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Exploratory behavior in active learning: A between- and within-person examination ☆

Jay H. Hardy III *, Eric Anthony Day, Michael G. Hughes, Xiaoqian Wang, Matthew J. Schuelke

University of Oklahoma, United States

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ABSTRACT

Despite being central to active learning theory, surprisingly little research has directly examined the antecedents and outcomes of exploratory behavior. This laboratory study addressed this gap using repeated measures to examine the role and dynamics of exploration in complex task learning. Findings showed task exploration was beneficial across a variety of learning outcomes. Dynamic effects were also observed: (a) exploration was positively related to practice performance at both between- and within-person levels, (b) exploration decreased across practice trials, and (c) decreases in exploration were mitigated by pre-training task-related knowledge. Although general mental ability (GMA) and pre-training task-related knowledge both exhibited effects on exploration, effects were stronger for pre-training task-related knowledge. Neither moderated the link between exploration and learning. Error framing moderated the GMA–exploration relationship such that higher-GMA learners explored more under approach versus avoid conditions. Results are discussed with respect to criticisms of discovery-based learning and implications for active learning.

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Introduction

Exploration has a rich history in the psychological literature as a fundamental behavioral information-gathering process central to human development and learning (Berlyne, 1954a, 1954b, 1955; Piaget & Cook, 1952). In a training context, the centrality of *exploratory behavior*—defined as an active interaction on the part of the trainee with the training environment through attempts at multiple solutions to the problem at hand (Dormann & Frese, 1994)—is an important tenet of the constructivist theory of learning (Bruner, 1961). Constructivism posits that learning is an active and inductive process whereby individuals explore to assimilate rules, principles, and strategies into knowledge and skill. This perspective has since come to serve as the foundation for a modern, learner-centered training paradigm known as the active learning approach (Bell & Kozlowski, 2008, 2010).

In general, empirical research has supported the notion that learners should be actively involved in the learning process (Bell & Kozlowski, 2008, 2010; Keith & Frese, 2008; Keith, Richter, & Naumann, 2010). However, despite the prominence of exploration in active learning theory (Bell & Kozlowski, 2010), its outcomes in these contexts are often debated. Early research on active learning found that exploratory behavior facilitated higher levels of learning and performance (Dormann & Frese, 1994). However, later findings suggested that learners in conditions that allow for task exploration often show better analogical and adaptive transfer outcomes but worse training performance relative to learners in proceduralized conditions that limit exploration (Bell & Kozlowski, 2008; Hesketh, 1997). Many attribute this pattern of findings to the implied relationship between exploration and the making of errors (Keith & Frese, 2008) or to varying degrees of guidance and structure in exploration-based interventions (Debowski, Wood, & Bandura, 2001; Smith, Ford, & Kozlowski, 1997). Critics of exploration-based interventions go even further, arguing that the utility of discovery and active learning approaches is limited for low ability or inexperienced learners due to high information-processing demands (Kirschner, Sweller, & Clark, 2006) or because inexperienced learners miss important material in exploration-based learning (Mayer, 2004). Often, these criticisms allude to the exploratory nature of discovery environments as the cause of such

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* Corresponding author. Address: Center for Applied Social Research, University of Oklahoma, 2 Partners Place, 3100 Monitor Ave., Suite 100, Norman, OK 73072, United States.

E-mail address: jhhardy@ou.edu (J.H. Hardy III).

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limitations and call for restrictions on trainee exploration (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011).

In this paper, we argue that conflicting conclusions regarding effects of exploration on performance in active learning can be addressed by resolving a level of analysis problem concerning the theoretical conceptualization and study of exploratory behavior in learning contexts. Specifically, most studies examining the role of exploration in active learning have not directly measured task exploration during the learning process but rather infer its effects through comparisons of exploration-based versus proceduralized interventions. Although there are clear advantages to manipulation-based (i.e., experimental) approaches, relying solely on such a design provides a limited examination of learner self-regulatory processes. Accordingly, many calls have been made for more studies that directly examine (e.g., via behavioral observation) mechanisms that account for active learning effects (Bell & Kozlowski, 2010; Debowski et al., 2001; Gully, Payne, Koles, & Whiteman, 2002), and several cognitive and motivational self-regulatory processes, such as metacognition, emotion control, self-efficacy, and goal setting have since been studied directly (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005; Kozlowski & Bell, 2006). However, the measurement of exploratory behavior during training has been generally overlooked. This omission from the literature is problematic for several reasons. First, and most central, is that by relying solely on manipulation-based operationalizations of exploration, active learning research diverges from its constructivist origins by studying exploration as a component of an intervention rather than as a behavioral process of the learner. Such an approach carries the untenable assumption that all trainees engage equally in task exploration when participating in active learning. Second, exploration-based interventions are inherently multi-faceted with multiple design and informational components influencing a variety of self-regulatory processes. This makes it difficult to isolate exploration as a mechanism facilitating or inhibiting learning outcomes. Consequently, when research points to potential problems with exploration-based interventions, it is difficult to identify the specific causes of the problems (Bell & Kozlowski, 2010). Without direct measurement, one cannot be sure if exploratory behavior *per se* is to blame for problems that might arise in discovery learning (cf. Charney, Reder, & Kusbit, 1990), thus limiting the development of targeted solutions. Third, by definition, self-regulation theory speaks to within-person, dynamic phenomena (Vancouver, Weinhardt, & Vigo, 2014). As such, repeated, direct measurements of exploration during the learning process are necessary to examine how exploration changes over time and to identify factors related to these changes. Finally, despite being identified as an important self-regulatory pathway that benefits learning (Kozlowski, Toney, et al., 2001), trainee behavior during practice has been relatively understudied in active learning research in favor of a stronger focus on more cognitive- and emotion-based mechanisms. Although cognition and emotion are certainly important, by overlooking trainee behavior, researchers are neglecting key processes by which learners interact with their environment.

Accordingly, our purpose was to examine the role and dynamics of exploration in complex task learning by using repeated, direct measurements of exploratory behavior across practice trials. Taking the perspective of curiosity theory, which views exploration as a dynamic, information-gathering process concerning how individuals approach and engage the complexity and novelty of task stimuli (Berlyne, 1960, 1966; Loewenstein, 1994), we tested and compared two proposed pathways by which the capability-based individual difference variables of general mental ability (GMA) and pre-training task-related knowledge (i.e., a composite of prior experience and baseline performance) are linked to learning outcomes via exploration. First, we examined a common proposition of critics of discovery learning that learner capabilities moderate the relationship between exploration and learning outcomes such that the positive relationships between exploration and learning outcomes are stronger for higher-capability individuals (Kirschner et al., 2006). Second, we examined the extent to which GMA and task-related knowledge *directly* and positively influence exploratory behavior, which in turn positively relates to learning outcomes. Furthermore, we compared whether the effects of exploration are related more to GMA versus task-related knowledge by testing similar pathways for both. With respect to the second pathway, we also examined how error framing instructions in error management training (EMT)—a common active learning intervention—directly influences exploration and moderates the influence of GMA and task-related knowledge on exploration. Finally, we expected that the underlying processes driving exploratory behavior's effects would fluctuate across practice trials. As such, we contend that exploration is dynamic and should be studied accordingly. Research has demonstrated that dynamic constructs can show differential effects depending on the between- and within-person levels of analysis (Vancouver, Thompson, Tischner, & Putka, 2002; Yeo, Loft, Xiao, & Kiewitz, 2009; Yeo & Neal, 2006). Therefore, we tested for dynamic trends during practice and took a nuanced approach by examining if effects on practice performance are similar or different at the between- and within-person levels. Fig. 1 summarizes these propositions and shows the model that served as our guiding framework.

The effects of exploratory behavior on learning

When examining learning outcomes, it is important to consider both proximal (i.e., knowledge and skill) and distal (i.e., adaptation) outcomes (Kraiger, Ford, & Salas, 1993). Accordingly, in this study, we examined multiple learning outcomes including task knowledge, practice performance, and analogical and adaptive transfer performance. *Task knowledge* is composed of both basic task knowledge, defined as the comprehension of basic task features and critical tasks, and strategic task knowledge, defined as the understanding necessary for situational assessment and prioritization (Kozlowski, Toney, et al., 2001). Skill-based outcomes included *practice performance*, defined as effectiveness during training, and *analogical transfer* (i.e., near transfer), defined as the capability to be effective in familiar performance situations after training. Skill adaptability or *adaptive transfer* (i.e., far transfer) is defined as the capability to use one's existing knowledge and skill in response to novel (e.g., more difficult, complex, and dynamic) performance demands (Ivancic & Hesketh, 2000).

It is particularly important to examine both proximal and distal outcomes when studying exploration given that manipulation-based approaches sometimes show crossover effects such that trainees in exploration conditions perform worse during practice but better on post-training tests of skill retention and adaptability (Bell & Kozlowski, 2008; Hesketh, 1997; McDaniel & Schlager, 1990). However, these findings are in reference to the comparison of interventions that are inherently multifaceted without measurements of exploratory behavior to link intervention effects to learning outcomes. Consequently, these findings are limited in the extent to which they can speak directly to how variability in exploratory behavior is associated with variability in both proximal and distal performance. For instance, trainees in proceduralized conditions are often provided with step-by-step task solutions during practice, whereas those in exploration-based conditions are not (e.g., Bell & Kozlowski, 2008; Dormann & Frese, 1994; Frese et al., 1991). This additional instruction and guidance directly affects performance scores during practice. Accordingly, many of the negative practice performance effects attributed to

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