfer items* that will not be discussed further, due to space limitations. Because we were most interested in long-term learning, and because the results of the posttest mirrored those of the retention test, we report only the results of the retention test.

Achievement Motivation

Achievement motivation items were adapted from Elliot and Church (1997). Two items assessed mastery orientation (e.g., “I want to learn as much as possible about math, even if I have to work hard”). Two items assessed performance orientation (e.g., “In math class, it is important for me to do well compared to others in my class”). Children responded on a 6-point, Likert-type scale ranging from 1 (*Strongly Disagree*) to 6 (*Strongly Agree*). Mastery-orientation and performance-orientation scores were created by averaging the two responses on each subscale (Elliot & Church, 1997).

Results

We examined the relationship between mastery and performance orientation and learning in the two tutoring conditions. We also examined children’s problem-solving strategies during tutoring. We used hierarchical linear regression for all analyses. The predictors in the model were mastery orientation score, performance orientation score, condition (dummy-coded), and two interaction terms (Condition \times Mastery Orientation, Condition \times Performance Orientation). Preliminary analyses showed no significant two-way interactions between mastery and performance orientation, or three-way interaction with condition, so they were not included in the final model. Thus, the final model

represents the independent and joint effects of achievement motivation and tutoring condition on the dependent variables (Barron & Harackiewicz, 2001). We also included children’s age and conceptual and procedural knowledge pretest scores to control for prior knowledge. Each predictor was centered. Significant interactions were explored through simple slopes analyses. Estimated means were plotted at one SD above and below the mean, to represent the effect of low versus high achievement motivation on the dependent variable as a function of condition.

No significant main effects of performance or mastery orientation emerged ($F_s < 1$). Therefore, only the results for Condition and Condition \times Achievement Motivation interactions will be reported. Children in the instruct-first and solve-first conditions did not differ at pretest by their procedural knowledge, conceptual knowledge, or achievement motivation ($F_s < 1$). Mastery and performance orientation were not correlated: $r(156) = .08, p = .151$.

Conceptual Knowledge

At retention test, a marginally significant main effect of condition emerged ($B = .05, SE = .03, p = .078$). Learners in the solve-first condition demonstrated higher conceptual knowledge than learners in the instruct-first condition. This effect of condition was qualified by a Mastery Orientation \times Condition interaction ($B = .08, SE = .04, p = .059$). As depicted in Figure 1, higher mastery orientation was associated with higher conceptual knowledge acquisition in the solve-first condition ($B = .08, SE = .03, p = .009$), indicating that higher mastery orientation helped children learn from exploration. Mastery orientation was unrelated to conceptual knowledge in the instruct-first condition ($B = 0$). There was no Performance Orientation \times Condition interaction ($B = 0$), indicating that performance orientation did not hurt conceptual knowledge.

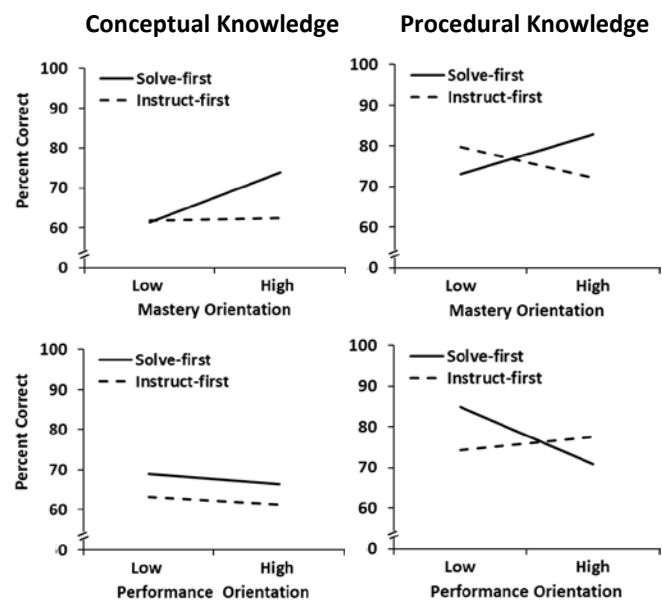


Figure 1. Conceptual and Procedural Knowledge

Procedural Knowledge

At retention test, the condition term was not significant ($B = .02$; Figure 1). A Mastery Orientation \times Condition interaction emerged ($B = .12$, $SE = .06$, $p = .036$). Higher mastery orientation was associated with a trend towards higher procedural knowledge in the solve-first condition ($B = .07$, $SE = .04$, $p = .118$), whereas it was associated with a trend towards poorer procedural knowledge in the instruct-first condition ($B = -.05$, $SE = .04$, $p = .159$).

A significant Performance Orientation \times Condition interaction also emerged ($B = -.11$, $SE = .05$, $p = .041$; Figure 1). Higher performance orientation was associated with lower procedural knowledge in the solve-first condition ($B = -.09$, $SE = .04$, $p = .035$) but was unrelated to procedural knowledge in the instruct-first condition ($B = .02$). Higher performance orientation reduced gains in procedural knowledge from exploration.

Performance during Tutoring Intervention

To provide further insight into how the knowledge acquisition observed at retention test may have emerged, we examined the problem-solving strategies children used during the tutoring session. Doing so indicates how children responded to difficulties encountered during exploration.

There was a main effect of condition on use of both relational strategies ($B = -.12$, $p = .01$) and operational strategies ($B = .09$, $p = .01$). On average, children in the solve-first condition used relational strategies less than children in the instruct-first condition—reflecting the overall difficulty of exploratory learning in the solve-first condition. This effect was qualified by interactions with both mastery orientation ($B = .15$, $p < .01$) and performance orientation ($B = -.16$, $p < .01$). As shown in Figure 2, higher mastery orientation was associated with increased use of relational strategies in the solve-first condition ($B = .11$, $p < .05$). In contrast, higher performance orientation was associated with decreased use of relational strategies in this condition ($B = -.11$, $p < .05$). Neither mastery nor performance orientation were associated with relational strategy use in the instruct-first condition ($B = -.03$ and $B = .04$). 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.

Operational strategy use was consistent with these findings. As shown in Figure 2, children in the solve-first condition used operational strategies more than children in the instruct-first condition. No interaction with mastery orientation was found ($B = -.04$). However, performance orientation interacted with condition ($B = .10$, $p < .05$). In the solve-first condition, higher performance orientation was associated with increased use of operational strategies ($B = .09$, $p < .01$). This finding suggests that the difficulty of exploratory learning leads children higher in performance-orientation to adopt developmentally immature strategies. No relationship with performance orientation was found in the instruct-first condition ($B = -.02$).

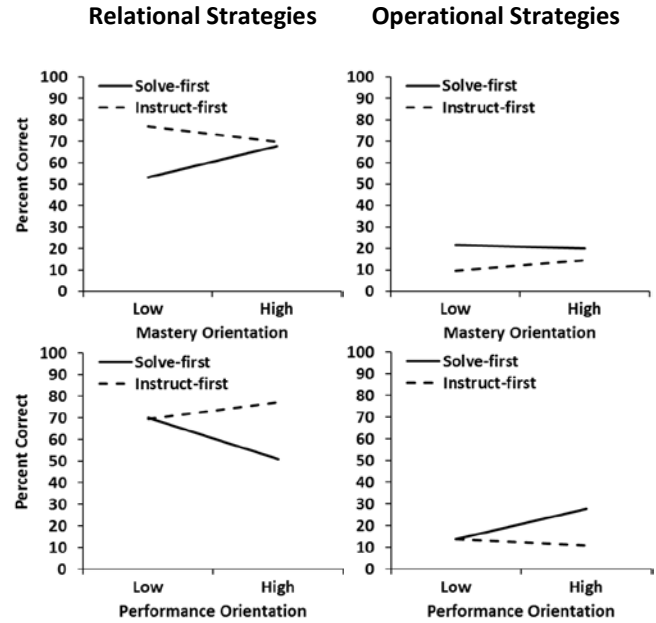


Figure 2. Strategy Use during Tutoring Session

Discussion

As predicted, children higher in mastery orientation learned a new mathematics concept better when a problem-solving session was used as an exploratory activity, rather than practice. That is, higher mastery orientation was associated with improved conceptual knowledge acquisition (and somewhat improved procedural knowledge) in a solve-first condition where problem-solving preceded formal instruction. Higher performance orientation, in contrast, did not facilitate learning from exploration: These children performed at normal levels on conceptual knowledge acquisition and did worse than normal on procedural knowledge acquisition (i.e., problem-solving success).

These differences in learning from exploration could be attributed to the challenge inherent in such activities. Children in the solve-first condition were less likely to use relational problem-solving strategies, which indicate a sophisticated understanding of mathematical equivalence. They relied more on operational strategies, erroneously treating the equal sign as a procedural cue (e.g., to add only the numbers to the left of the equal sign).

However, this overall effect of condition was moderated by achievement motivation. Children higher in mastery orientation tended to use relational strategies during exploration, not operational strategies. Moreover, children higher in performance orientation—who desire to prove their ability and, therefore, avoid challenge—tended to revert to developmentally simpler operational strategies. This finding is consistent with findings in the achievement motivation literature (cf. Diener & Dweck, 1978), and may help explain why exploration was only useful to some children. The challenge and confusion associated with exploratory learning may lead some children to explore

better strategies during learning, but lead others to persevere on poorer strategies, which impede learning.

Recent discussions on exploratory learning versus direct instruction have concluded that there may be benefits of combining aspects of both approaches (cf. Alfieri et al., 2011). The current findings demonstrate that using exploratory problem-solving activities prior to instruction can be beneficial—but namely for children who have a mastery-oriented approach to learning mathematics.

Hence, the current findings highlight the importance of considering motivational influences on learning and strategy selection. Teachers may want to emphasize mastery and promote a forgiving learning environment to help non-mastery oriented students cope better with the inherent challenge posed by exploration. Future research is needed to see if the deleterious effects of performance orientation on strategy selection can be mitigated with mastery framing.

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