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Achievement motivation and knowledge development during exploratory learning[☆]

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A B S T R A C T

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

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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, 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, 1988; 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 (1986, 2006) and Dweck and 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) $\times$ 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, 1988; Elliot, 2005; Hidi & Renninger, 2006). However, Dweck's (1986, 2006) and Dweck and 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 researches have 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, 1988; 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, 1988; 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

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